Worldwide Venture Capital

and Patent Creation

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

ABSTRACT

Companies need to be more innovative to exist and sustain profitability in today's competitive business environment. They try to increase innovation by increasing their internal knowledge through internal and external sources. One of the main external sources that may support firms in improving their capabilities is venture capital (VC). Venture capitalists not only provide financial support for new firms, but also provide value-added activities, such as leadership, administration, marketing and strategic directions. These activities may improve the competitive advantages, productivity, profitability, and innovation of businesses.

This study, based on historical data of VC investment and patenting, explores the effects of VC investment on firms' innovation in different intellectual property rights (IPR) environments and in many industries worldwide, utilizing large datasets and various empirical models. Our negative binomial as well as logistic regression models of the panel data present the significant and positive impacts of VC investment and IPR parameters on increasing business patenting rates under all legal systems, by controlling for cultural, regulatory, and economic and market conditions of the business environment. These rates vary by area. Details of our analysis show that British (Common) and French Civil legal systems, in order, are more effective than other legal platforms, followed by German and Scandinavian. These results can be extended to different world regions and countries, based on their legal system. These outcomes are also supported by detailed analyses on countries. Furthermore, VC investment positively influences most industries but the impact rates differ by industry.

In order to adjust our estimations and taking into account any flows in the panel data, we apply robust regression methods and cluster standard errors in the models. In order to test and address endogeneity concerns about the relationship between VC investment and firms' patenting activities, three methods are applied: reverse causality, the Heckman Selection model, and instrumental variables. The Ease to Do Business index, as a starting business parameter, is our instrument for VC investment and it ranks world economies from the highest to the lowest level. Higher rankings (which translate to low numerical ranks) indicate that the regulatory environment is supportive and simpler for business operations.

AKNOWLEDGEMENTS

First and foremost I must thank Professor Brian Cozzarin for his effective advice, support and encouragement during my entire program. I also thank my co-supervisor, Professor Douglas Cumming for his guidance and effective feedbacks through my research, as well as other members of my Dissertation Committee, Professors Rajarishi Nahata (Baruch College), Neil Brisley, Bon Koo, and Selcuk Onay, for their valuable insight and advice. I'd like to further thank Dr. Koo for providing my access to the Thomson Innovation database to obtain patent data required for this research.

DEDICATION

This thesis is dedicated to my entire family members for their patience, encouragement and support during my doctorate program. I will always appreciate all you have done.

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GLOSSARY

VC	Venture capital
CVC	Corporate venture capital
PE	Private equity
VCPE	Venture capital and private equity
WTO	World trade organization
WIPO	World intellectual property organization
IPR	Intellectual property rights
TRIPS	Trade-related aspects of intellectual property rights
IV	Instrumental variables
HCCME	Heteroskedasticity- consistent covariance matrix estimators
OLS	Ordinary least square
FE	Fixed effects
RE	Random effects
ZINB	Zero-inflated negative binomial
NB	Negative binomial
IPO	Initial public offering
R&D	Research and development
IRR	Internal rate of returns
SIC	Standard industrial classification
GDP	Gross domestic products
GII	Global innovation index
NVCA	National venture capital association
DWH	Durbin-Wu-Hausman
MSCI	Morgan Stanley capital index
USPTO	United States Patent and Trademark Office

CHAPTER 1: INTRODUCTION

1.1. Overview

The venture capital industry has an essential role in fostering economic development through supporting new businesses. It supports innovative firms and is a major factor in the development of technology start-ups, being primarily aimed at the commercialization of innovative ideas or technologies, especially in the US, Canada, Europe and Asia. Venture capitalists go beyond financing, as they typically take roles as directors, advisors, or even managers of nascent firms. Venture Capital (VC) investors may support firms to increase innovation, by adding to their internal knowledge and learning capability (Schildt et al., 2003), thereby enhancing these firms' probability of success in business growth, and by exiting through an Initial Public Offering (IPO) or private sale.

The effectiveness of VCs in business improvement and learning capacity may vary across industries and countries. For example, in technology-intensive industries, the pace and complexity of technological change are different than those in other industries, and force companies to continuously innovate to be competitive. However, new companies often do not possess the knowledge required for innovation. Therefore, the role of external sources of knowledge, leadership, and financial support are critical for new firms. We thus examine the relationship between VC investments in firms' innovative activities in larger scale, and more specifically, the effects of VC investment on nascent firms' innovation in different intellectual property support environments in all industries and locations. To do so, we consider and control for key country-based indices from cultural, legal, economic and market conditions perspectives.

1.2. Venture Capital Investment

VC raises money from individuals and investors to use in supporting entrepreneurial start-ups or high-risk firms that are either newly created or in their initial stages. Venture capitalists are not only providing financial support, but also providing value-added activities, such as leadership, administration, marketing and strategic directions for new businesses (e.g. Sapienza 1989a, 1989b; Cumming et al. 2005). These value-added activities may improve business competitive advantages, productivity, profitability, and innovation.

Fried and Hisrich (1994) divide the VC decision-making process into six stages: deal origination, VC firm-specific screening (e.g., size, industry and stage), generic screening (e.g., financial, market, management and deal criteria), first phase evaluation (e.g., due diligence, deal audit and risk evaluation), second phase evaluation (more extended evaluation), and closing (e.g., financial contract, incentives, closure). VC investors screen many business plans per year, but only a few are selected for investment (Groh, 2010; Goldfarb et al., 2005; Metrick, 2007; Kirsch et al., 2009). Of the many criteria that VC investors are considering during the decision-making process, Hisrich and Jankowicz (1990) separate out three main categories: the concept, management and returns.

In the concept category, four elements have been defined for investors: high potential for earnings and business growth; a good business idea that is currently in use or with the potential to be developed and released to the target market within two to three years; a business with a strong competitive advantage or in a non-competitive market; and finally, reasonable financial needs (Hisrich and Jankowicz, 1990; and Fried and Hisrich, 1994).

In terms of the management criteria, VCs are looking for many characteristics in the business managers, including personal and professional integrity and great performance at prior jobs as well as the current job. In later-stage investments, the concentration will be more on management performance in the current venture (Fried and Hisrich, 1994).

In the returns category, three elements are critical. The first is the chance to exit smoothly after investment. VC investors generally gain their investment returns by IPO, private sale, or buyback by themselves. VC investors expect to exit in a three- to ten-year time period. The second component is a high potential rate of return after investment. The VC investors' hurdle for Internal Rates of Return (IRR) is typically very high, in the 30-70% range. The third component of returns is a high potential of absolute return (Fried and Hisrich, 1994). VC investors are expecting high absolute returns, even if the IRR is high (Baden-Fuller, et al., 2006).

VC investors typically invest at six different rounds in ventures after finalizing a VC deal. The main six rounds of investment are the seed round, start-up financing, growth or first stage, second round, business expansion or mezzanine funding, and exit or bridge financing (Ross et. al, 2008). These funds may go to different sections of the business, including construction, sales and marketing, Research and Development (R&D). VC activities in a new firm improve internal knowledge and people's capability to be more innovative (Schildt et al., 2003).

1.3. Innovation and Patenting

In a business environment, innovation is the catalyst for growth. According to the Oslo Manual definition (OECD and Eurostat, 2005), innovation is the successful commercialization of a new product, service, process, or marketing method or substantial improvement of these categories. Therefore, a new or significantly improved solution is the minimum requirement for an innovation. Joseph Schumpeter, who made great contributions in early research, defined innovation as the key aspect of economic growth. Based on his opinion, technological innovation causes temporary monopolies in the market and has high potential impacts for a firm to earn abnormal returns. This monopoly would be challenged soon by imitators and competitors (Pol and Carroll, 2006). These temporary monopolies provide enough motivation for the business to develop its new technology (Pol and Caroll, 2006). Firms continuously search to improve customer satisfaction with better quality, durability, service, and prices through innovation with new technologies and strong business strategies (Heyne, 2010)

Innovations can be protected through patenting. A patent ensures exclusive rights and is granted by national or international organizations to the owner of a new innovation, providing them with legal authority for a limited time period to benefit from the new technological solution in the market and prevent others reproducing and selling the innovation. Essentially, a patent is a contract between the innovator and the public (Thomson Corp, 2007). Therefore, firms try to register their innovations through patent applications to protect them and reap economic rents. In the US, for example, patents can be granted to the inventors or discoverers of novel devices, products, processes, equipment, or materials, or those who substantially improve them (USPTO, 2011). Due to a lack of quantitative data for innovations, patent counts have been used as the standard measure of innovation by many researchers (for example, Griliches, 1990; Kortum and Lerner, 2000; Ahuja and Katila, 2001; Moser and Voena, 2012; and Moser, 2013).

Nations have different policies and procedures for patenting. It is critical for societies to establish robust intellectual property rights so as to promote innovation and improve their economy (Moser, 2013). Empirical studies confirm the effects of strong patent protection rules in promoting innovation and improving economic growth (for example, Chen and Puttitanun, 2005; Moser 2005; Park, 2008; and Moser, 2013).

1.4. Patent Registration

To help innovators in obtaining patent protection and rights in foreign countries, the Paris Convention was established in 1883 for the Protection of Industrial Property. The number of Contracting States is 174 as of spring 2013, and it is still growing (WIPO, 2013). This convention expands the geographical scope of individual patents, enabling innovators to benefit from a global market for their innovations. In addition, this union establishes a worldwide patent network in which economic infrastructures are inter-connected (WIPO, 2013).

The provisions of the union can be categorized into three main segments: “national treatment”, “common rules”, and “right of priority”. In terms of national treatment provisions, each country must provide the same rights and protection to other contracting state citizens that it provides to its own citizens. The union provides some common rules for contracting countries regarding patent legislation, countries interactions for patenting, etc. (Thomson Corp, 2007).

Right of priority is another category of the convention, in which an applicant who has submitted her first patent application in one of the contracting states may apply for patent protection in all the other contracting states within 12 months. Later applications for the same patent will be considered as the first application. Priority number and priority date are two main parameters in this regard (Thomson Corp, 2007). These two parameters are critical in the data collection and verification process for finding all unique patents and removing all duplicated application files that applicants opened in different states.

1.5. The Problem/Objective

Companies must be more innovative if they wish to exist and sustain profitability in today's competitive business environment. Consequently, they try to increase innovation by increasing their internal knowledge through internal and external sources. An extensive body of literature explores internal and external R&D expenditures and their effects on firms' innovation (Griliches, Pakes, and Hall, 1987; Griliches, 1990; Cozzarin, 2006; and Cozzarin 2008). Some studies examine the relationship between alternative—mainly external—sources of knowledge and firms' innovation rates for US and European industries (Henderson and Cockburn, 1994; Ahuja, 2000; and Stuart, 2000).

VC is one of the main external sources that fill the financing needs of young firms with strong growth potential but no assets that can be collateralized. VC investors also receive important rights to sit on the firm's board of directors, which allows them to influence the management team even if the investors hold a minority share (Gomez-Mejia et al., 1990, Kaplan, 2001). These active roles improve the learning capabilities and internal knowledge of new firms, which may impact their innovation output. Due to the significant roles and responsibilities of VCs in business development, this dissertation analyzes the effects of VC investment on innovation output (patents) in different industries and regions.

The literature on VC investment impact on innovation is rather thin. Researchers normally focus on a single industry in one region, and the results are not directly extendable to other regions due to different employment practices, regulatory policies, or public market conditions (Lerner, 2000). In addition, the results are not easily extendable to other industries, because innovation in some industries such as high technology fields is more critical than that in other industries. Finally, the research is hindered by small sample size. For instance, Caselli et al. (2009) use just 37 VC-backed firms and 112 non VC-backed firms in their sample in Italy, while Engel and Keilbach (2007) have 142 VC-backed firms and 21,375 non VC-backed firms (all firms are German). In contrast, we use a global data source for this study, which covers all regions and all industries. Our datasets are constructed using four main data sources: firm-level data on global firms' directories, investment-level data on VC investments, assignment-level data on patent applications, and country-level data on the World Bank and other global macroeconomic databases. We provide comprehensive global research, across industries, examining the effect of VC investment on innovation in different cultural, legal, economic and market conditions, and use a very large sample. The results of this study can support researchers, entrepreneurs, and policy makers in developed and developing countries by clarifying the effective level of VC investment in innovation based on industry and location, and considering intellectual property rights and controlling for socio-economic parameters.

This study proceeds as follows. First, we review literature pertaining to innovation (patenting) and external venturing. Second, we introduce the data elements, sources and collection process to construct datasets and present summary statistics of the data. Third, we develop several hypotheses and empirical models to examine the relationship between VC and patenting rates in different intellectual property environments. Finally, we discuss results and draws conclusions. A glossary of commonly used terms is provided in page xii.

CHAPTER 2: RESEARCH BACKGROUND

This review of the literature considers three main bodies of research pertaining to the relationship between VC and innovation: the source of innovation, VC investment attraction and impacts, and socioeconomic effects on innovation. At the end of the chapter, we summarize the motivation and contributions of this research.

2.1. Sources of Innovation

2.1.1. Sources of Innovation in Business Environments

Innovation can emerge from various sources. Drucker (1988) classified opportunities of innovation in seven categories: unpredicted innovation, due to unanticipated achievements, issues, failures or activities out of the boundaries; inconsistencies in business values, needs, or functions; gaps in processes, process improvement or redesign efforts; market or industry shifts and new opportunities arise for new products, services, methods; changes in demographic structures and living arrangements (e.g., population, education, income, employment); changes in social or personal attitudes and believes; new scientific and practical knowledge; and achievements that permit creation of new products, services and processes. Of these seven traditional sources, two of them exist outside a firm in a social and intellectual environment: changes in demographic and changes in human perceptions. New knowledge creation may occur outside or inside a firm based on the structure and size of the firm, and it has been the key source of innovation in this decade (Drucker, 1988). We discuss this topic further in the next section (§ 2.1.2).

Some other key elements are involved in the emergence of innovation. Engelberger (1982) identifies three requirements for a firm's innovations: an identified market need, availability of technology and knowledgeable resources, and financial sources to support. A market requirement for new product or services is the key motivation of innovation process (Kline, 1989). Based on the Kline Chain-Liked model of innovation, there is a complex and iterative cycle of sales and marketing, product design, manufacturing and R&D in innovation process (Kline, 1989).

In terms of financial support, firms attract required financial needs from internal or external sources. VC investment is a key external source that may have a contribution in firm's innovation process. We discuss more about the relationship between VC investment and firm's innovation in the next part of this chapter.

2.1.2. Increasing a Firm's Internal Knowledge

Firms try to increase their internal knowledge of new opportunities through internal or external sources of innovations (Schildt, Maula, and Keil, 2003). VCs, alliances, joint venture alliances, and acquisitions of entrepreneurial ventures are examples of external sources that support and enable firms to learn (Miles and Covin, 2002; Keil, 2002; Sharma and Chrisman, 1999). Schildt, Maula and Keil (2003) review and analyze the backgrounds of explorative and exploitative learning supported by these external corporate ventures. Based on their results, external venturing can be a good driver for supporting small firms to become more innovative and to grow faster through monitoring and tracking markets and technological developments. The authors analyze the interorganizational knowledge flows, by using patent citations between the largest ICT corporations and their external ventures from 1992-2000. However, they find a weak relationship between corporate VC investment, and explorative and exploitative learning outcomes. Based on their final result, learning through corporate VC investments is not focused on patented technology of the partner (Schildt, Maula and Keil, 2003). Dushnitsky and Lenox (2005), however, argue that investment activities, such as VC investment, facilitate a firm's learning and improve its innovative performance. Wadhwa and Kota (2006) continue this discussion of external knowledge sources from a different perspective. Based on their discussion, new information can help investing firms to address existing problems utilizing a different approach and to use it to enhance the firms' internal R&D capabilities. These capabilities support firms to develop and release new products in new markets earlier than rivals who do not have access to external sources of knowledge (Chesbrough and Tucci, 2003; Maula et al., 2003).

According to Wadhwa and Kota (2006), new learning capability of a firm is based on its current knowledge level. Prior discussions show that companies looking to restructure their knowledge stocks must go beyond their current technological and organizational frameworks and local search (Rosenkopf and Nerkar, 2001). Access to new sources of knowledge significantly increases the learning capacity of a target firm (Ahuja and Katila, 2001). In addition, post-investment activities by investors, such as leadership, monitoring, tracking and cultivating are effective and beneficial for improving a firm's learning. However, gaining and utilizing new technological knowledge entails further costs for the required resources. Resource limitations and information overload prevent investors from effectively managing a large portfolio of target firms (Keil et al., 2004). Based on this discussion and despite previous researchers' findings discussed above, Wadhwa and Kota (2006) focus on one single study. They use non-linear methods and find an inverted U-shaped (non-linear) relationship between corporate VC investment and a firm's internal knowledge increase through innovation. This might be a more complex relationship between corporate VC investment and firms than previous researchers found. Other researchers, such as Dushnitsky and Lenox (2005), did not examine this nonlinear relationship, and their sample was selected from a cross-section of industries. Finally, as Wadhwa and Kota (2006) indicated, their findings regarding the relationship between corporate VC investments and knowledge creation may raise the issue of the relationship between the potential innovation costs and VC investment, due to ultimate diminishing returns of knowledge creation by the investment.

2.1.3. Country and Industry Variation in Innovation

Innovation is a key element in the economic growth, due to its considerable influences on business efficiency and quality of life. Policymakers and regulators around the world are continuously working to develop socioeconomic environments to foster innovation. For instance, the US government launched a National Infrastructure Foundation that houses innovation programs, strengthens industry-university partnerships, and supports innovative economic development initiatives, especially to strengthen regional clusters (NSF, 2013). In 2010, the Federal Government of Canada increased the investment in research through general research funding for grant councils and regional innovation clusters (Dufour, 2010). In China, the national expenditure on basic research doubled between 2004 and 2008, and the government provided tax incentives for R&D and financial support for indigenous innovation (Rongpin, 2010). Several

Latin American countries, in particular Argentina, Brazil and Chile, have implemented an array of policies to foster innovation (Albornoz, 2010). The European Union has provided several plans to increase innovation, including raising the R&D expenditure to 3% of the GDP in 2010 (Tindemans, 2010). Furthermore, Russia established the Medvedev modernization program in order to create a diversified economy based on high technology and innovation (Russia Profile, 2009). The Government of Western Australia has also provided a number of innovation incentives, such as the Tropical Innovation Awards in 2010, which is open to all businesses in Australia and intended to promote innovation and technological change (Queensland government, 2013).

Due to the crucial roles of innovation on countries' economic growth and governments' efforts to promote innovation, it is necessary to know what factors determine a country's capacity to innovate and what elements must be in place to enable a country or a company to transform ideas into commercially successful goods and services for economic and social development. Policymakers and regulators continuously measure innovative performance and endeavor to improve policies and regulations. Dutta (2012), through the Global Innovation Index (GII) program, provides a model for evaluating innovation-related policy performance and improving innovation policies for optimal growth. He completed an extensive study on the global innovation index at a country level, based on 21 macroeconomic indices in seven different categories in the GII 2012 report. His model comprises 141 economies, which represent 94.9% of the world's population and 99.4% of the world's GDP (in current US dollars). He ranks all 141 economies in terms of innovation efforts. The top ten countries in the GII 2012 edition are Switzerland, Singapore, Sweden, Finland, the UK, the Netherlands, Denmark, Hong Kong (China), Ireland, and the US. The details of this ranking are provided in Table 2.1.

Table 2.1: The global innovation index 2012 (Dutta, 2012)

Country	2012 Score	Rank
Switzerland	68.24	1
Sweden	64.77	2
Singapore	63.47	3
Finland	61.78	4
United Kingdom	61.25	5
Netherlands	60.55	6
Denmark	59.93	7
Hong Kong (China)	58.72	8
Ireland	58.68	9
USA	57.69	10
Luxembourg	57.68	11
Canada	56.94	12
New Zealand	56.63	13
Norway	56.42	14
Germany	56.25	15
Malta	56.13	16
Israel	55.99	17
Iceland	55.73	18
Estonia	55.34	19
Belgium	54.29	20
Korea, Rep.	53.86	21
Austria	53.1	22
Australia	51.91	23
France	51.75	24
Japan	51.67	25
Slovenia	49.92	26
Czech Republic	49.72	27
Cyprus	47.89	28
Spain	47.25	29
Latvia	46.97	30
Hungary	46.54	31
Malaysia	45.93	32
Qatar	45.51	33
China	45.41	34
Portugal	45.29	35
Italy	44.48	36
United Arab Emirates	44.4	37
Lithuania	44.02	38
Chile	42.66	39
Slovakia	41.37	40
Bahrain	41.12	41
Croatia	40.68	42
Bulgaria	40.67	43
Poland	40.36	44
Montenegro	40.15	45
Serbia	39.95	46
Oman	39.5	47
Saudi Arabia	39.3	48
Mauritius	39.25	49
Moldova, Rep.	39.23	50
Russian Federation	37.88	51
Romania	37.78	52
Brunei Darussalam	37.72	53
South Africa	37.45	54
Kuwait	37.19	55
Jordan	37.13	56
Thailand	36.94	57
Brazil	36.58	58
Tunisia	36.51	59
Costa Rica	36.33	60
Lebanon	36.21	61
Macedonia, FYR	36.18	62
Ukraine	36.12	63
India	35.68	64
Colombia	35.49	65
Greece	35.27	66
Uruguay	35.13	67
Mongolia	34.99	68
Armenia	34.49	69
Argentina	34.43	70
Georgia	34.27	71
Bosnia and Herzegovin	34.17	72
Namibia	34.14	73
Turkey	34.14	74
Peru	34.07	75
Viet Nam	33.92	76
Guyana	33.67	77
Belarus	32.93	78
Mexico	32.86	79
Belize	32.52	80
Trinidad and Tobago	32.47	81
Swaziland	32.03	82
Kazakhstan	31.94	83
Paraguay	31.62	84
Botswana	31.38	85
Dominican Republic	30.94	86
Panama	30.92	87
Morocco	30.65	88
Azerbaijan	30.41	89
Albania	30.38	90
Jamaica	30.16	91
Ghana	29.61	92
El Salvador	29.51	93
Sri Lanka	29.12	94
Philippines	29.02	95
Kenya	28.94	96
Senegal	28.81	97
Ecuador	28.54	98
Guatemala	28.39	99
Indonesia	28.07	100
Fiji	27.92	101
Rwanda	27.9	102
Egypt	27.88	103
Iran, Islamic Rep.	27.35	104
Nicaragua	26.67	105
Gabon	26.46	106
Zambia	26.45	107
Tajikistan	26.43	108
Kyrgyzstan	26.42	109
Mozambique	26.33	110
Honduras	26.33	111
Bangladesh	26.09	112
Nepal	26.01	113
Bolivia, Plurinational St	25.84	114
Zimbabwe	25.74	115
Lesotho	25.69	116
Uganda	25.56	117
Venezuela, Bolivarian I	25.45	118
Mali	25.39	119
Malawi	25.36	120
Cameroon	25	121
Burkina Faso	24.63	122
Nigeria	24.57	123
Algeria	24.38	124
Benin	24.37	125
Madagascar	24.23	126
Uzbekistan	23.94	127
Tanzania, United Rep.	23.86	128
Cambodia	23.39	129
Gambia	23.29	130
Ethiopia	23.28	131
Syrian Arab Rep.	23.12	132
Pakistan	23.06	133
Côte d'Ivoire	22.62	134
Angola	22.22	135
Togo	20.52	136
Burundi	20.52	137
Lao PDR	20.21	138
Yemen	19.17	139
Niger	18.63	140
Sudan	16.81	141

Since the pace and complexity of technological change is different across industries, we do not expect to see the same innovation rates. Innovation can happen in all industries, including, for example hospitals (Salge and Vera, 2009), universities and local governments.

In the industry-level context, there is a close connection between innovation and various positive changes in quality, productivity, competitiveness, market needs, market share, and other aspects, based on the product or service type (Salge and Vera, 2012). Therefore, these impacts may be greater in high-technology industries than others. Some scholars have found that in high-technology industries, where rapid technological change is the norm, few organizations are able to build capabilities without access to external knowledge sources (e.g., Leonard-Barton, 1995).

2.2. VC Attraction and Impacts

2.2.1. VC Investment in Different Industries and Locations

VC investment attraction in different countries and industries is varied. Groh et al. (2013) provide combined metrics for benchmarking the attractiveness of 116 economies to absorb Venture Capital and Private Equity (VCPE) investments. Based on their research, the country's economic conditions; capital markets; tax rates and incentives; investment rights, support and corporate governance; society; and entrepreneurial environment and supports are the main categories of measures involved in VC investment attraction. Based on the Global VCPE Attractiveness Index for 2012 measured by Groh et al. (2013), the US, Canada, the UK, Japan, Singapore, Hong Kong, Australia, Sweden, Germany and Switzerland are the top ten countries for VC and PE activities. As we would expect, countries with a stronger economy, more business protection and support and higher levels of business culture are more successful in VC investment. Lerner and Schoar (2005), Hazaruka et al. (2009), Cumming et al. (2010) and others present data that is consistent with the view that a country's legality level, even legality pertaining to public markets, is important for VC attraction.

In terms of industrial types, according to Cumming and Knill (2009), VC investment rates may vary in different industries, because some industries are riskier than others and the types of opportunity available for each industry differ. Figure 2.1 demonstrates the VC investment in different industry sectors by dollar invested in the US in 2012 (NVCA, 2013). Based on this graph, Software was the first sector of VC investment in 2012, receiving 31% of the total this investment. Biotechnology is the second largest industry, with 15.4% of total VC investment. The Industry/Energy sector is the third one, with 10.5% of the total, due to the emerging markets and public interests of the clean technology. Finally, Medical Devices is the fourth position, at 9.4% (NVCA, 2013).

In addition, Figure 2.2 shows the VC investment in different stages by dollar invested in the US in 2012 (NVCA, 2013). The growth and expansion stage, also called mezzanine financing, is the main target of VC investment by 35%. Late and Early stages are the second and third targets of investment, by 32% and 30%, respectively. The seed stage attracts only 3% of the VC investment, because low level financing is needed to complete the initial phases of business development, such as proving a new idea. Crowdfunding is also emerging as an option for seed funding (Ahlers et a., 2012).

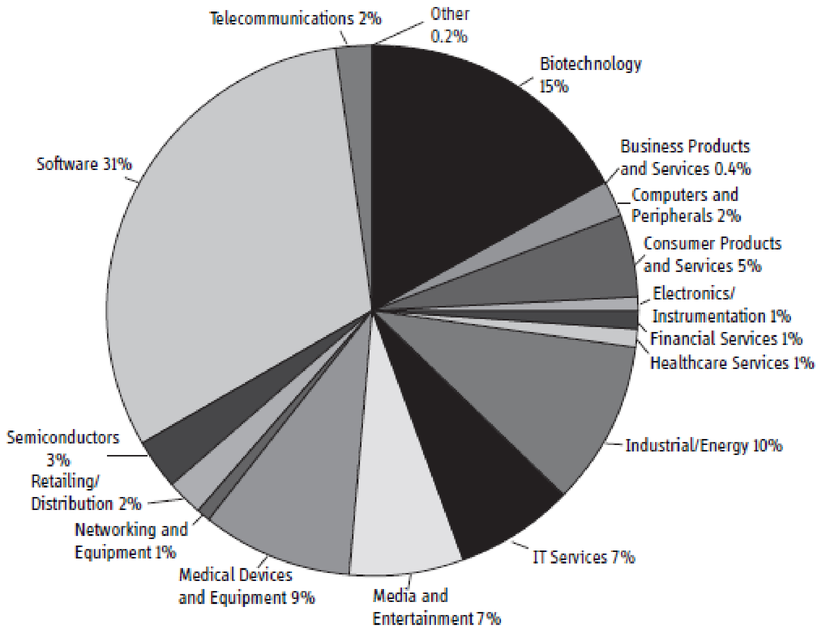


Figure 2.1: VC investments in 2012- industry sectors by dollar invested (NVCA, 2013)

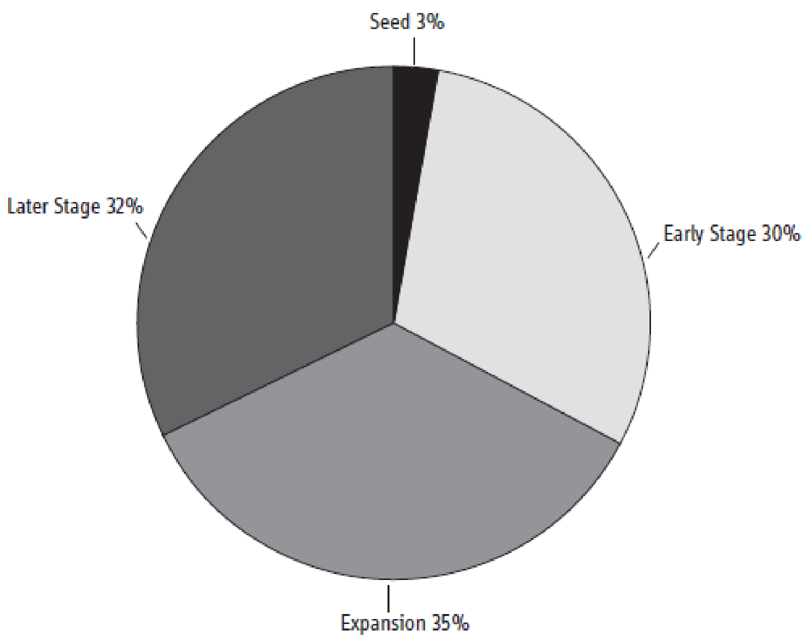


Figure 2.2: VC investments in 2012- stage by dollar invested (NVCA, 2013)

2.2.2. Value-added Role of Venture Capital

VC is theoretically and empirically a value-added source of finance for high-growth startup firms (Gompers and Lerner, 1999; Kanniainen and Keuschnigg, 2004; Sorensen, 2007; Fulghieri and Sevilir, 2009; Metrick and Yasuda, 2009; Cumming and Knill, 2010). In addition to the financial support, venture capitalists often have a key managerial role in entrepreneurial firms. This direct involvement creates value for the entrepreneurial firms in the form of comparative advantages and encourages these firms to select VCs (Gompers and Lerner, 1999; Wright and Lockett, 2003; Kanniainen and Keuschnigg, 2004; Jääskeläinen et al., 2006). Venture capitalists interact with their target firms through different channels, including board membership (Zahra et al., 2000; Dushnitsky and Lenox, 2005). This role as active board members supports the target firms to be informed about the technological changes through internal communication channels (Pisano, 1989). Having this leadership channel, the incoming knowledge is more efficiently taken and used by the target firms. Strong and stable relationships between VC and target firms enhance communication channels, interactions and effective transformation of tacit knowledge and skills to the target firms (Dhanaraj et al., 2004).

From a human resources management perspective, previously documented discussions assert that VCs help their companies recruit managers and other key human resources (Hellman and Puri, 2002), execute corporate governance and administration programs (Hochberg et al., 2007) and enable strategic collaborations (Lindsey, 2007). Since VC improves the firms' internal knowledge transfer channels, they can improve the human resources efficiency and effectiveness and add value to their target firms (Hellman and Puri, 2002).

The contribution of VC investment to the aforementioned activities is based on three main dimensions: the industry type of a target firm, stage of VC investment, and firm's location

(Boue, 2002). In terms of the industry type, based on Timmons and Bygrave (1986), there is a positive relationship between the industry experience and the value-added quality. It is also clear that the value-added services that each industry needs are not the same. For example, a biotechnology firm has different expectation than a transportation firm, due to different product life-cycles, pace technological changes and market conditions.

The investment stage can be divided to three main stages: early, growth and expansion, and divestment (Stedler 1987). A target firm's needs, goals, and leadership styles change during the life cycle of the firm (Churchill and Lewis, 1983; Flynn, 1991; Engel and Hofacker, 2001; and EVCA, 2002). According to Leitinger et al. (2000), in the early stage, the main attention and requirements are on operation management and marketing strategy. In the growth and expansion phase, the main attention and requirements are on business strategy, international business, and financing stages. Many authors believe that the highest VC value-added support happens in the early stage of investment (e.g., Landström, 1991: Elango et al., 1995; and Hellmann and Puri, 2002). According to Hellmann and Puri (2002), the role of internal firm's processes is critical in early stage, because VC is going to implement pre-defined reporting standards in the target firm.

In summary, according to these discussions and the literature of VC value added activities (e.g., Boue, 2002; Sapienza, 1989a & 1989b; and Cumming et al. 2005), we can list all potential VC value-added activities in target firms in Table 2.2.

Table 2.2: A list of value-added activities provided by VC for target firms

ID	Value Added Activities
1	Act as a member of the board and a part of the leadership team
2	Involve directly in the business strategic planning
3	Assist in organizational structure design
4	Assist in design, execution and improvement of internal processes
5	Monitor and provide effective feedback for different business aspects
6	Provide support and guidance regarding internationalization
7	Provide advice on business/market expansion
8	Involve directly in products/services design and development
9	Participate/provide advice regarding sales and marketing
10	Assist in budgeting/financial policies and planning
11	Assist in acquiring additional equity/debt (capital structure)
12	Assist in obtaining subsidies and external support
13	Offer/provide interface functionality to a group of investors
14	Assist in human resource management (planning, recruitment, training and motivation)
15	Support the business in selecting other service partners (e.g., suppliers and distributors)
16	Problem solving
17	Communicate with portfolio companies of the investor, partners, and other stakeholders
18	Participate in public and media affairs
19	Engage in legal affairs
20	Support the effective relationship between investors and the entrepreneur/venture
21	Act as friend, mentor or coach

Additionally, Figure 2.3 shows the VC value adding framework or process in regards to its target firm in three main sections. The value added content diagram demonstrates a list of potential value added items that can be accomplished by VC investors in both operational-level and strategic dimensions. The strategic items have a long term effects on the business. All business segments can be impacted by the strategic and operational activities. The value added hierarchy in Figure 2.3 shows the importance of the value-added activities for the entrepreneur, and for the implementation phase of transferring and executing value-added elements into a venture (Boue, 2002).

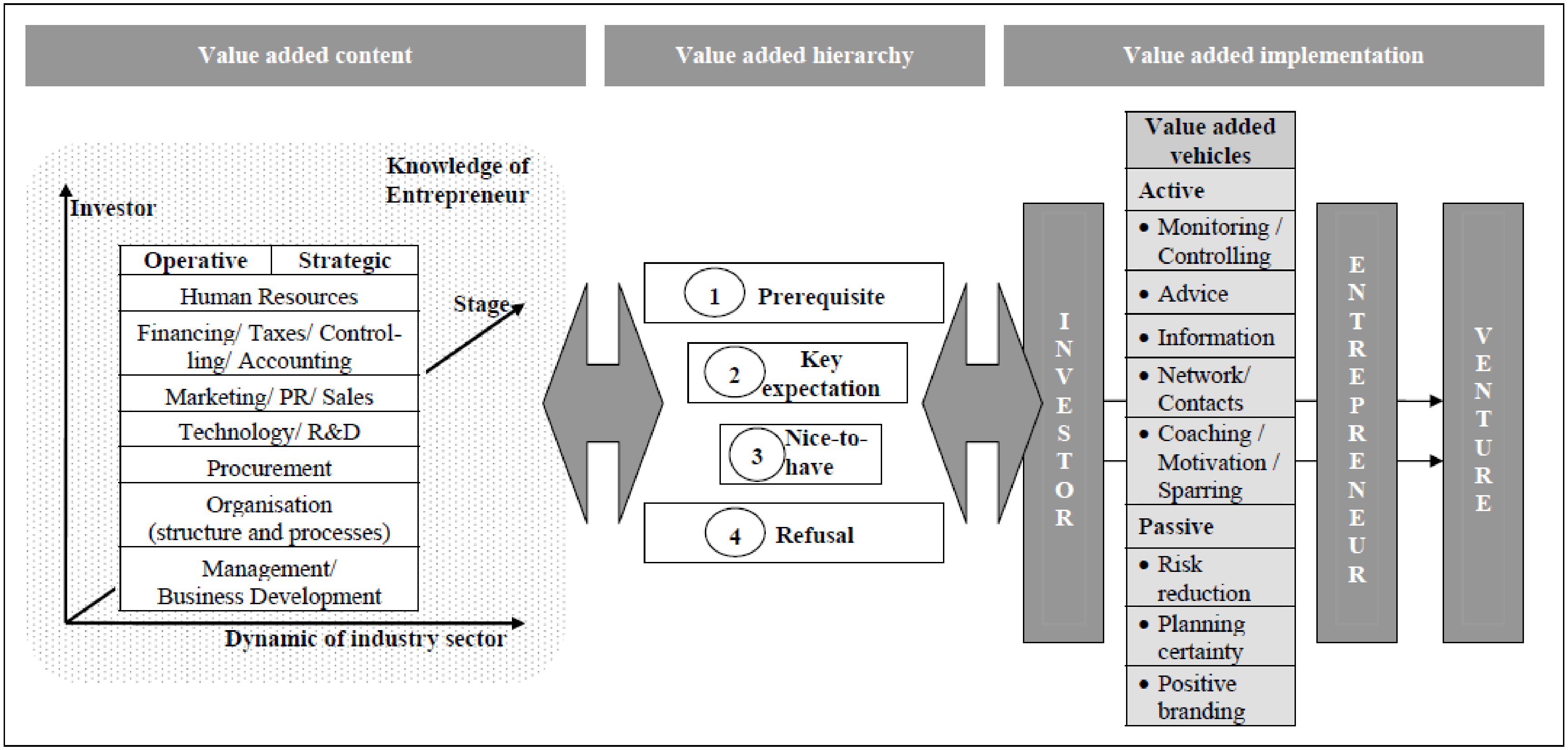


Figure 2.3: Model of the value adding process by venture capitalists (Boue, 2002)

2.2.3. Main Concerns in VC Relationship with Entrepreneur Firms

In the discussion of VC value added activities towards entrepreneur firms, it is necessary to consider the main concerns raised by scholars in regards to the relationships between investors, venture capitalists and entrepreneurs. As Sahman (1990) asserts, the VC structure and its incentive model mechanism must address two-stage agency relationship concerns. The first agency problems emerge between outside investors (the limited partners) and venture capitalists (the general partners), because VC firms raise money from their limited partners before funds are allocated to target firms. The second agency problem is about the relationship between venture capitalists and entrepreneurs. The VC investors deal with high degree of uncertainty and strong information asymmetries when they make investment decisions (Kirsch et al., 2009). The strong information asymmetries that they face cause adverse selection and moral hazard problems (Dessi and Yin, 2010).

These agency problems are much higher in target firms that focus on R&D investments and innovative projects. In order to mitigate these problems, venture capitalists screen more intensively to evaluate the most promising investment opportunities (Kirsch et al., 2009; Dessi and Yin, 2010). Besides, they provide required funds only in those stages that are related to the predefined achievable milestones. Therefore, VC firms create investment contracts based on this condition and become widely involve in information collection and monitoring processes to minimize moral hazard problems. Entrepreneurs also act more carefully than usual when employing VC funds (Dessi and Yin, 2010).

2.2.4. VC Investment Effects on Innovation

In terms of direct effects of VC investment on technological innovation and patenting rates, Kortum and Lerner (2000) test and measure these effects across twenty US industries over 30 years by industry and they find that VC activities significantly increase patenting rates. According to their results, VC investments are more effective than internal R&D activities in generating patents in the US. In their opinion, no evidence is available to suggest that their results can be extended globally, due to different employment practices, regulations and policies, or public market conditions. Lerner (2002) continues his previous study and analyzes the impact of VC on innovation during boom and bust periods in US industry. His study considers both a field-based and a statistical component, and shows that the effect of VC investment on innovation is not uniform. This situation decreases during rapid growth periods, or booms. VC industry is strongly cyclical and its effect on a firm's patenting is likely to move with this cyclical movement (Lerner, 2002).

Ueda and Hirukawa (2006) continue the study of Kortum and Lerner (2000) and confirm the result of a positive relationship between VC and patents in which VC investment is a highly effective driver of patent activities. The authors use samples of an extended time period, from 1965 to 2002 in the US. Unlike their positive results for the relationship between VC investment and patents, they do not find any significant and positive effect of VC investment on total productivity growth. However, they find a positive relation between VC investment and labor productivity growth because of technology substitution by VC-backed firms utilizing less human resources and more material, energy and technology. Mollica and Zingales (2007) find the positive results for the impacts of VC investment on innovation by exploiting cross sectional, cross industry, and time series variability of VC investments in the US. Dushnitsky and Lenox

(2005a) conduct this test again by using a sample of about 2300 US public firms over a 20-year period. Based on their result, the citation-weighted patenting output is positively correlated to the prior corporate VC investment. These authors also find that the relation between corporate VC investment and firm innovation rates is greater when firms hold their capacity to leverage venture knowledge received from external sources. They provide evidence of a strong association between corporate VC investment and patenting quality in the area of weak intellectual property protection and support, and in industries with rapid technological change (Dushnitsky and Lenox, 2005a).

In addition to the above research in the US, Popov and Roosenboom (2008) apply Kortum and Lerner's (2000) empirical methodology to examine the effect of VC investment in Europe. The authors use data of 18 European countries for the period 1991-2004, and find positive and significant impacts of VC on innovation. In contrast, Engel and Keilbach (2007) find different results in German industry: VC-backed firms register more patents than comparable non-VC- backed firms before receiving the VC investment. Based on their discussion, after investment, the number of firms' patents does not differ significantly anymore, but their growth rates are larger. Their finding suggests that the higher innovation in VC-backed firms occurs because of the VC selection process prior to the funding rather than to the venture funding itself. It seems that VCs' main focuses are on their target firms' growth and commercialization of existing innovations. Caselli et al. (2009), in conducting this study for Italian firms, find similar results to those of Engel and Keilbach (2007). They test two hypotheses regarding VC investments effects on innovation and the growth of innovative VC-backed firms in Italian industry. Using a sample of 37 Italian VC-backed IPOs on the Italian public market from 1995 to 2004, they select 37 twin but non VC-backed firms for the same period, by a simple statistical matching method. Their results show that although innovation is important during the VC selection process, VC-backed firms mostly focus on improving economic and managerial aspects of their firms after VC investment rather than promoting innovations. Table 2.3 shows a summary of the literature on causality between VC investment and innovation discussed above.

Table 2.3: Summary of literature on causality between VC and innovation (in chronological order)

Author (Year)	Article/Book Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
Kortum and Lerner (2000)	Assessing the contribution of venture capital to innovation	RAND Journal of Economics	Annual data for 20 manufacturing industries between 1965 and 1992 (over 3 decades) in the US From National Science Foundation (NSF)	Cobb Douglas model, Ordinary least square (OLS) for patent generating rate), some limitations and it is the first cut of quantifying the VC impact on innovation. Utilized instrumental variables (regulation change in 1979)	There is strong relation between VC and patenting. Estimated 8% contribution of VC on business innovations prior to 1992. Due to sharp increase in VC investment since 1992, and assuming constant VC power, by 1998, VC contribution increase to about 14% of total US business innovation.
Lerner (2002)	Boom and Bust in the Venture Capital Industry and the Impact on Innovation	Harvard NOM Research Paper	Venture capital fund-raising in US from 1969 to 2001 and their return of investment (from Venture Economics database)	Demand and supply curves of VC, agency problem, information asymmetry	"VC is a cyclical industry, and the VC effect on innovation is most likely to differ with this cycle."
Schildt, Maula, and Keil (2003)	Explorative and Exploitative Learning from External Corporate Ventures	Working Paper Series, Espoo, Finland	Sample of external corporate ventures of the largest 110 public U.S. corporations operating in four sectors of information and communications technology (ICT) industries. Financial measures for years 1989-2001 from *Compustat* database. Data of the external ventures from Thompson Financial SDC Platinum database.	Logistic regression model (a moving three-year window to construct patent class counts to reflect the focus of recent technological activities)	Corporate venturing and technological dependency have significant impacts on the likelihood of explorative learning (and innovation) by firms
Dushnitsky and Lenox (2005b)	When do incumbents learn from entrepreneurial ventures? Corporate venture capital and investing firm innovation rates	Research Policy	Data includes 2289 firms and 45,664 firm-year observations. The data collected from Venture Economic's VentureXpert database, patenting activity from the Hall et al. (2001) dataset derived from the U.S. Patent Office, and financial data from Standard & Poor's Compustat database. For annual patent output of each firm using the HJT dataset.	They used unbalanced panel analysis (negative binomial regression) for US public firms during the period 1969–1999. Their investigation builds on two theoretical pillars. First, the knowledge necessary to generate innovations may likely reside outside the boundary of incumbent firms. Second, entrepreneurial start-ups may be a valuable source of such knowledge. They used unbalanced panel data discrete random and fixed effect	CVC investments positively impact firms' patenting rates. This impact is greater when "firms operate in an external context that permits capitalization on venture knowledge and possess the internal capabilities to leverage that knowledge." "The level of citation-weighted patenting-output is positively related to the level of prior CVC investment." They believe the relation between CVC investment and patents' quality is strongest in weak IPR environments.

Table 2.3: Summary of literature on causality between VC and innovation (in chronological order)

Author (Year)	Article/Book Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
				models (with 1-year lag between our regressors and dependent variables)	
Dushnitsky and Lenox **(2005)**	When Do Firms Undertake R&D by Investing in New Ventures?	Strategic Management Journal	A sample of more than 1000 U.S. public firms for the period 1990–99. The VC data from Venture Economics' VentureXpert database, patenting activity from the Hall et al. (2001) dataset derived from the U.S. Patent Office, financial data from Standard & Poor's Compustat database, and appropriability data from the Carnegie Mellon Survey of R&D. The resulting dataset includes 1171 firms and 60,444 firm-year-sector observations.	They used unbalanced panel analysis for US public firms.	"Firms invest more corporate VC in sectors that are characterized by weak patent effectiveness and where complementary assets are important. Firm-level factors drive the decision to pursue external CVC". "A positive relationship exists between firm annual equity investments and internal cash flow, and CVC investment is affected jointly by the absolute and relative absorptive capacity of the firm".
Wadhwa and Kutha **(2006)**	Knowledge Creation Through External Venturing: Evidence from the Telecom Equipment Manufacturing Industry	Academy of Management Journal	Data of 36 firms in telecom equipment manufacturing industry during 1989-1999. The firms have VC funds at least once in start-ups. VC data from VentureXpert (NVCA source)	Nonlinear regression method is also used. Negative binomial regression with both random and fixed effects models	An inverted U-shape exists between CVC investment and innovation when investor involvement is low. This relationship will change positively when this involvement is high. .
Engel and Keilbach **(2007)**	Firm-level implications of early stage venture capital investment -- An empirical investigation	Journal of Empirical Finance	They collect data of over 21,000 new non VC-backed and 146 new VC-backed firms in Germany from 1995 to 1998, through German Patent Office (DPA), firms high level data from ZEW and firms details from Credit reform	Analysis based on twin companies Average Treatment Effects method)	VC-backed firms apply for more patents, but their innovation activities diminish after first VC investment. VC-backed firms have more sales growth than non VC-backed firms
Caselli et al.	Are Venture Capitalists a Catalyst for Innovation?	European Financial Management	They collected the data of 37 VC-backed IPOs and 37 non VC-backed firms as control group from 1995 to 2004.They	Matching for finding twin companies. They use average treatment effect method	VC-backed firms are more innovative than non VC-backed firms. However, when a VC decides to deliver funds, VCs seem to block the

Table 2.3: Summary of literature on causality between VC and innovation (in chronological order)

Author (Year)	Article/Book Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
(2009)			utilize SIMBA and EPO (for patents) and Italian association of VC investment		innovation process.
Popov and Roosenboom **(2009)**	Does private equity investment spur innovation?	European Central Bank (ECB) Working Paper	Data of VC activities in different industries in 18 main European countries from 1991 to 2004. VC data from EVCA (European Venture Capital Association), USPTO, European Patent Office (EPO)	OLS and instrumental variable regression analysis (similar to Kortum and Lerner, 2000)	VC has positive impact on innovation. This impact is less in Europe than in US. The results hold only for granted patents (VC does not impact number of patents)
Cumming and Knill **(2010)**	Disclosure, Venture Capital and Entrepreneurial Spawning	Journal of International Business Studies	Macroeconomic data for 34 countries over the years 1999-2008	OLS regression model for security law, multinomial logit model is used for entrepreneurs, For robustness check, two-step Heckman regressions	"Securities regulation facilitates VC-induced entrepreneurial spawning which means VC inspires new entrepreneurial ventures through mentoring and certification as an important value-added source of capital", and improves securities regulations increases the strength of this relationship.
Lerner et al. **(2011)**	Private Equity and Long-Run Investment: The Case of Innovation	Journal of Finance	Patent data of 495leveraged buyout (LBO) transactions in US from 1980 to 2005. Main source Capital IQ database, USPTO for patents	OLS and Poisson Regression Analysis	LBO firms become more focused concerning their innovation activity, and their patents show a higher quality. Thus LBO funds do not exploit the existing innovativeness of their portfolio firms to maximize short term profits.
Ueda and Hirukawa **(2011)**	Venture capital and innovation: which is first?	Pacific Economic Review	Data of US manufacturing industry from 1958 to 2001 (extended period of Kortum & Lerner, 2000). Data sources are VentureXpert, Bertelsman, Becker, and Gray's NBER-CES Manufacturing Industry Database (the NBER productivity database), the NBER patent database, and funds for industrial R&D performance for 1953—98 from National Science Foundation.	They used panel autoregressive regressions, Granger causality tests, and instrumental variables method.	"Total factor productivity growth of firms is often positively and significantly related to future VC investment". Little evidence found to support both the innovation-first and the VC-first hypotheses. Causality runs from innovation to VC investment.

2.3. Socio-economic Factors and Innovation

According to Cumming and Knill (2010), Groh et al. (2010), Dutta (2012) and other scholars, macroeconomic parameters are key drivers of innovation promotion. Cumming and Knill (2010) use three different types of macroeconomic indices as control parameters to examine the effect of VC investment and certain elements of securities laws on innovation. These indices are 1) New Businesses and New Businesses/GDP per capita for entrepreneurship and business startups, 2) Market Return, GDP per Capita, IPO Value and Domestic Credit are selected for the VC industry and the market of IPO and bank credit, and 3) Market Return and GDP per Capita indices for economic and market conditions.

Groh et al. (2010) review the literature on VC and Private Equity (PE) and conduct a similar study to rank VC and PE attractiveness in different countries. The authors categorize all relevant country-based indices in the six segments of economic condition, capital market, tax, Investment rights and corporate governance, society, and entrepreneurial environment and opportunities. They select 23 indices in these six categories to measure and rank countries position and provide 42 data series to proxy these segments. They apply different calculation methods for normalization, weighting, and aggregation of these 23 indices (Groh et al., 2010). Figure 2.4 reproduces their results for European countries. According to their analyses, despite the fact that the European countries are similar in many criteria, two main variations influence a country's attractiveness for VC activities: its investment protection level and corporate governance, and the maturity level of its capital markets in terms of size and liquidity, as a good representative for the professionalism of financial markets.

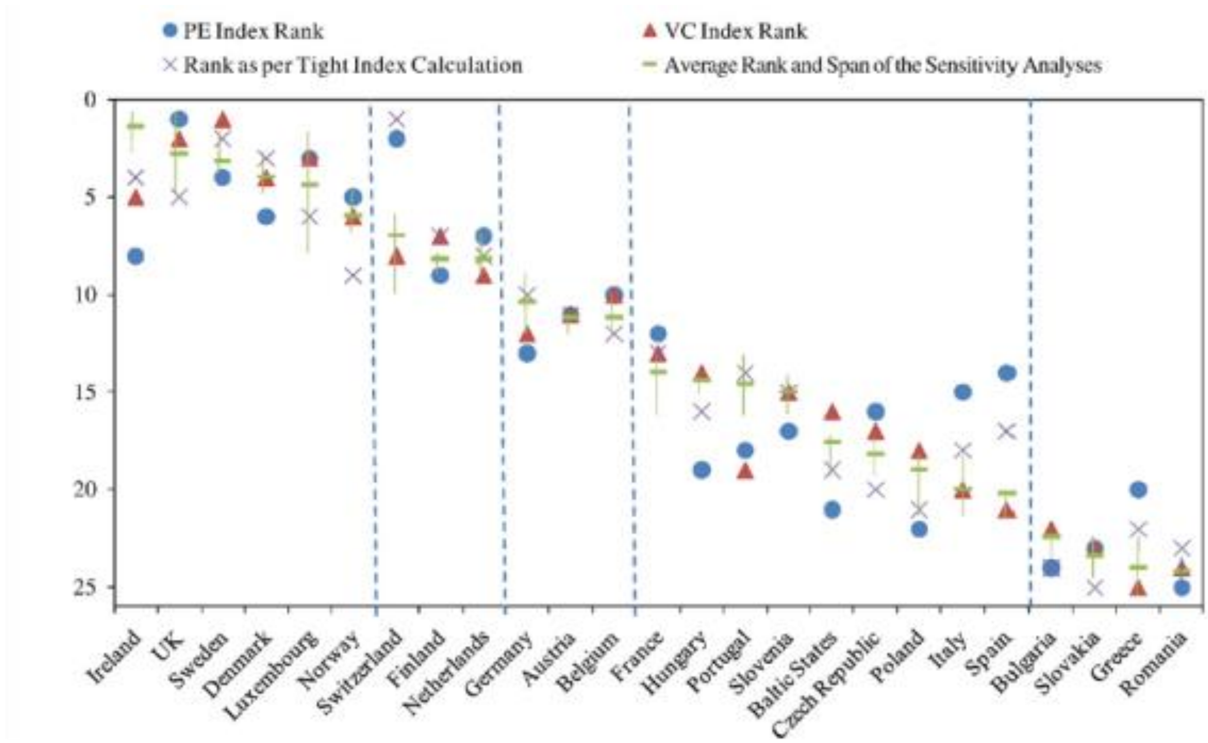


Figure 2.4: The VC and PE ranking in European countries (Groh et al., 2010)

Dutta (2012), in his recent GII Report, highlights the crucial roles of infrastructures for innovative environment. He measures and ranks every country's position in terms of innovation by utilizing macroeconomic related indices. His study relies on two main categories of indices: the innovation input and the innovation output sub-indices. Sub-indices are established based on pillars. For the innovation input sub-indices, five input pillars cover enablers of innovation in an economy, including regulations and business environment, human resources and research, infrastructure, market conditions, and business complexity. Innovation outputs are the outcomes of innovative activities within the economy. Dutta (2012) identifies two output pillars: "knowledge and technology outputs", and "creative outputs". He uses the simple average of the five input pillar results for input sub-index, and the simple average of the two output pillar results for output sub-index. For measuring the country's overall score, both input and output sub-indices have the same weight (Dutta, 2012).

All country-based indices discussed in the literature of innovation and VC investment can be divided into three main categories: culture, regulation, and economic and market conditions. In terms of culture, Hofstede's theory provides different dimensions for national cultures, which he terms the "power of distance", "individualism versus collectivism", "uncertainty or ambiguity", "masculinity versus feminity", and "long-term versus short-term orientation" (Hofstede, 1991, 2001). In relation to Hofstede's theory, Lazear (1990) and Blanchard (1997) discuss labor markets, and Gompers and Lerner (1998) analyze countries' R&D expenditure and small business. In our analysis, to control the cultural perspective of a country, labor forces (with a secondary education), secondary school enrollment, and R&D expenditure indices are added.

According to La Porta et al. (1998), a country's legal system is a key driver of business activities. They apply different legal and economic variables, such as company's origin and its legal system, integrity and efficiency of the current judicial system, corruption in government, expropriation risk score, GNP and GINI coefficient, type of shares' ownership, and quality of the accounting system. They find that investor protection laws vary across countries, and these variations have significant influences on corporate finance (La Porta et al., 1998). The main criteria that are often used to define a country's legal system are the following: historical background and growth of the legal system, theories and hierarchies of the foundation of law, the method and working process of jurists within the legal system, the characteristics of legal concepts utilized by the system, the legal institutions of the system, and the divisions of law employed within a system (Glendon et al., 1994). Legal systems are divided into Common law (British law) and Civil law (Roman law). Civil law has three families: French, German and

Scandinavian. Civil laws give investors weaker legal rights than common laws (La Porta, 1998). As part of this research, we are interested in determining the impact of VC investment on firms' patenting in different legal systems. This analysis helps us to find the relationship between the right of investors, the quality of enforcement of legal rules and other countries' legal system attributes.

2.4. Intellectual Property Rights (IPR)

As many scholars assert, it is not easy to find the optimum solution for IPR (e.g., Moser 2005; Granstrand, 2005; Lerner, 2005; and Moser 2013). Empirical studies data confirm the effects of strong IPR in encouraging invention, promoting innovation and improving economic growth (for example, Chen and Puttitanun, 2005; Moser 2005; Park, 2008; and Moser, 2013). On the theoretical side, while many researchers emphasize the positive role of IPR on promoting innovation and patenting (for example, Scotchmer and Green, 1990; Grossman and Lai, 2004; and Granstrand, 2005), others consider that no strong relationship exists between robust protection for intellectual properties and innovation growth (Lerner, 2009; Gangopadhyay and Mondal, 2012).

As Schwab (2011) explains, the IPR parameter demonstrates two major forms of intellectual property rights: patents and copyrights, and can be scored from weak to strong or enforced levels. For the IPR measurement and ranking, Ginarte and Park (1997) define five categories of parameters: coverage of patentability of products, membership in international intellectual support activities, mechanisms of enforcement, restrictions on patent rights, and duration of support.

According to Grossman and Lai (2004), providing stronger national intellectual property protection and support varies positively with the market conditions and innovation capacity of the country, because these two factors improve the marginal benefits and reduce deadweight losses or marginal costs of a more powerful patent protection and support system. Furthermore, Eicher and Penalosa (2006) show a positive correlation between the level of patent protection and economic development. Countries' policymakers and agents try to establish stronger intellectual property rights and support systems as economies grow and more knowledge collects. Park (2008) illustrates that the level of national patent systems improvement varies by level of national economic development. This change is smaller for those top developed countries that have already established strong patent protection systems. He provides countries' rankings from an IPR aspect based on Ginarte and Park's (1997) parameters for the period 1965-2005. According to his analysis of the distribution of patent strength across the world, this distribution is improved from a positively skewed shape prior to the late 1990s to a negatively skewed shape afterward. Based on this result, the patent protection index for most countries is above the mean, mostly after the arrival of the Trade-Related Aspects of Intellectual Property Rights (TRIPS)[1] agreement that sets down minimum requirements for intellectual property regulations, and the establishment of new patent laws in some countries (e.g., Ethiopia, Angola, Indonesia, Mozambique and New Guinea) with no previous patent systems (Park, 2008). Table 2.4 provides a summary of the literature about intellectual property protection and innovation/patenting discussed above.

[1] TRIPS is an international agreement that requires all World Trade Organization (WTO) members to provide

Table 2.4: Summary of literature on intellectual property protection and innovation (in chronological order)

Author (Year)	Research Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
Chin and Grossman (1988)	Intellectual Property Rights and North-South Trade	National Bureau of Economic Research	No empirical data (theoretical discussion)	Theoretical (mathematical models)	IPR improve economic efficiency in case of considerable innovation (but not in the case of small innovation)
Scotchmer and Green (1990)	Novelty and Disclosure in Patent Law	RAND Journal of Economics	No empirical data (theoretical discussion)	Using mathematical/ statistical distribution models (Poisson, decision tree, economic equilibrium model	Licensing is important in patenting, because it does not have negative impact on firm's profit. It also promotes innovation, due to patenting and disclosure supports.
Kortum and Lerner (1998)	Stronger Protection or Technological Revolution: What is Behind the Recent Surge in Patenting?	Carnegie-Rochester Conference Series on Public Policy	International patent data and industrial property statistics (from WIPO).Data from OECD and Federico	Regression analysis	The main reason of a jump in patenting in the US is because of changes in innovation management. Management focuses more on applied activities than before.
Sakakibara and Branstetter (2001)	Do Stronger Patents Induce More Innovation? Evidence from the 1988 Japanese Patent Law Reforms	RAND Journal of Economics	Japanese and U.S. patent data on 307 Japanese firms	Log-linear regression models	No strong relation exists between innovation increases and IPR reforms.
Chen and Puttitanun (2005)	Intellectual Property Rights and Innovation in Developing Countries	Journal of Development Economics	panel data for 64 developing countries during 1975–2000	Theoretical and empirical (panel data-regression) models	IPR have positive impact on innovation in developing countries
Granstrand	Innovation and intellectual property	The Oxford handbook of	Using the data of other studies in Japan, Sweden,	Review of other relevant studies and IPR	The IPR role in national, industrial and firm innovation rates was moderate before

Table 2.4: Summary of literature on intellectual property protection and innovation (in chronological order)

Author (Year)	Research Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
(2005)	rights (a book chapter)	innovation	and US	evolution in US and some other economies	new era. Today, IPR has an extended role which strategically impacts firms, sectorial and national economic growth
Lerner **(2005)**	150 Years of Patent Office Practice: Law and Institutions	American Law and Economics Review	administrative practices of the patent offices in 60 countries over a 150-year period	Cross sectional and regression analysis	In big and complex economies, there is a more options for patenting. In complex economies, "patentees were more likely to have more options, delay payment, apply for alternative utility model patents and delay the examination of patent application". Under Civil legal system there is more options for filing.
Moser **(2005)**	How Do Patent Laws Influence Innovation? Evidence from Nineteenth Century World's Fairs	American Economic Review	15000 innovations data at the Crystal Palace World's Fair in 1851 and at the Centennial Exhibition in 1876	Tests for the equality of distributions, discrete-choice regression	Patenting law is critical for a society to find the right direction of technological change. "Countries with no patent law may not benefit from innovation in various industries (focus is just on a few industries). Also mentioned, uniform patent laws across the world may decrease variation in the innovation direction between different countries".

Table 2.4: Summary of literature on intellectual property protection and innovation (in chronological order)

Author (Year)	Research Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
Branstetter, Fisman and Foley (2006)	Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from US Firm-Level Panel Data	Quarterly Journal of Economics	NBER for the US patent data, country-level data of IPR reform, U. S. Bureau of Economic Analysis (BEA) Survey for R&D and other data, Compustat	Cross-sectional linear regression models	"Limited evidence found that IPR reform spurs domestic innovation. Results also imply that U. S. multinationals respond to changes in IPR regimes abroad by significantly increasing technology transfer to reforming countries".
Quan (2007)	Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment? A Cross-Country Analysis of Pharmaceutical Patent Protection, 1978–2002	Review of Economics and Statistics	Data of pharmaceutical industry from 1978 to 2002 for 26 countries, their patent and R&D data as well as country-based indices for this time period	Panel Data- Fixed Effects regression models	"National patent protection alone does not stimulate domestic innovation, as estimated by changes in citation-weighted U.S. patent awards, domestic R&D, and pharmaceutical industry exports. However, domestic innovation accelerates in countries with higher levels of economic development, educational attainment, and economic freedom. Additionally, there appears to be an optimal level of IPR regulation above which further enhancement reduces innovative activities" (confirming U-shape relationship).
Park (2008)	International patent protection: 1960-2005	Research Policy	The country-based indices for patent protection for 122	Simple statistical analysis for measuring, scoring and	Countries' IPR ranking based on Ginarte and Park's (1997) parameters for the period 1965-2005, the patent

Table 2.4: Summary of literature on intellectual property protection and innovation (in chronological order)

Author (Year)	Research Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
			countries from 1960 to 2005	comparisons	strength distribution across the world is improved from a positively skewed shape prior to the late 1990s to negatively skewed shape afterward, mostly because of TRIPS agreement and other initiatives.
Lerner (2009)	The Empirical Impact of Intellectual Property Rights on Innovation: Puzzles and Clues	American Economic Review	Selection 60 largest countries (by GDP in 1997) listed in the International Monetary Fund's International Financial Statistics and their policy change over the past 150 years, from 1850 to 1999. He found 177 events in 51 out of 60 nations.	Theoretical and empirical studies	Expected positive effects of improving patent protection on innovation not found. This result is not same as that of the findings of "law and finance" literature.
Blind (2012)	The influence of regulations on innovation: A quantitative assessment for OECD countries	Research Policy	Panel data of 21 OECD countries during the period 1998-2004	Panel data- fixed effects model of a linear regression	"Different types of regulations generate various impacts, and even a single type of regulation can influence innovation in various ways depending on how the regulation is implemented" (not completely confirmed that the regulatory condition framework influences innovation)

Table 2.4: Summary of literature on intellectual property protection and innovation (in chronological order)

Author (Year)	Research Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
Gangopadhyay and Mondal **(2012)**	Does stronger protection of intellectual property stimulate innovation?	Economics Letters	No empirical data	Theoretical economic models	IPR may hamper dissemination of "scientific knowledge from innovation in a standard endogenous growth model". Stronger IPR may decrease innovation rate.
Moser **(2013)**	Patents and Innovation: evidence from Economic History	Journal of Economic Prospective	No empirical data	High level discussion of economic trends	Existing historical evidence propose that "patent policies granting strong IPR to early generations of inventors, may discourage innovation. In contrast, policies that encouraging diffusion of ideas and modifying patent laws to facilitate entry and competition may prompt innovation".
Yang **(2013)**	Horizontal inventive step and international protection of intellectual property	International Review of Economics & Finance	No empirical data	Theoretical economic models	"When two countries with sufficiently different research efficiencies open trade with each other, they will both lower their patentability requirements from their respective autarky levels. The model suggests that these countries may want to strengthen their collaboration in patentability requirement".
Boldrin and Levine	What's Intellectual Property Good for?	Revue économique	No empirical data	No model (general discussion)	IPR is not a good solution in globalization of economy and trade, because of creating monopolies. "To

Table 2.4: Summary of literature on intellectual property protection and innovation (in chronological order)

Author (Year)	Research Title	Journal	Data (Type & Source)	Method/Model	Summary of Findings
(2013)					become wealthy, a country must regulate trade and strive for trade surpluses".
Chu and Pan (2013)	The Escape-Infringement Effect of Blocking Patents on Innovation and Economic Growth	Macroeconomic Dynamics	No empirical data	Quality-ladder (Grossman–Helpman) model	"Patent breadth has a positive effect on innovation; blocking patents negatively effects innovation under an exogenous step size of innovation".
Hudson and Minea (2013)	Innovation, Intellectual Property Rights, and Economic Development: A Unified Empirical Investigation	World Development	Macroeconomic data of different countries	Theoretical model as well as linear and nonlinear regression analysis	"The effect of IPR on innovation is more complex than previously thought (nonlinearities depending on the initial levels of both IPR and per capita GDP)". "A single global level of IPR is in general sub-optimal".

2.5. Our Motivation and Contributions

The literature on VC investment effects on innovation growth is relatively thin and is based on US data and that of a few Western European countries. There is a lack of research to explore and compare the VC effects on innovation globally. As discussed earlier, the business environment in other developed and developing regions varies because of different economic policies and employment practices, cultures, patenting regulations, and public market conditions. In addition, the current literature covers only manufacturing and a few information technology industries. However, innovation has a crucial role in other industries as well.

The extensive research detailed in this thesis adds to the literature by examining VC impacts in different intellectual property protection environments, legal systems, regulations, cultures, economic and market conditions across the world. Since the pace, complexity and role of technological change and innovation in different industries vary, industries experience different rates of innovation and patenting and even attraction of VC investment. Thus, it is necessary to test and measure the VC investment impacts (both tangible and intangible) on patenting rates across industries and regions utilizing large-scale data. Policymakers around the world are continuously working to develop socioeconomic environments for fostering innovation by establishing the necessary infrastructure, by revising rights, regulations, and protection, and by providing innovation awards and other strategic initiatives. The results of this study support researchers and policymakers in understanding the role of VC on innovation in various legal and protection environments, locations and industries, and the effect of countries' socio-economic parameters.

CHAPTER 3: DATA

3.1. Overview

Data collection has been a major effort in this research process. Large amounts of data were collected from different sources for both VC-backed and non VC-backed firms. This iterative process took 13 months of collection, verification, matching and merging of data.

Three large datasets comprise the study. The first dataset is the information of all global VC-backed firms that have had at least one VC deal between January 2000 and January 2011. In this 11-year timeframe, over 25000 VC deals occurred worldwide. Zephyr, as a part of BVD (Bureau Van Dijk Co.) is the main source of this data. Zephyr is a comprehensive global database of deal information which contains information on M&A, IPO, private equity and VC deals and rumors. All completed VC deals from January 01, 2000 until January 01, 2011 were retrieved from the Zephyr database for seven main parameters: acquirer (VC investor), target (sponsored) firms of VC deal, VC deal number, deal status, date and amount of completed deal, country, and industry type based on the Standard Industrial Classification (SIC) codes[1]. The list of two-digit SIC codes and industry types are provided in Appendix C. The second dataset is the list of global non VC-

[1] Standard Industrial Classification (SIC) codes were provided and assigned by the U.S. government in 1937 for industries classification. SIC codes are broadly classified into industry group, major group and division, based on the number of digits (from 1 to 4 digits) and used by other countries as well. This classification was developed for data collection, classification, presentation and analysis of data, and it is utilized by various agencies of the federal government, state agencies and private organizations. These codes cover all business categories, including fishing, hunting and trapping, agriculture, forestry, mining, construction, manufacturing, transportation, communications, electric, gas and sanitary services, wholesale trade, retail trade, finance; insurance and real estate, personal, business, professional, repair, recreation and other services, and public administration (US Government, 2013).

backed firms and forms the reference (control) group for this study. The number of required non VC-backed firms is based on the number of VC-backed firms in each industry and location. We stratify the matching process by SIC code and country. The data is retrieved randomly from the LexisNexis system, which covers both private and public firms through Hoover's and other global business directories. Hoover's, Inc., a subsidiary of Dun & Bradstreet, is a business research company that has provided information on U.S. and foreign companies and industries since 1990. Hoover's maintains a database of 66 million public and private companies across the world. For the control group, we extracted similar parameters to Zephyr: company name, location, industry (US SIC Code), and company size (employees, annual sales, total assets).

The third dataset is global patent information. The patent data for all VC-backed and non VC-backed lists were retrieved and aggregated from the Thomson Innovation database between January 1995 and May 2012. Thomson Innovation, a part of Thomson Reuters, is a comprehensive and global source of full-text patents and published applications. This database was used to retrieve all patent information of all VC-backed and non VC-backed firms that we collected in the previous steps. The main parameters of our patent database are: assignee/applicant, location (address), application and publication number, application and publication date, application and publication country, number of assignee (for each), industry (IPC, ECLA, US Class), assignee (based on DWPI), priority number, priority date and inventors.

Collecting and matching the datasets resulted in four main categories of firms for the research:

1. Firms that receive VC and have no patents (i.e., never show up in the patent database)
2. Firms that receive VC and have patents (patents could be pre- and post- VC)
3. Firms that have patents and do not have VC

4. Firms that have no patent and do not have VC

In addition to the aforementioned data elements, we collected three more datasets for country-level indices to control a firm's socioeconomic environment from three different aspects: regulatory, cultural, and economic and market conditions. Based on Cumming and Knill (2010) and Groh et al. (2010), the indices Intellectual Property Rights (IPR), Political Stability and Absence of Violence, Regulatory Quality, Business Extent of Disclosure, and Taxes can be added for regulation control. The cultural indices contain Labor Force (with Secondary Education), Secondary School Enrollment, and R&D Expenditure.

For economic and market conditions, according to Cumming and Knill (2010), Groh et al. (2010), Dutta (2012), and MSCI (2013), Return on Equity, Market Capitalization, MSCI Return, GDP per capita (current US$), and Business Entry Rate indices are selected and added. Details of these indices are in Table 3.1. These indices were extracted from the World Bank database, Morgan Stanley Capital International (MSCI) system, Doing Business Project (led by International Finance Corporation and the World Bank) and the World Economic Forum data platform for the time period 2000 to 2012. Since these indices may not be independent of each other, it is necessary to test their pairwise correlations and reduce collinearity concerns.

In this study, we include all industries and legal systems (and regions) to compare patenting rates, and to examine the effectiveness of VC investment on business innovation by area. The results of this study clarify for researchers, entrepreneurs, and policy makers in developed and developing countries the effectiveness of VC investment on innovation, based on industry and location.

Table 3.1: List of the country-based variables/indices (for 11 years from 2000 to 2011)

Variable	Definition	Source*
Legal System	Countries' Legal System: Common or British Law, Civil Law (French, German and Scandinavian), and Muslim	La Porta et al. (1998) +Univ of Ottawa
Intellectual Property Protection/Rights (IPR)	Shows two major forms of intellectual property protection/rights: patents and copyrights, and scored from weakest (1) to strongest (7) levels	World Economic Forum
Political Stability and Absence of Violence	Evaluates government stability, tensions, violations and security (from -2.5: weak to 2.5: strong)	World Bank
Regulatory Quality	Government ability to define and establish comprehensive policies and regulations that support private sectors	World Bank
Business Extent of Disclosure	Level of investors' protection for disclosure of business ownership and financial information (0=less disclosure to 10=more disclosure)	World Bank
Taxes on Income, Profits and Capital Gains(% of revenue)	Tax rates based on net income, corporate profits and capital gain	World Bank
Return on Equity (%)	The annual rate of return on shareholders' equity and is equal to net income divided by total equity in a fiscal year	World Bank
Market Capitalization of Listed Companies (current US$)	Market value of all shares outstanding	World Bank
MSCI Return	Established by Morgan Stanley Capital International to measure stock market performance	Morgan Stanley Capital International
GDP per Capita (current US$)	Measures the annual national GDP per capita based on the US$ currency	World Bank
New Businesses Registered	The number of newly registered limited liability corporation	World Bank
Labor Force with Secondary Education (% of total)	The percentage of the labor forces that has completed secondary education level.	World Bank
School Enrollment, Secondary (% net)	Net school enrolment rate in secondary level in all programs	World Bank
Research and Development Expenditure (% of GDP)	The proportion of R&D expenditure (for basic and applied research as well as experimental development) out of total GDP	World Bank

* Screenshots of the data sources are provided in Appendix A.

3.2. Data Collection, Cleansing and Merging Process

Collecting large-scale datasets for this research was a complicated, iterative and time-consuming process. All three databases have different access restrictions, and search and data-extraction limitations. This section provides a brief overview of the high-level process of data collection, processing and merging through different sources.

The first step is retrieving the required data from the Zephyr database and finalizing the VC dataset, including defining parameters based on analysis requirements and Zephyr's own limitations; retrieving outputs from Zephyr and exporting to other usable formats (i.e., Ms-Excel); rationalizing the VC dataset (i.e., sorting, cleaning, reorganizing the dataset prior to merging).

The second step is defining requirements and retrieving the required data from LexisNexis. Since the non VC-backed firms list is the control group in the study, for stratifying data, it was necessary to estimate the number of control firms (non VC-backed) for each industry and location based on the treatment group (the VC-backed firms list). According to the VC-backed list, a matrix was created to define the minimum requirements for each industry and region. After that, active firms were retrieved randomly from LexisNexis based on the defined parameters. The non VC-backed data also had to be rationalized (sort, clean, reorder, and remove any VC-backed firms erroneously included).

In the third step, we retrieved required patent data from Thomson Innovation, first defining our parameters, retrieving the data and then exporting it to usable formats. Due to the system's limitations, 40 firms were entered in each run. We completed over 2,200 data entry and query runs. All 2,200 Excel files (over 1600 megabytes of data) were aggregated and the patent dataset was rationalized by sorting, cleaning, reorganizing the data. At the end, we had over 600 megabyte of data.

The fourth step was matching and merging firms and patent datasets, including the creation of a new parameter for firm names by removing all inconsistencies (suffixes, spaces, and additional characters) using VBA codes. VBA codes were created to remove duplicate firm names and country, so that VC-backed, non VC-backed, and patent datasets could be merged. For example, if we have "1366TECHNOLOGIES INC." as a US company in the VC dataset and "1366 TECHNOLOGIES INCORPORATED" as a US company in the patent dataset, we consider them to be the same company and automatically bring all VC deals and patent data of this company together.

In the final stage, we verified, completed quality assurance, and merged all datasets. Merging included converting the matched datasets to the proper format for merging (generating a pivot table) and then merging through the common field. This process of data collection, cleansing and merging is demonstrated in Figure 3.3. The main results of the process are two comprehensive lists of all VC-backed and non VC-backed firms with their patent data (from 1995 to May 2012); the total number of these firms in each industry/location and the proportion of patent owners are demonstrated in Tables 3.2, 3.3, 3.4 and 3.5.

3.3. Major Limitations, Issues and Assumptions in Data Collection Process

Many limitations and issues arise during data collection using the data sources/databases indicated above. We highlight some of the key limitations and issues here. In the Zephyr database, target firm naming conventions are not consistent or standardized. There is no location (country code) information for some target firms, and there is not enough VC deal information for some world regions. In the LexisNexis application, the system does not show a firm's data for a few industries/locations. In addition, a limitation is placed on the number of queries/runs that be viewed to extract data.

The Thomson Innovation database imposes more limitations than others. The key name of firms must be entered manually in order to extract their patent data (we entered up to 40 firms in each run). Since the assignee/applicant naming convention is not consistent and standardized, we just entered the key word of every firm's name. The main issue here is that we retrieve the patent data of all firms that have the same key word. In addition, in this database, we can only extract/export up to 30,000 patents in each run (for up to 40 firms). Therefore, sometimes, we need to reduce the number of firms in each run to ensure that we collect all firms' patents.

Other limitations of Thomson Innovation include its data-retrieved speed, lack of standard company code for assignees/applicants in the system, lack of country code for firm/applicant (it has application and publication countries), and lack of address for many firms. Moreover, the system does not accept any non-letter characters (e.g., &,@,(),{,[,;,:, ",…) in a firm's name and these characters must be removed manually during data entry. SIC codes do not exist in the system. Instead, they use International Patent Classification (IPC), the European Classification System (ECLA), and US Class. Some patent record data is also lacking.

In addition to the aforementioned problems, some other restrictions arise in the data collection process. Both the Access and Excel applications used to aggregate and merge exported files of other databases have limited capacity for large-scale datasets, due to their limited number of rows and columns. Therefore, our files are split into different files or sheets for data processing. These MS-Office tools also have only a limited capacity and capability for data cleansing, calculation and processing our large main files (over 100MB), even though we employed two different servers for these purposes. We applied Visual Basic and advanced Excel functions to improve this process and reduce the cycle time. The main issues and limitations in the process of data collection, cleansing and merging are also demonstrated in Figure 3.4.

In macroeconomics databases, such as the World Bank, MSCI and Doing Business programs, there are some gaps and limitations as well. The datasets do not cover all countries and/or years, and for some key indices, data does not exist for 2011 and 2012. For the missing data points, we apply the three simple methods proposed by Nardo et al. (2005a). The methods were 1) trying to find missing data in other databases or via the Internet, 2) interpolating between adjacent data records, and 3) using the latest available data before 2011. For the second item, we use the median of that variable for the same legal system for the missing data point.

Table 3.2: Number of VC-backed firms that own patents (out of total in the list*)

	2-DIGIT SIC CODE																
COUNTRY	**20**	**28**	**30**	**32**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Australia	(1)	6(10)			(1)	(1)	4(8)		2(3)	(3)	1(2)			2(13)	8(15)	0(5)	23(62)
Bermuda														(2)		0(6)	(8)
Canada	(3)	11(30)	(3)	(1)	(2)	5(8)	30(66)		7(19)	2(11)	(2)	(3)	1(2)	56(198)	35(84)	1(20)	148(452)
Great Britain (UK)	2(18)	35(73)	1(6)	2(2)	3(7)	11(42)	70(146)	(9)	57(118)	6(71)	5(20)	1(14)	(8)	167(861)	161(321)	25(381)	546(2097)
Hong Kong		(1)					(2)							(9)	(1)	0(2)	(15)
Ireland		1(6)				2(4)	3(13)		3(12)	(8)			(1)	14(111)	5(13)	1(12)	29(180)
Israel		13(23)		1(1)		13(22)	37(77)	1(2)	34(67)	2(7)	(4)	1(1)		78(186)	36(66)	8(24)	224(480)
India	(2)	2(7)	(1)		(1)	(3)	(2)	(2)	(4)	(6)	(2)	(1)		1(69)	1(14)	0(54)	4(168)
Cayman Islands		(1)					(5)			(1)				(10)	(1)	0(5)	(23)
Malaysia		(2)												(6)		0(1)	(9)
New Zealand		(4)				(1)								1(7)	(6)		1(18)
Singapore		1(2)				(1)	(3)		(2)	2(4)				(11)	(2)	0(3)	3(28)
United States	5(28)	183(375)	2(10)	4(11)	5(15)	93(169)	459(896)	12(30)	306(541)	52(221)	9(40)	12(39)	2(17)	1589(4515)	594(1119)	135(730)	3462(8756)
South Africa									(1)	(2)		(1)	(1)	(6)	(3)	0(2)	(16)
Others in British law		0(1)								0(2)		0(1)		1(6)	0(1)	0(1)	1(12)
British law	**7(52)**	**252(535)**	**3(20)**	**7(15)**	**8(26)**	**124(251)**	**603(1218)**	**13(43)**	**409(767)**	**64(336)**	**15(70)**	**14(60)**	**3(29)**	**1909(6010)**	**840(1646)**	**170(1246)**	**4441(12324)**
China	1(4)	5(16)	(1)	(2)	(2)	1(5)	6(23)	(2)	(1)	(8)	1(3)	(2)	(2)	8(152)	(16)	3(75)	25(314)
Czech Republic								(1)	1(1)					(6)		0(1)	1(9)
Iceland										(1)				(1)			(2)
Liechtenstein		(1)															(1)
Lithuania																0(1)	(1)
Poland						(1)					(1)			(13)		0(7)	(22)
Romania												(1)		(3)			(4)
Russian Federation										(3)				(6)		0(6)	(15)
Others in Civil law	0(2)	0(1)		0(2)		0(1)	0(1)	0(2)		0(4)	0(1)	0(1)		0(36)	1(4)	0(17)	1(72)
Civil law	**1(6)**	**5(18)**	**(1)**	**(4)**	**(2)**	**1(7)**	**6(24)**	**(5)**	**1(2)**	**(16)**	**1(5)**	**(4)**	**(2)**	**8(217)**	**1(20)**	**3(107)**	**27(440)**

*Numbers in the bracket show the total number of VC-backed firms for that country/industry in the main dataset

Table 3.2: Number of VC-backed firms that own patents (out of total in the list*)- continued

	2-DIGIT SIC CODE																
COUNTRY	**20**	**28**	**30**	**32**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Belgium	(2)	4(6)	1(1)		(2)	1(4)	2(7)	(1)	6(8)	(5)	(1)		(1)	10(73)	11(21)	3(17)	38(149)
Brazil	(1)						(2)		(1)	(1)				(10)	(2)	0(1)	(18)
Chile									(1)	(1)				(1)			(3)
Spain	(8)	2(14)	(2)		1(2)	5(13)	2(9)	(1)	5(11)	1(19)	(5)	(3)	(3)	7(123)	9(53)	1(79)	33(345)
France	(8)	8(24)	2(4)	1(2)	1(3)	11(21)	34(67)	1(4)	22(44)	4(35)	1(10)	(8)	(3)	91(480)	53(107)	10(144)	239(964)
Italy	2(3)	3(4)	(1)	(1)		1(4)	2(6)	1(2)	2(5)	(13)	(1)	(3)	(1)	5(39)	9(12)	4(20)	29(115)
Luxembourg		1(1)												1(9)		0(3)	2(13)
Netherlands	(1)	5(16)	1(2)	(1)		1(4)	6(19)	(3)	3(9)	1(12)	1(2)	(4)	(4)	13(90)	10(29)	3(31)	44(227)
Others in French Civil law	0(1)	0(1)					0(3)			0(2)		0(1)		0(13)	0(1)	0(9)	0(31)
Civil law- French	**2(24)**	**23(66)**	**4(10)**	**1(4)**	**2(7)**	**19(46)**	**46(113)**	**2(11)**	**38(79)**	**6(88)**	**2(19)**	**(19)**	**(12)**	**127(838)**	**92(225)**	**21(304)**	**385(1865)**
Austria		2(10)			(2)	1(3)	1(9)		3(6)	(5)	(1)			2(40)	7(18)	0(7)	16(101)
Switzerland		10(13)				3(5)	7(13)		8(16)		(1)			10(42)	17(35)	0(15)	55(140)
Germany	(2)	34(47)	1(4)	(3)	2(3)	10(33)	29(62)	2(4)	37(73)	3(27)	2(7)	(4)	(2)	80(451)	89(165)	8(116)	297(1003)
Croatia (Hrvatska)		(1)						1(1)		(1)				(4)			1(7)
Hungary	(1)						(1)							1(7)	(1)	0(2)	1(12)
Japan		(2)				2(3)	3(5)		1(1)	1(2)				20(69)	3(8)	1(17)	31(107)
Korea (South)			1(2)				2(7)							(3)	1(1)	2(2)	6(15)
Taiwan						2(2)	(3)				1(1)			1(3)	(3)		4(12)
Others in German Civil law																0(6)	0(6)
Civil law- German	**(3)**	**46(73)**	**2(6)**	**(3)**	**2(5)**	**18(46)**	**42(100)**	**3(5)**	**49(96)**	**4(35)**	**3(10)**	**(4)**	**(2)**	**114(619)**	**117(231)**	**11(165)**	**411(1403)**
Denmark	(1)	3(6)				1(2)	8(8)		3(8)	(6)	(1)	1(3)		12(53)	27(37)	1(7)	56(132)
Finland		(2)	1(1)		(1)	5(7)	7(13)		5(9)	1(1)		(1)		23(87)	9(17)	3(15)	54(154)
Norway		4(4)				2(6)	4(10)	(1)	2(2)		1(1)			3(19)	5(9)	1(7)	22(59)
Sweden	1(1)	10(17)	1(1)		1(2)	2(6)	17(34)	2(3)	13(25)	1(11)		(3)	(1)	32(147)	28(45)	7(37)	115(333)
Others in Scandinavian Civil																	
Civil law- Scandinavian	**1(2)**	**17(29)**	**2(2)**		**1(3)**	**10(21)**	**36(65)**	**2(4)**	**23(44)**	**2(18)**	**1(2)**	**1(7)**	**(1)**	**70(306)**	**69(108)**	**12(66)**	**247(678)**
Country Data Not Exist		**(1)**			**(1)**		**3(9)**	**(1)**	**2(3)**	**(1)**	**(1)**	**(2)**	**(1)**	**(28)**	**1(6)**	**1(10)**	**7(64)**
Saudi Arabia		(1)			(1)		3(9)	(1)	2(3)	(1)	(1)	(2)	(1)	(28)	1(6)	1(10)	7(64)
Grand Total	**11(87)**	**343(722)**	**11(39)**	**8(26)**	**13(44)**	**172(371)**	**736(1529)**	**20(69)**	**522(991)**	**76(494)**	**22(107)**	**15(96)**	**3(47)**	**2228(8018)**	**1120(2236)**	**218(1898)**	**5518(16774)**

Table 3.3: The proportion of VC-backed firms that own patents (out of total VC-backed firms)

	2-DIGIT SIC CODE																
COUNTRY	**20**	**28**	**30**	**32**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Australia	0%	60%			0%	0%	50%		67%	0%	50%			15%	53%	0%	37%
Bermuda														0%		0%	0%
Canada	0%	37%	0%	0%	0%	63%	45%		37%	18%	0%	0%	50%	28%	42%	5%	33%
Great Britain (UK)	11%	48%	17%	100%	43%	26%	48%	0%	48%	8%	25%	7%	0%	19%	50%	7%	26%
Hong Kong		0%					0%							0%	0%	0%	0%
Ireland		17%				50%	23%		25%	0%			0%	13%	38%	8%	16%
Israel		57%		100%		59%	48%	50%	51%	29%	0%	100%		42%	55%	33%	47%
India	0%	29%	0%		0%	0%	0%	0%	0%	0%	0%	0%		1%	7%	0%	2%
Cayman Islands		0%					0%			0%				0%	0%	0%	0%
Malaysia		0%												0%		0%	0%
New Zealand		0%				0%								14%	0%		6%
Singapore		50%				0%	0%		0%	50%				0%	0%	0%	11%
United States	18%	49%	20%	36%	33%	55%	51%	40%	57%	24%	23%	31%	12%	35%	53%	18%	40%
South Africa									0%	0%		0%	0%	0%	0%	0%	0%
Others in British law		0%								0%		0%		17%	0%	0%	8%
British law	**13%**	**47%**	**15%**	**47%**	**31%**	**49%**	**50%**	**30%**	**53%**	**19%**	**21%**	**23%**	**10%**	**32%**	**51%**	**14%**	**36%**
China	25%	31%	0%	0%	0%	20%	26%	0%	0%	0%	33%	0%	0%	5%	0%	4%	8%
Czech Republic								0%	100%					0%		0%	11%
Iceland										0%				0%			0%
Liechtenstein		0%															0%
Lithuania																0%	0%
Poland						0%					0%			0%		0%	0%
Romania												0%		0%			0%
Russian Federation										0%				0%		0%	0%
Others in Civil law	0%	0%		0%		0%	0%	0%		0%	0%	0%		0%	25%	0%	1%
Civil law	**17%**	**28%**	**0%**	**0%**	**0%**	**14%**	**25%**	**0%**	**50%**	**0%**	**20%**	**0%**	**0%**	**4%**	**5%**	**3%**	**6%**

Table 3.3: The proportion of VC-backed firms that own patents (out of total VC-backed firms)- continued

	2-DIGIT SIC CODE																
COUNTRY	**20**	**28**	**30**	**32**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Belgium	0%	67%	100%		0%	25%	29%	0%	75%	0%	0%		0%	14%	52%	18%	26%
Brazil	0%						0%		0%	0%				0%	0%	0%	0%
Chile									0%	0%				0%			0%
Spain	0%	14%	0%		50%	38%	22%	0%	45%	5%	0%	0%	0%	6%	17%	1%	10%
France	0%	33%	50%	50%	33%	52%	51%	25%	50%	11%	10%	0%	0%	19%	50%	7%	25%
Italy	67%	75%	0%	0%		25%	33%	50%	40%	0%	0%	0%	0%	13%	75%	20%	25%
Luxembourg		100%												11%		0%	15%
Netherlands	0%	31%	50%	0%		25%	32%	0%	33%	8%	50%	0%	0%	14%	34%	10%	19%
Others in French Civil law	0%	0%					0%			0%		0%		0%	0%	0%	0%
Civil law- French	**8%**	**35%**	**40%**	**25%**	**29%**	**41%**	**41%**	**18%**	**48%**	**7%**	**11%**	**0%**	**0%**	**15%**	**41%**	**7%**	**21%**
Austria		20%			0%	33%	11%		50%	0%	0%			5%	39%	0%	16%
Switzerland		77%				60%	54%		50%		0%			24%	49%	0%	39%
Germany	0%	72%	25%	0%	67%	30%	47%	50%	51%	11%	29%	0%	0%	18%	54%	7%	30%
Croatia (Hrvatska)		0%						100%		0%				0%			14%
Hungary	0%						0%							14%	0%	0%	8%
Japan		0%				67%	60%		100%	50%				29%	38%	6%	29%
Korea (South)			50%				29%							0%	100%	100%	40%
Taiwan						100%	0%				100%			33%	0%		33%
Others in German Civil law																0%	0%
Civil law- German	**0%**	**63%**	**33%**	**0%**	**40%**	**39%**	**42%**	**60%**	**51%**	**11%**	**30%**	**0%**	**0%**	**18%**	**51%**	**7%**	**29%**
Denmark	0%	50%				50%	100%		38%	0%	0%	33%		23%	73%	14%	42%
Finland		0%	100%		0%	71%	54%		56%	100%		0%		26%	53%	20%	35%
Norway		100%				33%	40%	0%	100%		100%			16%	56%	14%	37%
Sweden	100%	59%	100%		50%	33%	50%	67%	52%	9%		0%	0%	22%	62%	19%	35%
Others in Scandinavian Civil																	
Civil law- Scandinavian	**50%**	**59%**	**100%**		**33%**	**48%**	**55%**	**50%**	**52%**	**11%**	**50%**	**14%**	**0%**	**23%**	**64%**	**18%**	**36%**
Country Data Not Exist		**0%**			**0%**		**33%**	**0%**	**67%**	**0%**	**0%**	**0%**	**0%**	**0%**	**17%**	**10%**	**11%**
Saudi Arabia		0%			0%		33%	0%	67%	0%	0%	0%	0%	0%	17%	10%	11%
Grand Total	**12.6%**	**47.5%**	**28.2%**	**30.8%**	**29.5%**	**46.4%**	**48.1%**	**29.0%**	**52.7%**	**15.4%**	**20.6%**	**15.6%**	**6.4%**	**27.8%**	**50.1%**	**11.5%**	**32.9%**

Table 3.4: Number of non VC-backed firms that own patents (out of total in the list*)

	2-DIGIT SIC CODE															
COUNTRY	**20**	**28**	**30**	**33**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Australia	1(4)	1(13)			2(4)	0(5)	3(12)		2(5)	0(7)	0(4)	0(2)	1(5)	0(3)	0(1)	7(74)	17(139)
Bermuda										0(1)				1(3)	0(1)	0(10)	1(15)
Canada	0(6)	11(36)	1(5)	0(1)	1(3)	0(9)	33(72)	1(2)	15(23)	3(14)	1(3)	0(20)	1(11)	39(215)	13(95)	8(213)	127(728)
Great Britain (UK)	2(29)	19(84)	6(9)	0(5)	2(12)	2(51)	25(176)	4(17)	20(138)	3(83)	1(25)	5(21)	1(12)	34(919)	12(351)	42(619)	178(2551)
Hong Kong	0(1)	0(2)					0(3)					1(4)	0(2)	0(12)	0(2)	0(10)	1(36)
Ireland	0(1)	2(8)				1(6)	1(16)		2(17)	1(11)			0(1)	2(123)	1(18)	1(30)	11(231)
Israel		8(28)	0(1)		0(2)	9(25)	18(85)	2(4)	26(73)	1(10)	2(4)	0(2)		17(202)	1(75)	2(50)	86(561)
India	0(4)	2(9)	0(1)	0(4)	0(2)	1(5)	1(2)	1(3)	2(6)	1(9)	0(2)	0(2)	0(1)	5(84)	1(19)	5(88)	19(241)
Cayman Islands							0(1)			0(2)				1(12)	0(2)	0(10)	1(27)
Malaysia	0(1)	0(2)		0(2)	0(1)	0(1)	0(2)	0(2)			0(1)	0(4)	0(1)	0(9)		1(24)	1(50)
New Zealand	0(1)	3(4)				0(2)								0(10)	2(6)	1(2)	6(25)
Singapore		1(4)				1(2)	1(5)		0(4)	2(6)	0(1)	0(4)	1(3)	2(13)	0(3)	0(13)	8(58)
United States	11(120)	115(375)	19(85)	9(73)	18(166)	43(237)	253(896)	12(72)	201(541)	25(230)	8(86)	34(755)	24(488)	325(4533)	129(1125)	184(8224)	1410(18006)
South Africa		1(1)		0(1)				0(2)	0(2)	0(3)		0(2)	0(2)	0(9)	1(5)	0(14)	2(41)
Others in British law	0(1)	0(3)						0(1)		0(2)		0(3)		0(3)	0(2)	0(7)	0(22)
British law	**14(168)**	**163(569)**	**26(101)**	**9(86)**	**23(190)**	**57(343)**	**335(1270)**	**20(103)**	**268(809)**	**36(378)**	**12(126)**	**40(819)**	**28(526)**	**426(6150)**	**160(1705)**	**251(9388)**	**1868(22731)**
China	0(6)	0(20)	1(1)		1(6)	3(7)	5(27)	0(4)	0(2)	3(10)	0(5)	2(7)	0(4)	7(171)	4(16)	10(305)	36(591)
Czech Republic				0(1)	0(3)		0(1)	1(2)	1(2)			0(6)		0(8)		0(6)	2(29)
Estonia						0(2)								0(6)	2(4)	0(4)	2(16)
Liechtenstein		1(2)															1(2)
Morocco										1(1)						0(1)	1(2)
Poland			0(1)		0(1)	0(2)	0(1)				0(2)		0(3)	2(17)		2(23)	4(50)
Russian Federation	0(2)	0(1)		0(2)	0(1)	0(1)		0(2)		0(5)		0(4)	0(5)	0(9)		1(54)	1(86)
Others in Civil law	0(7)	0(5)	0(4)	0(5)	0(1)	0(1)	0(5)	0(3)		0(8)	0(2)	0(9)	0(7)	0(45)	0(1)	0(144)	0(247)
Civil law	**0(15)**	**1(28)**	**1(6)**	**0(8)**	**1(12)**	**3(13)**	**5(34)**	**1(11)**	**1(4)**	**4(24)**	**0(9)**	**2(26)**	**0(19)**	**9(256)**	**6(21)**	**13(537)**	**47(1023)**

*Numbers in the bracket show the total number of non VC-backed firms for that country/industry in the main dataset

Table 3.4: Number of non VC-backed firms that own patents (out of total in the list*)- continued

	2-DIGIT SIC CODE															
COUNTRY	**20**	**28**	**30**	**33**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Argentina		1(11)			0(4)		0(10)		0(5)	0(2)	0(4)			0(14)	0(22)	0(46)	1(118)
Belgium	0(4)	5(8)	1(3)		1(2)	1(6)	4(9)	0(2)	1(11)	0(10)	0(2)	0(2)	0(2)	0(81)	0(27)	0(41)	13(210)
Brazil	0(1)	1(2)	0(1)	0(1)		0(2)	1(3)				0(1)	0(2)	0(6)	0(1)		0(25)	2(45)
Spain	0(8)	5(17)	1(4)	0(1)	0(22)	3(17)	2(12)	1(3)	2(14)	3(25)	0(8)	0(14)	0(15)	5(123)	3(55)	2(307)	27(645)
France	1(35)	10(27)	2(8)	0(2)	2(12)	1(26)	14(73)	1(6)	15(54)	4(38)	1(14)	1(41)	1(30)	13(507)	4(123)	10(468)	80(1464)
Italy	4(25)	2(10)	1(7)	3(11)	0(34)	14(25)	4(13)	0(5)	1(7)	4(19)	1(5)	5(51)	1(46)	1(48)	1(17)	25(476)	67(799)
Netherlands	0(1)	5(14)	0(3)			3(6)	2(25)	0(5)	2(13)	0(16)	1(4)	0(4)	0(6)	3(103)	1(36)	0(59)	17(295)
Turkey	0(3)	1(3)			0(1)	0(1)	0(1)									0(5)	1(14)
Others in French Civil law	0(5)	0(4)	0(1)	0(2)	0(2)		0(3)	0(1)	0(2)	0(6)	0(1)	0(2)	0(2)	0(28)	0(2)	0(70)	0(131)
Civil law- French	**5(82)**	**30(96)**	**5(27)**	**3(17)**	**3(77)**	**22(83)**	**27(149)**	**2(22)**	**21(106)**	**11(116)**	**3(39)**	**6(116)**	**2(107)**	**22(905)**	**9(282)**	**37(1497)**	**208(3721)**
Austria	0(2)	3(11)		1(2)	1(1)	1(5)	3(13)		1(9)	0(8)	0(2)	0(2)		0(50)	0(24)	1(23)	11(152)
Switzerland		3(16)		0(1)	0(3)	3(8)	6(16)		7(19)		0(2)		0(1)	0(51)	5(40)	3(48)	27(205)
Germany	0(5)	17(51)	3(6)	1(2)	2(18)	12(42)	21(68)	5(6)	35(69)	4(25)	1(9)	0(24)	1(10)	14(483)	6(184)	11(306)	133(1308)
Croatia (Hrvatska)		1(2)						0(2)		0(1)				0(6)		0(3)	1(14)
Japan	7(12)	12(13)		6(7)	5(6)	8(8)	11(12)	2(3)	4(5)	0(2)	0(1)	5(11)	3(15)	25(75)	3(9)	40(129)	131(308)
Korea (South)	2(2)	2(4)	3(4)	1(1)			7(9)	0(1)			2(2)	1(1)		1(4)	1(1)	6(10)	26(39)
Taiwan		1(2)			0(1)	5(5)	9(13)		2(2)		0(2)	2(4)	1(1)	2(5)	4(5)	0(3)	26(43)
Others in German Civil law	0(3)						0(1)						0(2)	0(10)	0(2)	0(20)	0(38)
Civil law- German	**9(24)**	**39(99)**	**6(10)**	**9(13)**	**8(29)**	**29(68)**	**57(132)**	**7(12)**	**49(104)**	**4(36)**	**3(18)**	**8(42)**	**5(29)**	**42(684)**	**19(265)**	**61(542)**	**355(2107)**
Denmark	0(1)	5(9)			0(4)	1(2)	3(11)		6(8)	0(9)	0(2)	0(4)	1(2)	0(66)	5(46)	0(45)	21(209)
Finland	0(1)	3(4)	2(2)	0(1)	0(2)	5(10)	1(12)		4(16)	0(1)		0(3)	0(2)	15(97)	1(19)	3(39)	34(209)
Norway	0(1)	2(6)				4(9)	6(14)	0(2)	0(3)		0(2)	1(4)		0(1)	1(3)	6(64)	20(109)
Sweden	0(3)	5(15)	1(2)	1(3)	0(5)	3(9)	3(40)	0(3)	14(27)	3(11)	0(1)	0(3)	0(6)	6(205)	11(49)	5(108)	52(490)
Others in Scandinavian Civi																	
Civil law- Scandinavian	**0(6)**	**15(34)**	**3(4)**	**1(4)**	**0(11)**	**13(30)**	**13(77)**	**0(5)**	**24(54)**	**3(21)**	**0(5)**	**1(14)**	**1(10)**	**21(369)**	**18(117)**	**14(256)**	**127(1017)**
Saudi Arabia												(1)					
Grand Total	**28(295)**	**248(826)**	**41(148)**	**22(128)**	**35(319)**	**124(537)**	**437(1662)**	**30(153)**	**363(1077)**	**58(575)**	**18(197)**	**57(1018)**	**36(691)**	**520(8364)**	**212(2390)**	**376(12220)**	**2605(30600)**

Table 3.5: The proportion of non VC-backed firms that own patents (out of total non VC-backed firms)

	2-DIGIT SIC CODE																
COUNTRY	**20**	**28**	**30**	**33**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Australia	25%	8%			50%	0%	25%		40%	0%	0%	0%	20%	0%	0%	9%	12%
Bermuda										0%				33%	0%	0%	7%
Canada	0%	31%	20%	0%	33%	0%	46%	50%	65%	21%	33%	0%	9%	18%	14%	4%	17%
Great Britain (UK)	7%	23%	67%	0%	17%	4%	14%	24%	14%	4%	4%	24%	8%	4%	3%	7%	7%
Hong Kong	0%	0%					0%					25%	0%	0%	0%	0%	3%
Ireland	0%	25%				17%	6%		12%	9%			0%	2%	6%	3%	5%
Israel		29%	0%		0%	36%	21%	50%	36%	10%	50%	0%		8%	1%	4%	15%
India	0%	22%	0%	0%	0%	20%	50%	33%	33%	11%	0%	0%	0%	6%	5%	6%	8%
Cayman Islands							0%			0%				8%	0%	0%	4%
Malaysia	0%	0%		0%	0%	0%	0%	0%			0%	0%	0%	0%		4%	2%
New Zealand	0%	75%				0%								0%	33%	50%	24%
Singapore		25%				50%	20%		0%	33%	0%	0%	33%	15%	0%	0%	14%
United States	9%	31%	22%	12%	11%	18%	28%	17%	37%	11%	9%	5%	5%	7%	11%	2%	8%
South Africa		100%		0%				0%	0%	0%		0%	0%	0%	20%	0%	5%
Others in British law	0%	0%						0%		0%		0%		0%	0%	0%	0%
British law	**8%**	**29%**	**26%**	**10%**	**12%**	**17%**	**26%**	**19%**	**33%**	**10%**	**10%**	**5%**	**5%**	**7%**	**9%**	**3%**	**8%**
China	0%	0%	100%		17%	43%	19%	0%	0%	30%	0%	29%	0%	4%	25%	3%	6%
Czech Republic				0%	0%		0%	50%	50%			0%		0%		0%	7%
Estonia						0%								0%	50%	0%	13%
Liechtenstein		50%															50%
Morocco										100%						0%	50%
Poland			0%		0%	0%	0%				0%		0%	12%		9%	8%
Russian Federation	0%	0%		0%	0%	0%		0%		0%		0%	0%	0%		2%	1%
Others in Civil law	0%	0%	0%	0%	0%	0%	0%	0%		0%	0%	0%	0%	0%	0%	0%	0%
Civil law	**0%**	**4%**	**17%**	**0%**	**8%**	**23%**	**15%**	**9%**	**25%**	**17%**	**0%**	**8%**	**0%**	**4%**	**29%**	**2%**	**5%**

Table 3.5: The proportion of non VC-backed firms that own patents (out of total non VC-backed firms)- continued

	2-DIGIT SIC CODE																
COUNTRY	**20**	**28**	**30**	**33**	**34**	**35**	**36**	**37**	**38**	**48**	**49**	**50**	**51**	**73**	**87**	**Other Codes**	**Grand Total**
Argentina		9%			0%		0%		0%	0%	0%			0%	0%	0%	1%
Belgium	0%	63%	33%		50%	17%	44%	0%	9%	0%	0%	0%	0%	0%	0%	0%	6%
Brazil	0%	50%	0%	0%		0%	33%				0%	0%	0%	0%		0%	4%
Spain	0%	29%	25%	0%	0%	18%	17%	33%	14%	12%	0%	0%	0%	4%	5%	1%	4%
France	3%	37%	25%	0%	17%	4%	19%	17%	28%	11%	7%	2%	3%	3%	3%	2%	5%
Italy	16%	20%	14%	27%	0%	56%	31%	0%	14%	21%	20%	10%	2%	2%	6%	5%	8%
Netherlands	0%	36%	0%			50%	8%	0%	15%	0%	25%	0%	0%	3%	3%	0%	6%
Turkey	0%	33%			0%	0%	0%									0%	7%
Others in French Civil law	0%	0%	0%	0%	0%		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Civil law- French	**6%**	**31%**	**19%**	**18%**	**4%**	**27%**	**18%**	**9%**	**20%**	**9%**	**8%**	**5%**	**2%**	**2%**	**3%**	**2%**	**6%**
Austria	0%	27%		50%	100%	20%	23%		11%	0%	0%	0%		0%	0%	4%	7%
Switzerland		19%		0%	0%	38%	38%		37%		0%		0%	0%	13%	6%	13%
Germany	0%	33%	50%	50%	11%	29%	31%	83%	51%	16%	11%	0%	10%	3%	3%	4%	10%
Croatia (Hrvatska)		50%						0%		0%				0%		0%	7%
Japan	58%	92%		86%	83%	100%	92%	67%	80%	0%	0%	45%	20%	33%	33%	31%	43%
Korea (South)	100%	50%	75%	100%			78%	0%			100%	100%		25%	100%	60%	67%
Taiwan		50%			0%	100%	69%		100%		0%	50%	100%	40%	80%	0%	60%
Others in German Civil law	0%						0%						0%	0%	0%	0%	0%
Civil law- German	**38%**	**39%**	**60%**	**69%**	**28%**	**43%**	**43%**	**58%**	**47%**	**11%**	**17%**	**19%**	**17%**	**6%**	**7%**	**11%**	**17%**
Denmark	0%	56%			0%	50%	27%		75%	0%	0%	0%	50%	0%	11%	0%	10%
Finland	0%	75%	100%	0%	0%	50%	8%		25%	0%		0%	0%	15%	5%	8%	16%
Norway	0%	33%				44%	43%	0%	0%		0%	25%		0%	33%	9%	18%
Sweden	0%	33%	50%	33%	0%	33%	8%	0%	52%	27%	0%	0%	0%	3%	22%	5%	11%
Others in Scandinavian Civi																	
Civil law- Scandinavian	**0%**	**44%**	**75%**	**25%**	**0%**	**43%**	**17%**	**0%**	**44%**	**14%**	**0%**	**7%**	**10%**	**6%**	**15%**	**5%**	**12%**
Saudi Arabia												**0%**					
Grand Total	**9.5%**	**30.0%**	**27.7%**	**17.2%**	**11.0%**	**23.1%**	**26.3%**	**19.6%**	**33.7%**	**10.1%**	**9.1%**	**5.6%**	**5.2%**	**6.2%**	**8.9%**	**3.1%**	**8.5%**

3.4. Patent Family Issues

A patent family is a group of various patent documents that essentially cover the same innovation in different countries. In each country, when an innovator opens a patent application file, he first receives a local/national application number and application date. In the next step, the patent document is published and the innovator receives a publication number and a publication date. The application number or publication number may show the same family of patents or duplications, based on their codes (ProQuest, 2010). For example, in the US Patent and Trademark Office (USPTO), after application, users can amend the patent and get a new “A” number. For example, application numbers 20120609A1, 20120609A2 and 20120609A3 show a family of patents (duplication) which refers to a single innovation. Therefore, we have to remove the double counting of the patent in A2 and A3 (Thomson Corp, 2007). Figure 3.1 shows a generic international patenting process provided by the World Intellectual Property Organization (WIPO, 2012) and demonstrates the main steps of filing an application, patent publication and granting steps in international and local offices.

As discussed in Chapter 1 (§ 1.3- Patent Registration), right of priority was a key discussion in the Paris convention, under which the priority number and priority date are assigned to those applications that are submitted first in one of the contracting states and need protection in all the other contracting states within 12 months. The later applications will then be regarded as if they had been filed on the same day as the first application (Thomson Corp, 2007). In complex families, multiple priority numbers and dates occur. In a patent family, the first publication is denoted as the basic publication. Patent families may cover more than one patent from the same country. In this case, the later patent files are usually additions or improvements to the previous files. The application numbers and priority numbers are critical for identifying patent families or duplicates (ProQuest, 2010).

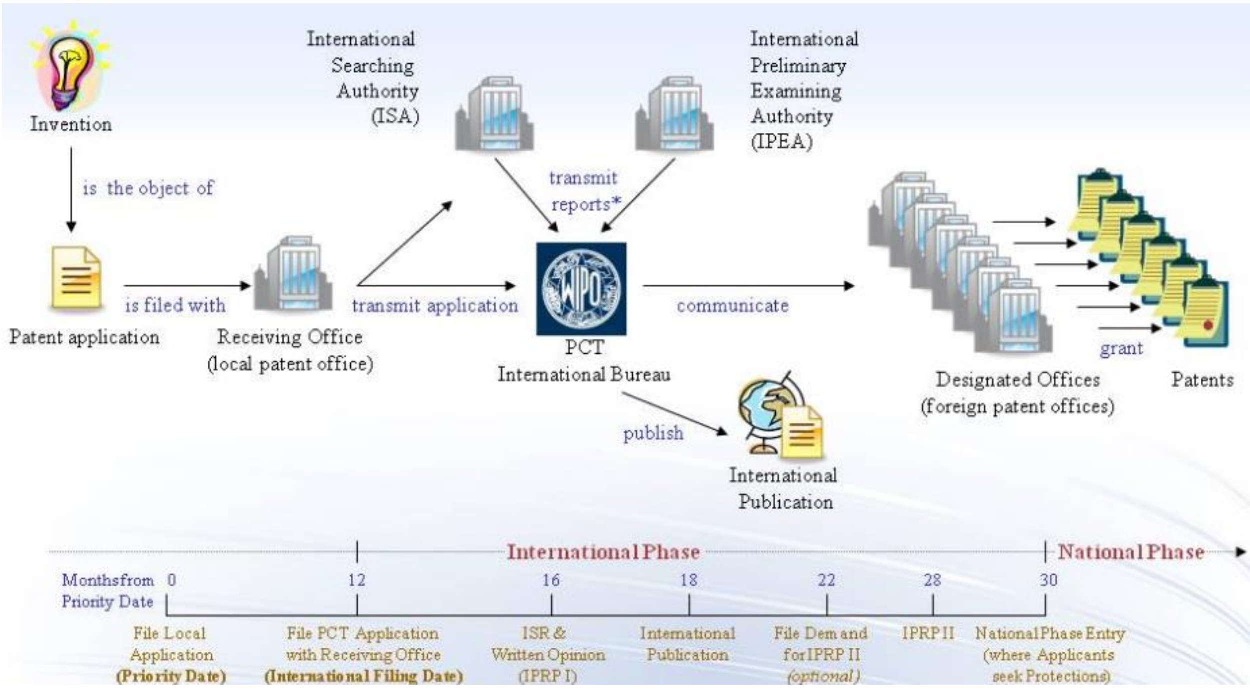


Figure 3.1: Generic patenting process (WIPO, 2012)

Finding and removing patent duplications is one of the main efforts in the cleaning and finalizing of our large datasets, due to double counting and patent family concerns. To remove duplication, we can use and compare different parameters, including the assignee name, applicant name, inventor name, priority date, priority number, country (first two digits). In the first step, if two patents have the same application number, application date, application country, priority number and priority date, then duplication is considered to exist, regardless of different publication numbers.

In the second step, if the application numbers of two patents differ, but their priority numbers agree, duplication is again said to exist (ProQuest, 2012). All duplications are removed before matching and merging datasets. Figure 3.2 shows our process of merging patent data and removing duplications.

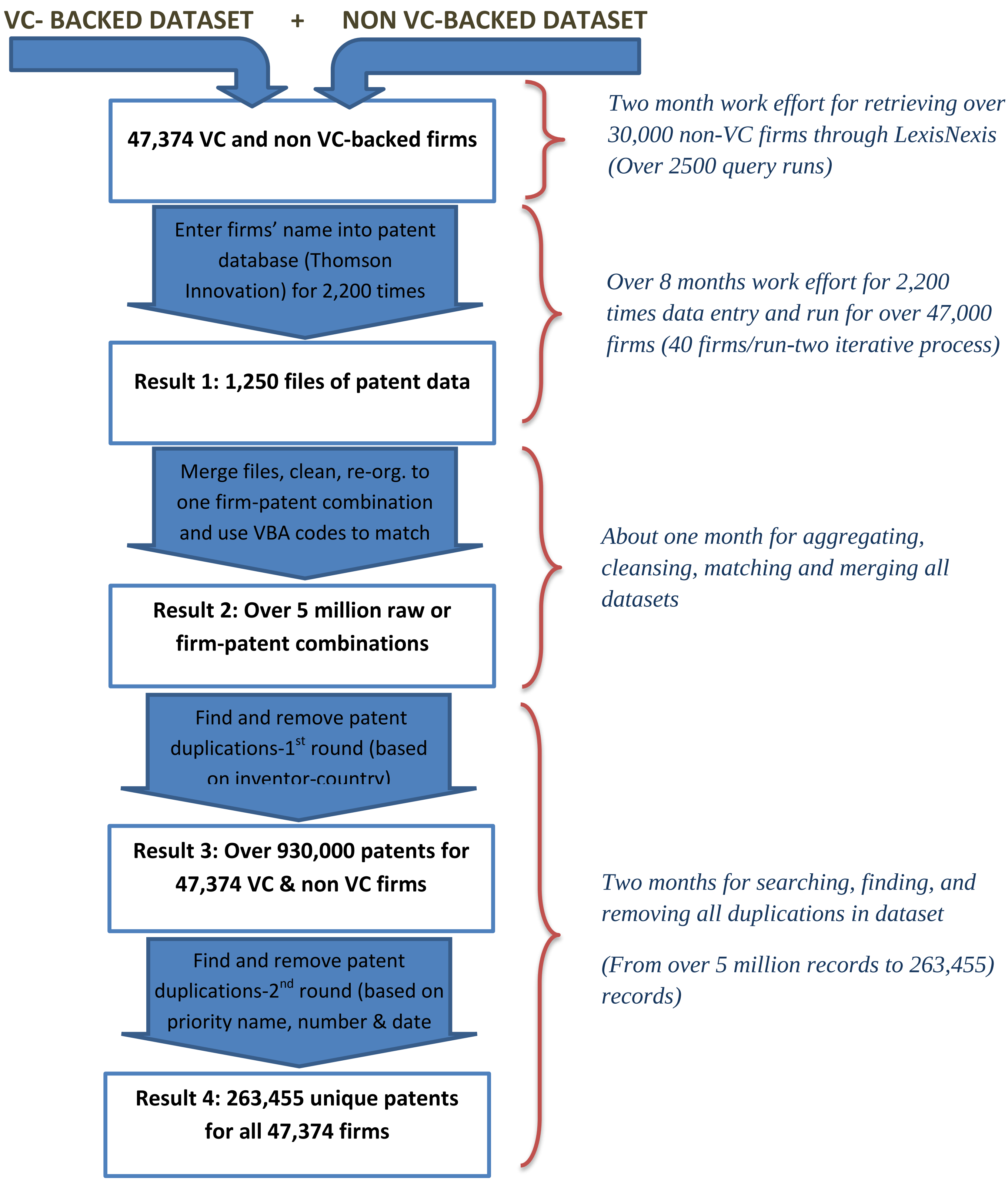


Figure 3.2: Main steps of merging patent data and removing duplications

3.5. Summary of Data Collection Process

The process of data collection, cleansing, matching, merging of all VC-backed and non VC-backed firms is shown in Figure 3.3. This process is divided into eight main stages starting from retrieving VC data toward merging with the final patent dataset. The next two paragraphs provide a summary of data for both VC-backed and non VC-backed firms in which we try to demonstrate the number of firms (and their patents) in the main locations and industries for both lists in four separate tables.

Tables 3.2 and 3.3 show the main VC-backed firms' countries and industries in the list. About 52% of VC-backed firms are located in the US and 12% in Great Britain. Other active countries are Germany (6%), France (6%), Canada (3%), Israel (2%), Spain (2%), Sweden (2%) and China (2%). According to this data, 40% of VC-backed firms in US hold patents, while only 26% of British firms hold patents. This number is 30%, 25%, 33%, 47%, 10%, 39% and 8% for German, French, Canadian, Israelis, Spanish, Swedish and Chinese companies, respectively.

In terms of industry, SIC codes SIC-73 (Business Services), 87 (Engineering, Accounting, Research, Management, and Related Services), 36 (Electronic and Other Electrical Equipment and Components, Except Computer Equipment), 38 (Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks), 28 (Chemicals and Allied Products) and 48 (Communications) are, in order, the most active industries for VC deals during the 2000-2011 period. In the VC-backed list, industry codes 38, 87, 36 and 28 are the most active industries in innovation and patenting. In these four industries, the patent owners are 53%, 50%, 48% and 47% out of the total firms in that specific industry, respectively.

Similarly, Tables 3.3 and 3.4 illustrate the number of non VC-backed firms in the main countries/locations and main industries. In our analysis, this list is the control group for each location and industry. In order to stratify the matching process by SIC and location, the number of non VC-backed firms collected for each SIC/country combination is at least equal to or more than that of the corresponding VC-backed firms.

Define VC required fields and retrieve data from Zephyr	Clean and rationalize the VC dataset (based on target firm)	Retrieve non VC-backed firms from LexisNexis (based on VC list for each SIC/ country)	Clean and rationalize the non VC-backed dataset	Define patent required field and Retrieve data from Thomson Innovation	Clean and rationalize the patent dataset (based on applicant)	Finalize the table	Merge VC and Patent datasets
Main Steps:							
Define fields/ variables based on the requirements and Zephyr database limitations	Change the order and sort the table based on target (VC-backed) firm	Create a matrix of country/industry for VC-backed list to define required non VC list	Export outputs to Excel and rationalize the non VC dataset (sorting, cleansing, reordering,..)	Define fields/ variables based on our requirements and patent database limitations	Combine Excel files extracted from patent database (over 1200 Excel files)	Use firms' table as the baseline and search if VC firms are in patent dataset	Clean the table
Enter input parameters in the Zephyr system and run the query	Change the table from one firm/deal to one firm with its all deals	Define fields/ variables based on our requirements and LexisNexis limitations	Remove those firms that exist in VC-backed list	Select 40 firm names from firm dataset and enter into Thomson manually (by typing)	Change the table (from many co. to one patent in each row to one co./patent) first	Match (initial match) of two datasets (combine common firms and their VC and Patent data)	Create the final table and fix the format
Retrieve and verify results	Check and remove duplications and sort	Enter input parameters in LexisNexis, run the query and verify outcomes	Check and remove duplications and sort the list	Retrive their patent data	Remove all duplications and sort	Match (final match) of two datasets	Final check of the result
Export the output data of VC deals to Ms-Excel	Create a new field for name and remove suffix and additional characters (to use for final merge)		Create a new field for name, remove suffix, and additional characters (to use for final merge)	Export the output data of each 40 firms to Excel	Create a new field for firm name, remove suffix and additional characters	Check the results of match (manually)	
	Verify the VC table in terms of accuracy of the process (Q/A)		Verify the non VC table in terms of accuracy of the process (Q/A)	Repeat 3 last steps for over 47000 firms maually (around 1200 times)	Convert the table from one firm/patent row to one firm with its all patents in that row		

Figure 3.3: Process of data collection, cleansing, and merging all VC-backed and non VC-backed firms

Define VC required fields and retrieve data from Zephyr	Clean and rationalize the VC dataset (based on target firm)	Retrieve non VC-backed firms from LexisNexis (based on VC list for each SIC/ country)	Clean and rationalize the non VC-backed dataset	Define patent required field and Retrieve data from Thomson Innovation	Clean and rationalize the patent dataset (based on applicant)	Finalize the table	Merge VC and Patent datasets
Main Issues:							
Target firms naming convention is not consistant and standard in Zephyr		Lack of data for some industries/locations	Low speed of Excel and servers	Assignee/applicant firms naming conventions not consistant and standard in patent database	Both Access and Excel have limitations for the number of rows and columns (impacted the process time)	Hard to merge datasets due to inconsitent and non-standard firms' naming convention in databases (especially	
Lack of country code for some companies		Limitation per query/run to view or extract firms data		Manual entry needed for all companies	Low speed of data cleansing, due to very large size of the files (over 100MB)	limitation of MS-Office capacity to merge data in a more effective way	
Not enough VC deal info for some world regions				Limitation of each view/report (up to 30,000 records/run)	Limitation of systems (computers) speed		
				Low spead to generating reports			
				No consistant and standard company code			
				No country data for companies' origion			
				Not accepted non-letter characters in the firms' name (e.g., &,@,...)			
				No application date or industry code for some patents			

Figure 3.4: The main issues/limitations in the process of data collection, cleansing, and merging all firms

CHAPTER 4: HYPOTHESES AND METHODS

4.1. Hypotheses

Our main target is to examine the impact of VC investment on a firm's innovation in general and in different industries and regions, considering the IPR parameter and controlling for other country-level factors. Therefore, in this section, we frame three theoretical hypotheses, starting with a broadly framed hypothesis in Section 4.1.1 to examine the effects of VC investment on a firm's patenting in different intellectual property support environments. Section 4.1.2 covers the second hypothesis concerning VC effects in various legal systems and countries. Section 4.1.3 extends the previous hypothesis and addresses VC investment impacts in different industries.

4.1.1. Broadly Framed Hypothesis

Venture capitalists play a key role in target firms, by providing considerable value-added support in leadership, administration and operations services. Testing and measuring the impact of VC investment in increasing a firm's internal knowledge and innovative activities in different environments is the main objective of the first hypothesis (1a). We are also interested in testing and measuring VC investment and IPR parameters together to investigate in detail how VC investors affect start-up firms when they are located in different protection rights and support areas across the world (hypothesis 1b). As many scholars explain, economic development improves the level of patent protection in society (Park, 2008; Eicher and Penalosa, 2006), and increasing innovative capacity and market size encourages regulators and policymakers to provide stronger patent regulations (Grossman and Lai, 2004); however, this level of support is not necessarily equal in similar economies. All countries have recently started developing their regulations to support innovative activities and intellectual property ownership, particularly after TRIPS and other international enforcements were implemented. Hence, the distribution of patent strength has significantly changed from a positively skewed shape prior to the late 1990s to a negatively skewed shape afterward, and the patent index score of most countries are above the mean (Park, 2008). Based on this discussion, our hypotheses are:

Hypothesis 1a: VC investment effects are significant on a firm's patenting rate in different intellectual property support environments, when other cultural, regulatory and macroeconomics factors are controlled for.

Hypothesis 1b: Stronger intellectual property protection and support environments improve the effectiveness of VC investment on a firm's patenting rate.

The IPR index ranks 186 economies and shows the protection rate of two major forms of intellectual property rights: patents and copyrights, scoring it from "weak and not enforced" to "strong and enforced" (Schwab, 2011).

4.1.2. VC and Legal Systems Hypothesis

The legal system is a foundation of a country and is one of the key distinguishing aspects for investment attraction and business support. The study of legal rules in a business context focuses on the rights of investors and how these rules are executed. As mentioned earlier, countries can be categorized under different legal systems: Common law (British law), Civil law (Roman law) and others. Civil law has three families: French, German and Scandinavian (La Porta et. al, 1998). Common law provides investors with stronger legal rights and protection than Civil law (La Porta et. al, 1998). According to the literature, key factors that determine a country's legal system include processes and procedures of jurists, historical trends of legal system evolution and growth, concepts and structure of law, organizational structure and interrelationship between legal sectors (Glendon et al., 1994).

By testing the impacts of VC investment on firm's patenting in different legal systems and countries, we can find the relationship between the rights of investors, quality of enforcement of legal rules, and other national attributes. The hypothesis for this is:

Hypothesis 2: VC investment impact is significant and varies by legal system and country.

The key distinguishing factors between countries are the legal system, cultural, economic and market conditions, and other regulatory elements.

4.1.3. VC and Industry Hypothesis

According to a study by Groh et al. (2013), VC investment attraction in different locations and industries is varied. In addition to the legal infrastructure of a firm's location, it is critical to consider a firm's industry. As Cumming and Knill (2009) asserted, VC investment rates may vary in different industries, because of risk levels and available opportunities in different industries. In addition, some studies, such as those by Timmons and Bygrave (1986), and Boue (2002), show that the VC contribution to target firms is varied and related to three main dimensions: industry, stage of investment, and the country where the target firms are located

(Boue, 2002). The contribution of VC funds and value added activities to the firm's internal sectors may not be the same across different industries. For example, R&D departments may receive more funds in high- technology industries than those in transportation services. In addition, the pace and complexity of technological change vary in different industries and is not expected to see the same innovation rates, but innovation can emerge in any industry (Salge and Vera, 2009). In the industry-level context, innovation may connect to many effective changes in an organization, including market growth, quality, productivity and cost reduction (Salge and Vera, 2012). We may face these impacts in higher proportion in biomedical and high-technology industries than others.

Therefore, it is important to study how effective VC investment is on innovation in various industry sectors, due to the diversity of VC financial and non-financial contributions. This is a novel study to measure this effect and compare the results in many industries together. Below is the hypothesis for testing and measuring VC investment on a firm's patenting applications by industry:

Hypothesis 3: VC investment impact on a firm's patenting rate is significant and varies by industry.

As mentioned earlier in Chapter 3, firms' industry data are retrieved from the main data sources based on two-digit Standard Industrial Classification (SIC) codes. The list of all 88 SIC codes and their definitions are provided in Appendix C; however, only 83 SIC codes exist in our panel dataset.

Table 4.1: Summary of the theoretical hypotheses

Hypothesis	Description	Econometric Model	Other Econ. Techniques
Hypo. 1	1a. VC investment effects are significant on a firm's patenting rate in different intellectual property support environments	Panel Negative Binomial Regression	DWH test, robustness and clustering SE, endogeneity tests (reverse causality, instrumental variables and Heckman Selection)
	1b. Stronger intellectual property protection and support environments improve the effectiveness of VC investment on a firm's patenting rate	Panel Negative Binomial Regression	
Hypo. 2	VC investment impact is significant and varies by legal system and country	Panel Negative Binomial Regression + Causality Test	---
Hypo. 3	VC investment impact is significant and varies by industry	Panel Negative Binomial Regression + Causality Test	---

4.2. Method

Our data includes 47,374 firms from 99 countries and 83 industries, with their 263,455 patent applications taken out between January 1995 and May 2012. Between January 2000 and January 2011, 25,112 VC deals took place. In addition to the IPR index, 14 socio-economic indices exist in the data and measure the cultural, regulatory, and economic and market conditions of firm environments annually from 2000 to 2011. Therefore, a balanced panel data is established with 568,488 firm-year observations.

In order to discuss econometric models, based on these datasets and the above hypotheses, first we need to list all variables of the study.

4.2.1. Measures or Variables

- **Dependent (Response) Variable**

Our dependent variable is the rate of a firm's patenting, operationalized by the annual number of successful patent applications for firm *i* in year *t* and it is dispersed from zero to 2025 patents. This variable shows the number of unique patent applications filed by a firm in a given year (application date). The application date of filing a patent, more proximally shows the time of new innovation (Griliches, 1990; Wadhwa and Kotha, 2006).

- **Independent (Explanatory) Variables**

The VC investment variable shows whether a firm received any VC investment. Since the VC investment value ($) for some VC deals are not available in the database, and we do not have enough information about the distribution of VC funds in each year after investment, we assign a dummy variable to the VC investment variable. VC investment effects reduce over time. The potential VC influences on target firms' innovation are estimated from one to five years after investment (Schildt et al., 2003; and Dushnitsky and Lenox, 2005). Therefore, by considering a one-year lag for VC initial effects; in the panel data, the VC variable is coded as 1 from 1 to 5 years after investment and 0 for other times and for all non VC-backed firms.

IPR is considered as a continuous variable reflecting the score of intellectual property protection and support by a firm's location. Industry is a dummy variable to show the primary industry of firms. We define 82 dummy variables for 83 two-digit SIC codes in the data. Five dummy variables reflect all the national legal systems.

- **Control Variables**

As discussed earlier in Chapter 3 (§ 3.1), to control for country-level factors that might affect a firm's rate of innovation and patenting, several control variables are included from three different aspects of a firm's socioeconomic environment: cultural, regulatory, and economic and market conditions. These indices are listed in Table 3.1.

4.2.2. Econometric Modeling

Since we deal with a multi-dimensional dataset that contains observations on several parameters over multiple time periods for each firm, we utilize longitudinal or panel data analysis. Because each firm is observed over 12 years, this panel is a balanced dataset. There are two important panel data models: the random effects and fixed effects which help us to control and correct for unobserved heterogeneity. The fixed effect model (also known as the within estimator) is useful to control this heterogeneity when it is constant over time and correlated with independent variables. We can remove this constant from the data through differencing; for instance, first difference eliminates any time-invariant elements of the data.

The main assumption in the random effects model (also called a variance component model) is that there is no correlation between the random variable or the entity's error term and the predictors. This allows for time-invariant variables to act as explanatory variables (Torres-Reyna, 2013). There are two common assumptions for fixed and random effects. In the fixed effects assumption, the individual specific effects are correlated with the explanatory variables; however, in the random effects assumption, these individual specific effects are uncorrelated with the explanatory variables (Hausman, 1978). It is necessary to statistically test whether these effects are correlated with the independent variables, using a Durbin-Wu-Hausman (DWH) test.

Defining an appropriate regression model for our analyses is based on the defined hypotheses, variables and panel data. The dependent variable (i.e., the number of patents in year *t*), is a count variable and takes a non-negative integer value. We use econometric methods to quantify statistical relationships that are believed to hold between our parameters and account for heterokedastic and non-normal residuals (Hausman et al., 1984). The value of this response variable in our large-scale dataset ranges from zero to 2,025 patents. This wide range of values with many zero values may indicate non-normality in residual distribution and overdispersion. A Poisson or negative binomial regression model, the latter being a general form of Poisson regression model, is a good candidate for our panel data analysis. The Poisson regression model has some limitations however. The model assumes that the variability of patent numbers within a covariate group is equal to the mean. If the variance is greater than the mean, it will cause underestimation of standard errors and overestimation of the significance of the regression parameters (Cameron and Trivedi, 1998). Therefore, we can apply a Poisson quasi-likelihood, with overdispersion parameter or a negative binomial regression model, but the latter is better, because the overdispersion parameter in a negative binomial regression has an unconditional distribution, while it has a conditional distribution (Poisson distribution) in the Poisson quasi-likelihood model (Rodriguez, 2013). The negative binomial distribution has one additional parameter, used to correct the variance independently of the mean (Cameron and Trivedi, 1998). We can write our negative binomial regression model in the following format:

$$Y_{it} = X_{it}\beta + u_i + e_{it} \quad (1)$$

t = 2000, 2001,…, 2011 (time) and i = 1, 2,…., 47374 (firm)

Where Y_{it} is the dependent variable observed for firm *i* at time *t*. As we know, in the negative binomial regression, a log-link function transforms the count response variables to continuous variables:

$$E(Y) = \mu$$

$$Log(\mu) = X\beta + u + e \quad (2)$$

$$or\ \mu = exp^{X\beta+u+e}$$

μ is the average of patent count we are modeling. X_{it} is the time-variant regressors, u_i is the unobserved time-invariant individual fixed effect, and e_{it} is the main error term

$$Y = \begin{pmatrix} Y_{1,2000} \\ Y_{1,2001} \\ Y_{1,2002} \\ \vdots \\ Y_{1,2011} \\ Y_{2,2000} \\ \vdots \\ Y_{2,2011} \\ \vdots \\ Y_{47,374,2000} \\ \vdots \\ Y_{47,374,2011} \end{pmatrix} \qquad e = \begin{pmatrix} e_{1,2000} \\ e_{1,2001} \\ e_{1,2002} \\ \vdots \\ e_{1,2011} \\ e_{2,2000} \\ \vdots \\ e_{2,2011} \\ \vdots \\ e_{47,374,2000} \\ \vdots \\ e_{47,374,2011} \end{pmatrix} \quad (3)$$

$$X = \begin{pmatrix} X_{1,1,2000} & X_{1,2,2000} & \cdots & X_{1,101,2000} \\ X_{1,1,2001} & X_{1,2,2001} & \cdots & X_{1,101,2001} \\ X_{1,1,2002} & X_{1,2,2002} & \cdots & X_{1,101,2002} \\ \vdots & \vdots & \vdots & \vdots \\ X_{1,1,2011} & X_{1,2,2011} & \cdots & X_{1,101,2011} \\ X_{2,1,2000} & X_{2,2,2000} & \cdots & X_{2,101,2000} \\ \vdots & \vdots & \vdots & \vdots \\ X_{2,1,2011} & X_{2,2,2011} & \cdots & X_{2,101,2011} \\ \vdots & \vdots & \vdots & \vdots \\ X_{47,374,1,2000} & X_{47,374,2,2000} & \cdots & X_{47,374,101,2000} \\ \vdots & \vdots & \cdots & \vdots \\ X_{47,374,1,2011} & X_{47,374,2,2011} & & X_{47,374,101,2011} \end{pmatrix} \qquad \beta = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \vdots \\ \vdots \\ \beta_{101} \end{pmatrix}$$

Note: X is a 568,488×101 matrix, and β is 101×1 matrix.

Matrix X columns show the explanatory variables, including: 1:VC investment, 2:IPR, 3:business extend to disclosure, 4: political stability and absence of violence, 5: GDP per capita, 6: labor force with secondary education, 7: business entry rate (new business registrations as % of total), 8: research and development expenditure (% of GDP), 9: return on equity (%), 10: school enrollment, secondary (% net), 11: market capitalization of listed companies (current USD), 12: taxes on income, profits and capital gains (% of revenue), 13: MSCI return index (annual), 14:VC*IPR (interaction), 15 to 19: dummy variables of six legal systems, and 20 to 101: cover 82 dummy variables of 83 existing SIC codes in the panel data.

Since the response variable contains excess zero-counted values, a zero-inflated negative binomial model can be utilized here. This distribution allows for frequent zero-valued observations and reduces over dispersion of the data (Yau et al. 2003). Our zero-inflated negative binomial regression for the panel data is applied to examine all aforementioned hypotheses in Section 4.1 through many regression models, starting with the independent variables, adding control variables and other econometric techniques discussed below.

In order to address multicollinearity and other robustness concerns, we statistically test the robustness of the model and cluster standard errors by firms and industry. Regarding endogeneity, three different methods are proposed to address any type of potential endogeneity in the main models: reverse causality, instrumental variables and Heckman Selection models. These methods are explained in the sections that follow.

4.2.3. Durbin-Watson Test

In order to select between a fixed or random effects model, based on Hausman (1978), we can run a Durbin-Wu-Hausman (DWH) statistical test to check which assumption is valid in our panel data. The DWH test evaluates the significance of a model estimator versus that of an alternative estimator. It helps us evaluate whether a statistical model corresponds to the data. In this test, the null hypothesis is that the preferred model is the random effects one. If the random effects assumption holds (does not reject the null hypothesis), the random effects model is more consistent, but if this assumption does not hold (it rejects the null hypothesis or the DWH test fails), the fixed effects model is more efficient than the random effects model (Greene, 2008). We basically test whether the error terms are correlated with the regressors. The null hypothesis is that they are not correlated. It is necessary to run the fixed and random effects models separately first and perform the following statistical test based on both estimates.

H_0*: The main regression error terms in the panel data analysis are not correlated with the regressors*

According to Hausman (1978), and Davidson and Mackinnon (2004), this test is based on the idea that, under the null hypothesis (H_0), the difference between the coefficient matrix of both the fixed effects and random effects model ($\hat{\beta}_n^{RE} - \hat{\beta}_n^{FE}$) is asymptotically zero. If the null is true, we have:

$$\sqrt{n}\,(\hat{\beta}_n^{RE} - \hat{\beta}_n^{FE}) \xrightarrow{d} N(0, W - V) \tag{4}$$

Or by Continuous Mapping Theorem (CMT)[1] in econometrics:

$$n\,(\hat{\beta}_n^{RE} - \hat{\beta}_n^{FE})'(W - V)^{-1}\left(\hat{\beta}_n^{RE} - \hat{\beta}_n^{FE}\right) \xrightarrow{d} \chi^2_{(k)} \tag{5}$$

This equation (5), by Slutsky's theorem[2], implies:

$$DWH_n = n\,(\hat{\beta}_n^{RE} - \hat{\beta}_n^{FE})'\left(\widehat{W}_n - \widehat{V}_n\right)^{-1}\left(\hat{\beta}_n^{RE} - \hat{\beta}_n^{FE}\right) \xrightarrow{d} \chi^2_{(k)} \tag{6}$$

$\hat{\beta}_n^{RE}$ is the coefficient vector from the Random Effects (RE) model

$\hat{\beta}_n^{FE}$ is the coefficient vector from the Fixed Effects (FE) model

$\widehat{W}_n$ and $\widehat{V}_n$ are the covariance matrices for the RE and FE models respectively. They are called Heteroskedasticity- Consistent Covariance Matrix Estimators (HCCMEs), and can be estimated by the following equations (their explanatory matrix, X, for $\widehat{W}_n$ and $\widehat{V}_n$ are different):

$$\widehat{V}_n = \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \frac{1}{n}\sum_{i=1}^{n} \widehat{U}_i^2 X'_i X_i \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \tag{7}$$

---

[1] Continuous Mapping Theorem (CMT) indicates that continuous functions are limit-preserving and allow us to calculate asymptotically distribution of the parameter estimate ($\hat{\beta}$) (Hansen, 2012). It also applies to vectors of random sequences, i.e., if $S_n = \left(S_{n,1}, \dots, S_{n,k}\right), c = (c_1, \dots\dots c_k), Z = (Z_1, \dots . Z_k)$, and $g: \mathbb{R}^k - \mathbb{R}^l$ be a continuous function, we have: $S_n \xrightarrow{P} c \;\Rightarrow g(S_n) \xrightarrow{P} g(c)$ and $S_n \xrightarrow{d} Z$ (convergence in distribution Z) $\Rightarrow g(S_n) \xrightarrow{d} g(Z)$ as $n \to \infty$

In addition, if we have $S_{n,1} \xrightarrow{d} N(0,1) and\ S_{n,2} \xrightarrow{d} N(0,1),$ then $S_{n,1}^2 + S_{n,2}^2 \xrightarrow{d} \chi^2_{(2)}$

[2] Slutsky's Theorem is a special case of CMT which provides some algebraic equations on convergent sequences of real and random numbers (Hansen, 2012):

If $S_n \xrightarrow{d} Z$ and $T_n \xrightarrow{P} c$, then $S_n + T_n \xrightarrow{d} Z + c$ and $S_n T_n \xrightarrow{d} Zc$ as $n \to \infty$

$$\widehat{W}_n = \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \frac{1}{n}\sum_{i=1}^{n} \widehat{U}_i^2 X'_i X_i \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \qquad (8)$$

X_i is the random vector of the explanatory variables matrix.

The DWH_n statistic has asymptotically Chi-squared distribution with degrees of freedom equal to the rank of matrix $W - V$.

4.2.4. Robustness and Clustering Standard Errors

Classical estimation methods, such as OLS, rely heavily on assumptions that may not often exist in practice, such as normally or asymptotically normal distribution of error terms, and independence of variables. However, if heterokedasticity and correlation occur within the groups, OLS or other classical estimators often perform very poorly. Suppose our generic regression model is:

$$Y_{it} = X_{it}\beta + u_i + e_{it} \qquad (9)$$

t=2000, 2001,…, 2011, and i=1,2,3,….47374 (firm)

Where *t* is the panel data index (year), with multiple observations on firms over time period 2000-2011 and u_i can be explained as individual-level fixed effects or errors. e_{it} is the main error terms and generally assumed that is *iid* (independently and identically distributed) but sometimes this assumption is not valid. We can relax this assumption and consider clustered errors. That means in the panel data, there is correlation between observations within group *i* in some unknown way, causing correlation in e_{it} within *i*, but that groups *i* and *j* do not have correlated errors.

If clustered errors do exist, OLS results will still be unbiased, but standard errors may not be accurate, causing an incorrect conclusion in our panel data analysis (Nicols and Schaffer, 2007). Therefore, to ensure that the results are robust and unbiased, we apply robust regression methods and cluster standard errors for two main variables in the zero-inflated negative binomial model. As Nicols and Schaffer (2007) indicate, the robust regression methods help to adjust our estimations, by taking into account some of the flaws in the panel data.

4.2.5. Tests of Endogeneity

Endogeneity is about correlations between explanatory variables and error term. The main reasons of endogeneity can be measurement error, omitted variables, autoregression with autocorrelated errors and simultaneity in the regression model (Miller et. al, 2010). To address any endogeneity concern between the dependent and independent variables, all scenarios of potential endogeneity are tested through three powerful methods: the reverse causality test, instrumental variables and Heckman Selection models.

4.2.5.1. Reverse Causality

For reverse causality, the Granger Causality approach is adopted to measure and test the difference in VC-backed firms' patenting rates before and after VC investment for a five-year window of investment. This test supports our main regression analysis to ensure that causality runs mainly from X to Y, not vice versa (McLeod, 2009). In other words, venture capitalists are attracted to firms with patents (the selection effect) and VC causes firms to undertake more patenting (the treatment effect). For this test, two main parameters are defined, the first concerns the rate of patenting for VC-backed firms before VC investment and the second concerns the rate of patenting for these firms after investment during a five-year window. The pre-VC patent count is divided by five to create an annual patent rate variable before investment. Likewise, the number of patents occurring in the five-year window subsequent to VC investment is also divided by five to produce a post-VC patent rate variable, as shown in Figure 4.1 below.

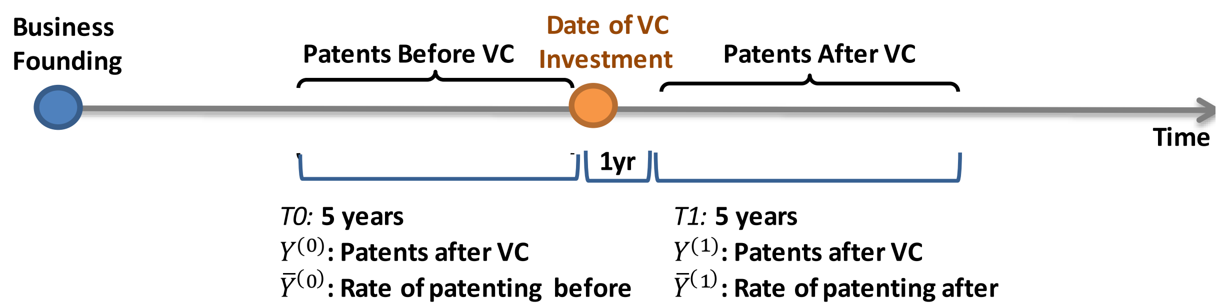


Figure 4.1: Reverse causality effects

Our null hypothesis for this test is:

H_0: *The patenting rates before and after VC investment are not significantly different.*

Our key parameter for this test is the difference in the patenting rate before and after investment ($\bar{\theta}$). This analytical model proceeds as follows. Denote $Y_i^{(1)}$ as the outcome of the target variable after VC investment in firm *i*, that is, the total registered patents in a five-year window after investment, and $Y_i^{(0)}$ as the total registered patents in a five-year window before VC investment in the firm *i*. The evaluation task is then expressed formally as measuring the average treatment effect (adopted from Engel and Keilbach, 2007),

$$\bar{\theta} = E\left(\bar{Y}_i^{(1)} - \bar{Y}_i^{(0)} \middle| VC = 1\right) = E\left(\left(\bar{Y}_i^{(1)} \middle| VC = 1\right) - E\left(\bar{Y}_i^{(0)} \middle| VC = 1\right)\right) \quad (10)$$

In equation (10), $E\left(\bar{Y}_i^{(0)} \middle| VC = 1\right)$ is the average yearly patenting rate (annual rate) before investment for all VC-backed firms, and $E\left(\bar{Y}_i^{(1)} \middle| VC = 1\right)$ is the average patenting rate after investment. $\bar{\theta}$ is the average difference in patenting rates before and after investment. The time period for counting patents and calculating patent rates is from January 1995 to May 2012. This method can be used to test the impact of VC investment at a country-level and industry-level as well, and will be discussed later.

In order to select the right approach/distribution function for this testing, it is necessary to check the normality of the dataset. If it has an asymptotically normal distribution, we can use a Z-statistic (Student's t-test for small sample size):

$H_0: \bar{\theta} = 0$ (*The average of patenting rate before and after VC investments is not significantly different)*

$$Z_{\bar{\theta}} = \frac{\bar{\theta} - 0}{\sigma_{\bar{\theta}}} \sim Z_{\alpha}, Where\ \sigma_{\bar{\theta}} = \sigma/\sqrt{n} \quad (11)$$

For comparing average differences between two environments (group *i* and *j*):

Test for $\bar{\theta}_i - \bar{\theta}_j$ (in case of normality):

$$Z_{\bar{\theta}_i - \bar{\theta}_j} = \frac{(\bar{\theta}_i - \bar{\theta}_j) + (\bar{\theta}_i^0 - \bar{\theta}_j^0)}{\sqrt{\frac{\sigma_i^2}{n_i} + \frac{\sigma_j^2}{n_j}}} \quad (12)$$

Otherwise, we can utilize non-parametric models like the Kernel or bootstrapping method for this analysis. If we reject the null hypothesis, we can conclude that the patenting rate before and after investment is different. In the case of positive results, this rate is greater after investment, and in the case of a negative outcome, this rate is greater before investment.

4.2.5.2. Instrumental Variables

The instrumental variables method is an effective solution to test the relationship between VC and innovation when a controlled experiment is not feasible and when there is a concern regarding endogeneity in the relationship between explanatory and response variables. This method allows consistent estimation when the explanatory variables (covariates) are correlated with the error terms of a regression relationship (Wooldridge, 2006). A valid instrument has to satisfy two restrictions. First, it has to be correlated with the endogenous variable or VC investment, conditional on the other covariates. Second, it should not be correlated with the main regression error terms (Wooldridge, 2006 and Vasco, 2011). Therefore, in order to estimate the effects of VC investment (x) on our response variable or patenting rate (y), an instrument (z), as the third variable, should be defined that affects y only through its effect on x. Basically this approach involves regressing the matrix X on some variables that are known to be exogenous and then using the predicted value of $X_i(Z_i)$ from a regression of X on Z to replace X_i (a matrix element of X) in our main regression equation (1).

In this study, since we feel that VC funding could be endogenous with patenting activity, we can find a good instrument for VC financing, denoted as V (in dollars). The way to check for a proper instrument Z is (Wooldridge, 2006 and Vasco, 2011):

$$Cov\ (Z, V) \neq 0$$

$$Cov\ (Z, \epsilon) = 0 \qquad (13)$$

Figure 4.2 simply shows the relationship between IV, the regressor (VC investment variable) and the main response variable (the patent variable).

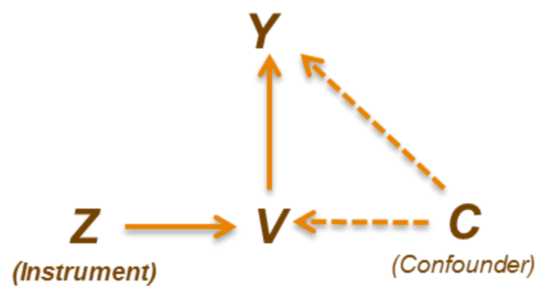


Figure 4.2: IV relation with the regressor and main response variable

In the above pair conditions (13), the first one shows that the covariance between the instrumental variable and the VC investment variable should be different than zero. The second condition shows the covariance between the instrumental variable and the error term of the main model. To check condition 2, we need to run the following discrete regression models. Based on our previous discussion, since the output of the main model is a counting (discrete) parameter with integer positive values, we can use Poisson or negative binomial regression:

$P\ (Negative\ Binomial\ of\ Patents) = a0 + a1V + \epsilon$

$Cov\ (Z, \epsilon) = 0$ *(approximately)*

If Z is a good instrument, then (based on Guan, 2003):

- **Step 1**

$Tobit(V) = b_0 + b_1 Z + \varphi$ *(we use Tobit because V has many cases of zeros)* (14)

The predicted values of VC investment ($\hat{V}$) from this equation (14) is collected and used in the Step 2 regression (15):

- **Step 2**

$$P(Negative\ Binomial\ of\ Patents) = c_0 + c_1\hat{V} + \sum_{i=2}^{n} c_i X_i + \psi \qquad (15)$$

c_1 *is the coefficient of* $\hat{V}$ *(predicted value of VC investment)*

c_i *is the regression coefficients of other exogenous covariates*

X_i *contains a set of exogenous covariates*

Ψ *is the error term*

Since the form of distribution that we get is unknown, we can use bootstrap standard errors for the ψ parameter. Bootstrapping is a nonparametric estimation method for a statistic distribution using random resampling. The simple assumption is that our current sample is a good representative of the main population. It allows us to avoid theoretical calculation, and it is a straightforward way for our model to obtain estimates of standard errors for complex estimators of unknown distribution (Guan, 2003).

According to the above conditions and our extensive analyses around many IV candidates, the Ease to Do Business index, as a starting business parameter, is our instrument for VC investment. This variable is closely correlated with VC investment but not with the error term of the main regression model. The data for the Ease of Doing Business index is collected from the World Bank, Doing Business project for the time period 2000-2011. The Ease of Doing Business index ranks world economies from 1 to 185 (1 shows the highest and 185 shows the lowest rank). Higher rankings (translate to low numerical ranks) indicate that the regulatory environment is supportive and simpler for business operations. The Ease of Doing Business index averages the economic percentile rankings on the ten following criteria, made up of different indicators, giving equal weight to each criterion (World Bank, 2013) as shown in Table 4.2:

Table 4.2: Ease of Doing Business criteria

ID	Category	Criteria
1	Business Setup	Procedures, expenditure and time for establishing a new business, obtaining any required legal permits
2	Construction Permissions	Procedures, expenditure and time to gain all necessary building permits
3	Obtaining electricity	Procedures, expenditure and time for receiving electricity for buildings
4	Property registration	Procedures, expenditure and time necessary to register new properties or transfer ownership
5	Credit acquisition	Procedures and time for getting credit, sharing credit data (depth of credit information index), and legal rights of borrowers and lenders
6	Investors protection and support	Procedure and time for shareholders to suit misconducts, responsibility and liability of business agents, clearness of related-party transactions
7	Tax payment	Expenditure, procedure and time spent for tax documentation and processing, number and rate of taxes and mandatory contributions
8	Trading (import and export)	Expenditure, procedures, time and number of required documents for import and export
9	Contracts enforcement	Expenditure, procedures and efficiency of judicial system in resolving a business dispute
10	Resolution of business failure	Expenditure, procedures, time and outcomes of filing bankruptcy and closing, and recovery rates (%)
11	Employment (as additional criteria)	Expenditure, process and time for hiring qualified workers, flexibility in regulations and working hours, and availability of required resources

At the end of the IV method, we need to statistically test and compare our previous models (with no instrumental variable) versus the IV method, to select the most consistent method. The DWH test (Hausman, 1978) can be applied to conduct this test, and it is based on the idea that under the null hypothesis (H_0), the difference of coefficients ($\hat{\beta}_n^{IV} - \hat{\beta}_n^{NB}$) should not be zero only due to sampling error. The null hypothesis can be written as H_0*: E(X'u)= 0* (exogeneity condition), which means that there is no correlation between the X matrix and the error terms.

If the null is true, we have

$$\sqrt{n}\left(\widehat{\beta}_n^{IV} - \widehat{\beta}_n^{NB}\right) \xrightarrow{d} N(0, W - V) \qquad (16)$$

Or by Continuous Mapping Theorem (CMT) in econometrics:

$$n\,(\hat{\beta}_n^{IV} - \hat{\beta}_n^{NB})'(W - V)^{-1}\left(\hat{\beta}_n^{IV} - \hat{\beta}_n^{NB}\right) \xrightarrow{d} \chi^2_{(k)} \qquad (17)$$

This equation, by Slutsky's theorem, implies:

$$DWH_n = n\,(\hat{\beta}_n^{IV} - \hat{\beta}_n^{NB})'\left(\widehat{W}_n - \hat{V}_n\right)^{-1}\left(\hat{\beta}_n^{IV} - \hat{\beta}_n^{NB}\right) \xrightarrow{d} \chi^2_{(k)} \qquad (18)$$

$\hat{\beta}_n^{IV}$ is the coefficient vector from the consistent estimator (IV model)

$\hat{\beta}_n^{NB}$ is the coefficient vector from the efficient estimator(our general negative binomial model)

$\widehat{W}_n$ and $\hat{V}_n$ are the covariance matrices of the consistent and efficient estimators and can be written as (their explanatory matrix, *X*, for $\widehat{W}_n$ and $\hat{V}_n$ are different):

$$\hat{V}_n = \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \frac{1}{n}\sum_{i=1}^{n} \widehat{U}_i^2 X'_i X_i \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \qquad (19)$$

$$\widehat{W}_n = \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \frac{1}{n}\sum_{i=1}^{n} \widehat{U}_i^2 X'_i X_i \left(\frac{1}{n}\sum_{i=1}^{n} X'_i X_i\right)^{-1} \qquad (20)$$

We test at a 95% confidence level using Chi-square distribution with *k* degrees of freedom (equal to the rank of matrix $W - V$).

4.2.5.3. Heckman Selection Model

Heckman (1976, 1979) proposed a two-step practical method to correct for selection bias and treat the sample selection problem as an omitted variable problem. This method helps to test for bias in sample selection and provides a two-step regression for our bias-corrected model based on a normality assumption. The Heckman procedure is an ex-ante correction method and it is an effective tool for our panel regression analysis. In this analysis, we need to follow two main steps. First, the selection equation predicts the probability that VC investors invest. This regression equation contains explanatory variables that are expected to determine the investment likelihood of VCs in their target firms.

In the first stage, based on Heckman (1976, 1979), the probability of VC investment is a probit regression of the form:

$$Prob(VC = 1|Z) = \phi\left(Z_{\gamma}\right) \quad (21)$$

Where VC indicates VC investment (VC = 1 if the firm received VC funds and VC = 0 otherwise), Z is a vector of explanatory variables, γ is a vector of unknown parameters, and Φ is the cumulative distribution function of the standard normal distribution. Estimation of the equation (in the first step) provides results that can be used to predict the VC investment probability for each firm.

- **Step 1: Selection Equation**

  Zi = latent variable, dependent variable (DV) of selection equation (VC Investment)*

  Wi = vector of covariates for unit i for selection equation

  α = vector of coefficients for selection equation

ε_i= random disturbance for unit i for selection equation

$$Z_i = W_i\alpha + \varepsilon_i \quad (22)$$

The predicted value (predicted VC Investment) obtained from the first stage regression model is incorporated as an additional regressor in the second stage negative binomial log-linear regression to control for potential endogeneity (Heughebaert and Manigart, 2012).

- **Step 2: Outcome Equation**

y_i= DV of outcome equation (log-link function of patents)

X_i= vector of covariates for unit i for outcome equation (including predicted VC Investment variable)

β= vector of coefficients for outcome equation

u_i= random disturbance for unit i for outcome equation

$$y_i = X_i\beta + u_i \quad (23)$$

The results of Heckman Selection model will be compared with the main negative binomial regression results to determine whether any endogeneity exists in the NB regression. We can apply the DWH method again for this comparison.

CHAPTER 5: RESULTS

5.1. Summary Statistics

Further to the summary of the data in Tables 3.2, 3.3, 3.4, and 3.5, we provide four additional sets of summary statistics: a quick summary of patent data and patent owners (Tables 5.1), patent numbers based on legal systems and countries (Table 5.2), a summary of the continuous variables (Table 5.3), and a correlation matrix (Table 5.4).

Tables 5.1 and 5.2 show the total number of firms in the dataset and their patents in various countries and legal systems. The total number of VC-backed and non VC-backed firms is 47,374, taken from 99 countries and 83 industries, with 263,455 patents held between January 1995 and May 2012. Of these firms, 17% own at least one patent, while 33% of the VC-backed firms have patents, only 8.5% of the non VC-backed firms do. The most active countries in both VC investment and patenting are the United States, Great Britain, West European countries, Canada, Israel and China. The most active legal system is British law in this regard. The most attractive industries for VC investors are SIC-73 (Business Services), 87 (Engineering, Accounting, Research, Management and Related Services), 36 (Electronic and Other Electrical Equipment and Components, Except Computer Equipment) 38 (Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks), 28 (Chemicals and Allied Products) and 48 (Communications) in that order, while industries SIC-38 (Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods;

Watches and Clocks), 28 (Chemicals and Allied Products) and 48 (Communications), 87 (Engineering, Accounting, Research, Management and Related Services) and 73 (Business Services) are more active industries in terms of patenting rates due to the critical roles of innovation in these industries and their rapid technological change. The two-digit SIC codes utilized in the research and their definitions are listed in Appendix C.

Table 5.1: A quick summary of patent data

Firms Category	Total Number of Firms	Patent Owners (% of total)	Total Patents	Average Patents/ Firm	Average Patents/ Patent Owners	Most Active Country in patenting (% of all patents)*	Most Active Industry in Patenting	Most Active Firms: Name (Country)	Most Active Firms: Patents (% of all)
All Firms	47374	8123 (17%)	263455	5.6	32.4	US (51%), DE (12%), JP (8%)	36 (32%), 38 (16%), 28 (12%)		
VC-Backed Firms	16774	5518 (33%)	52646	3.1	9.5	US (62%), GB (15%), DE (5%)	87 (31%), 36 (22%), 73 (19%)	QINETIQ LTD (GB)	1111 (2%)
Non VC-Backed Firms	30600	2605 (8.5%)	210809	6.9	80.9	US (49%), DE (14%), JP (10%)	36 (34%), 38 (17%), 28 (13%)	Siemens Aktiengesellschaft (DE)	14390 (7%)

* US: United States, DE: Germany, JP: Japan, GB: Great Britain

* Industry codes in the table: 36: Electronic and Other Electrical Equipment and Components, Except Computer Equipment, 38: Transportation Equipment, 28: Chemicals and Allied Products, 87: Engineering, Accounting, Research, Management and Related Services, 73: Business Services

Table 5.2: Patent numbers based on the country, country's legal system, and firm's category (VC-backed and non VC-backed)

	ALL FIRMS			VC-BACKED FIRMS			NON VC-BACKED FIRMS		
Country	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**
Australia	201	40	358	62	23	227	139	17	131
Barbados	3			1			2		
Bermuda	23	1	3	8			15	1	3
Bahamas	1						1		
Canada	1180	275	3042	452	148	1077	728	127	1965
Cyprus	2						2		
Great Britain (UK)	4648	724	10380	2097	546	7741	2551	178	2639
Hong Kong	51	1	2	15			36	1	2
Ireland	411	40	343	180	29	136	231	11	207
Israel	1041	310	3011	480	224	1536	561	86	1475
India	409	23	270	168	4	52	241	19	218
Cayman Islands	50	1	122	23			27	1	122
Liberia	1			1					
Malaysia	59	1	3	9			50	1	3
Nigeria	3			1			2		
New Zealand	43	7	108	18	1	2	25	6	106
Papua New Guinea	1						1		
Pakistan	7			1			6		
Singapore	86	11	51	28	3	8	58	8	43
Trinidad and Tobago	3			1			2		
Tanzania	1						1		
Uganda	3			1			2		
United States	26762	4872	135633	8756	3462	32510	18006	1410	103123
British Virgin Islands	9	1	3	6	1	3	3		
South Africa	57	2	30	16			41	2	30
British Common law (Total)	***35055***	***6309 (18%)***	***153359***	***12324***	***4441(36%)***	***43292***	***22731***	***1868 (8%)***	***110067***
British Common law (Mean)	***1402.2***	***420.6***	***10223.9***	***586.9***	***444.1***	***4329.2***	***947.1***	***133.4***	***7861.9***
British Common law (Median)	***43***	***11***	***122***	***16***	***26***	***181.5***	***26***	***9.5***	***126.5***
United Arab Emirates	21			8			13		
Armenia	1			1					
Bulgaria	24			7			17		

Table 5.2: Patent numbers based on the country, country's legal system, and firm's category (VC-backed and non VC-backed)

Country	ALL FIRMS			VC-BACKED FIRMS			NON VC-BACKED FIRMS		
	Total Number of Firms	Patent Owners (% of total)	Total Patents	Total Number of Firms	Patent Owners (% of total)	Total Patents	Total Number of Firms	Patent Owners (% of total)	Total Patents
Bahrain	1						1		
China	905	61	5624	314	25	302	591	36	5322
Colombia	3			1			2		
Costa Rica	3			1			2		
Czech Republic	38	3	225	9	1	1	29	2	224
Algeria	6			2			4		
Ecuador	1						1		
Estonia	28	3	23	12	1	6	16	2	17
Egypt	2						2		
Ethiopia	1						1		
Gabon	1						1		
Iran	2						2		
Iceland	7			2			5		
Jordan	8			3			5		
Kazakhstan	1						1		
Lebanon	4			1			3		
Liechtenstein	3	1	1	1			2	1	1
Sri Lanka	1						1		
Lithuania	6			1			5		
Latvia	17			4			13		
Morocco	2	1	3				2	1	3
Monaco	1						1		
Moldova	3			1			2		
Malta	1						1		
Mauritius	4			1			3		
Mexico	26			2			24		
Peru	5						5		
Poland	72	4	5	22			50	4	5
Qatar	1						1		
Romania	40			4			36		
Russian Federation	101	1	29	15			86	1	29

Table 5.2: Patent numbers based on the country, country's legal system, and firm's category (VC-backed and non VC-backed)

	ALL FIRMS			VC-BACKED FIRMS			NON VC-BACKED FIRMS		
Country	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**
Rwanda	1			1					
Slovenia	7						7		
Senegal	2			1			1		
Thailand	13			2			11		
Tunisia	3			1			2		
Ukraine	43			1			42		
Uruguay	10			4			6		
Venezuela	5			1			4		
Viet Nam	39			17			22		
Civil law (Total)	***1463***	***74 (5%)***	***5910***	***440***	***27 (6%)***	***309***	***1023***	***47 (5%)***	***5601***
Civil law (Mean)	***34.0***	***10.6***	***844.3***	***15.2***	***9.0***	***103.0***	***25.0***	***6.7***	***800.1***
Civil law (Median)	***4***	***3***	***23***	***2***	***1***	***6***	***4***	***2***	***17***
Argentina	124	1	1	6			118	1	1
Belgium	359	51	1761	149	38	323	210	13	1438
Brazil	63	2	3	18			45	2	3
Chile	17			3			14		
Spain	990	60	876	345	33	210	645	27	666
France	2428	319	9214	964	239	1583	1464	80	7631
Guadeloupe	2						2		
Greece	21			4			17		
Indonesia	15			2			13		
Italy	914	96	1521	115	29	125	799	67	1396
Luxembourg	33	2	6	13	2	6	20		
Martinique	1						1		
Netherlands	522	61	1355	227	44	194	295	17	1161
Philippines	12			2			10		
Portugal	68			16			52		
Reunion	2						2		
Turkey	15	1	1	1			14	1	1
Civil law- French (Total)	***5586***	***593 (11%)***	***14738***	***1865***	***385 (21%)***	***2441***	***3721***	***208 (6%)***	***12297***
Civil law- French (Mean)	***328.6***	***65.9***	***1637.6***	***133.2***	***64.2***	***406.8***	***218.9***	***26.0***	***1537.1***

Table 5.2: Patent numbers based on the country, country's legal system, and firm's category (VC-backed and non VC-backed)

	ALL FIRMS			**VC-BACKED FIRMS**			**NON VC-BACKED FIRMS**		
Country	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**	**Total Number of Firms**	**Patent Owners (% of total)**	**Total Patents**
Civil law- French (Median)	***33***	***51***	***876***	***14.5***	***35.5***	***202***	***20***	***15***	***913.5***
Austria	253	27	804	101	16	149	152	11	655
Switzerland	345	82	1835	140	55	491	205	27	1344
Germany	2311	430	31474	1003	297	2720	1308	133	28754
Croatia (Hrvatska)	21	2	35	7	1	1	14	1	34
Hungary	40	1	1	12	1	1	28		
Japan	415	162	21074	107	31	285	308	131	20789
Korea (South)	54	32	19351	15	6	252	39	26	19099
Slovak Republic	16			6			10		
Taiwan	55	30	7248	12	4	96	43	26	7152
Civil law- German (total)	***3510***	***766 (22%)***	***81822***	***1403***	***411 (29%)***	***3995***	***2107***	***355 (17%)***	***77827***
Civil law- German (Mean)	***390.0***	***95.8***	***10227.8***	***155.9***	***51.4***	***499.4***	***234.1***	***50.7***	***11118.1***
Civil law- German (Median)	***55***	***31***	***4541.5***	***15***	***11***	***200.5***	***43***	***26***	***7152***
Denmark	341	77	3131	132	56	414	209	21	2717
Finland	363	88	1277	154	54	453	209	34	824
Norway	168	42	314	59	22	122	109	20	192
Sweden	823	167	2894	333	115	1610	490	52	1284
Civil law- Scandinavian (Total)	***1695***	***374 (22%)***	***7616***	***678***	***247 (36%)***	***2599***	***1017***	***127 (12%)***	***5017***
Civil law- Scandinavian (Mean)	***423.8***	***93.5***	***1904.0***	***169.5***	***61.8***	***649.8***	***254.3***	***31.8***	***1254.3***
Civil law- Scandinavian (Median)	***352***	***82.5***	***2085.5***	***143***	***55***	***433.5***	***209***	***27.5***	***1054***
0	64	7	10	64	7	10			
Country Data Not Exist	***64***	***7***	***10***	***64***	***7***	***10***	***0***	***0***	***0***
SA	1						1		
Muslim law	***1***						***1***		
All Legal Systems (Total)	**47374**	**8123 (17%)**	**263455**	**16774**	**5518 (33%)**	**52646**	**30600**	**2605 (8.5%)**	**210809**
All Legal Systems (Mean)	**473.7**	**184.6**	**5987.6**	**215.1**	**172.4**	**1645.2**	**318.8**	**65.1**	**5270.2**
All Legal Systems (Median)	**16.5**	**25**	**292**	**8.5**	**27**	**202**	**13.5**	**15**	**221**

Table 5.3 provides summary statistics for the continuous variables, their samples, and observations that have been made for our longitudinal study. The firms' patent numbers dispersed from 0 to 2025, with an average 0.37 patent per firm-year. The amount of VC invested in the sample varies from zero to $893 million. We also observe that the range of IPR variable is from 0 to 6.48, with mean and median equal to 4.05 and 4.13 (out of 7), thanks to WIPO and other international initiatives, such as the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement that sets down minimum requirements for intellectual property support and regulations, and the establishment of new patent laws in many countries with no previous patent granting and protection systems (Park, 2008). As discussed earlier in Chapter 2 (§ 2.4), the distribution of patent strength across the world has improved from a positively skewed shape prior to the late 1990s to a negatively skewed shape afterward. Thus, the patent protection index for most countries is above the mean (Park, 2008). The definition of other socio-economic parameters is provided in Chapter 3, Table 3.1. Details of the instrumental variable are also provided in Chapter 4, Table 4.2.

It is worthwhile comparing the historical trend of patent volumes, VC deals, and other country-based indices in Figures 5.1, 5.2 and 5.3. The slight patent volumes increase during 2000-2008 and sharp decrease after 2008 are consistent with the IPR index trend as well as the economic and market conditions indices changes, including in the GDP per Capita, Market Capitalization, Business Entry Rate, and Regulatory Quality. The patent trend is also correlated to some extent with R&D Expenditure, Tax, and MSCI indices after 2008. The main reason for this sharp reduction is the global economic recession, which started at the end of 2008 and affected the entire world economy, with greater impacts to some countries than others. The VC deal volume drop in 2001 and 2002 and increase afterward is consistent with the trends in the

Regulatory Quality, Market Capitalization and Business Entry Rate indices. In most of these graphs, we see a slight reduction in 2008 as well.

As a check on collinearity between explanatory variables, pairwise correlations are calculated and shown in Table 5.4. For the country-based indices that change over the years 2000-2011, we use the average value of those indices. If a country's index for a specific data point is blank, as mentioned earlier, we apply the simple method of Nardo et al. (2005a) by order: searching other databases or via Internet, interpolating between the adjacent data records (e.g., using median of that variable of the same legal system), and using the latest available data before 2011. For any missing data in 2011, we forecast the data based on the historical trend of the index for the corresponding country.

Since IPR is one of the key variables of interest, we focus on pairwise correlations between control variables (listed from 1 to 14 in Table 5.4, except IPR). Based on the results in Table 5.4, a strong correlation exists between Political Stability and Regulatory Quality indices. The Regulatory Quality index also has strong correlations with the key elements of the legal system variable, as another variable of interest. Therefore, we can exclude the Regulatory Quality index from the model and keep the Political Stability index in our analyses.

Table 5.3: Summary statistics for the continuous variables

Variable	Observ.	Median	Mean	Std. Dev.	Min	Max
Patent	568,488*	0	0.372	9.879	0	2025
VC Investment	568,488	0	0.464	4.572	0	893.34
Socio-Economic Parameters (Country-Based Indices)						
Intellectual Property Protection/Rights (IPR)	1,188**	4.05	4.13	1.136	0.00	6.48
Political Stability and Absence of Violence	1,188	0.40	0.16	0.94	-2.73	1.67
Regulatory Quality	1,188	0.67	0.56	0.86	-1.88	2.00
Business Extent of Disclosure	1,188	6	5.71	2.875	0	10
Taxes on Income, Profits and Capital Gains(% of revenue)	1,188	23.910	25.317	12.608	0.014	66.715
Return on Equity (%)	1,188	12.206	13.562	35.744	-143.95	1001.163
Market Capitalization of Listed Companies (current US$)	1,188	4.67E+10	4.22E+11	1.66E+12	2147314	1.20E+13
MSCI Return	1,188	10.89%	9.91%	0.348	-83.87%	184.15%
GDP per Capita (current US$)	1,188	9242	18321	22891	113	186243
Business Entry Rate (new registration as % of total)	1,188	8.758	9.262	2.849	1.725	19.442
Labor Force with Secondary Education (% of total)	1,188	42.650	45.062	13.104	6.400	80.200
School Enrollment, Secondary (% net)	1,188	84.449	82.623	11.988	13.321	99.939
Research and Development Expenditure (% of GDP)	1,188	0.846	1.071	0.860	0.037	4.804
Instrumental Variable						
Ease of Doing Business	1,188	52	64.51	46.063	1	179
Details of the Legal System Variables (not included in the main regression models)						
Limited Gov. Powers	1,188	0	0.07	0.256	0	1
Absence of Corruption	1,188	0.614	0.602	0.164	0	0.927
Order and Security	1,188	0.549	0.566	0.195	0	0.956
Fundamental Rights	1,188	0.721	0.710	0.158	0	0.928
Open Government	1,188	0.599	0.625	0.161	0	0.929
Regulatory Enforcement	1,188	0.512	0.540	0.162	0	0.935
Civil Justice	1,188	0.533	0.552	0.157	0	0.893
Criminal Justice	1,188	0.560	0.567	0.136	0	0.816

* 568,488 firm-year observations for 47,374 firms between 2000 and 2011

** 1,188 country-year observations for 99 countries between 2000 and 2011

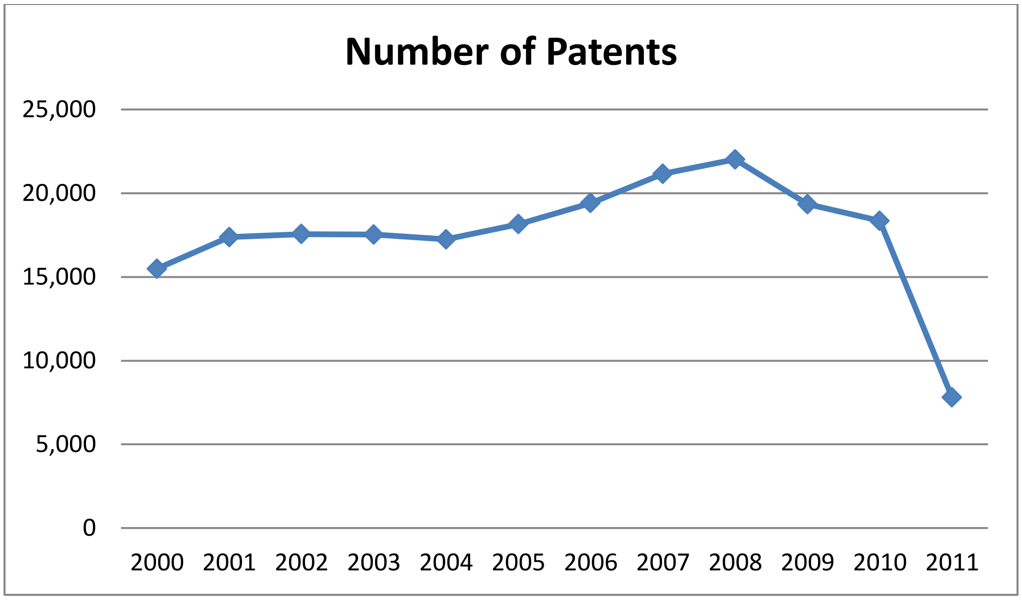


Figure 5.1: Historical trend of the firms' annual patents

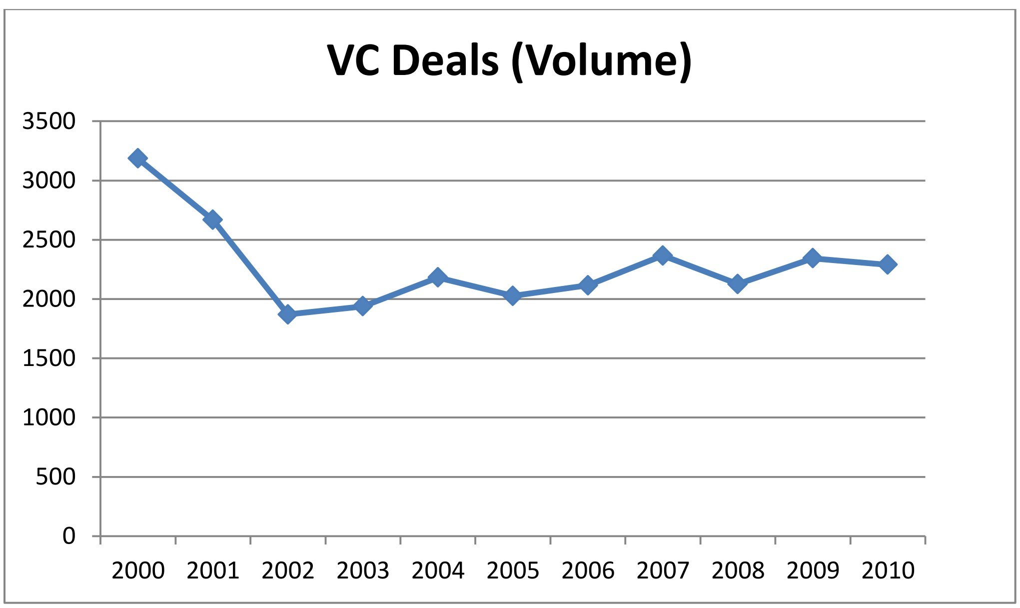


Figure 5.2: Historical trend of the total VC deals (volume)

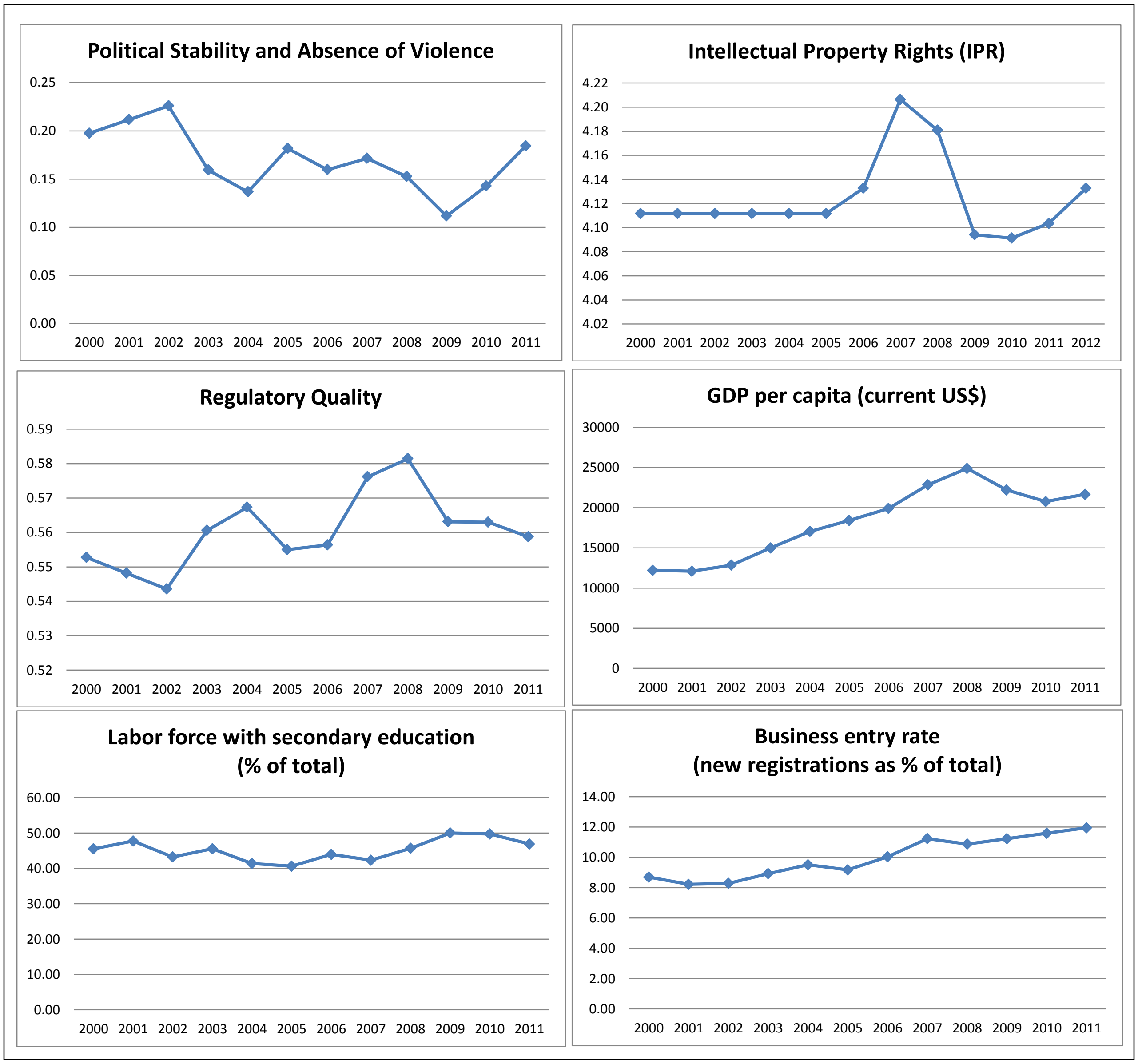


Figure 5.3: Historical trends of the country-based indices

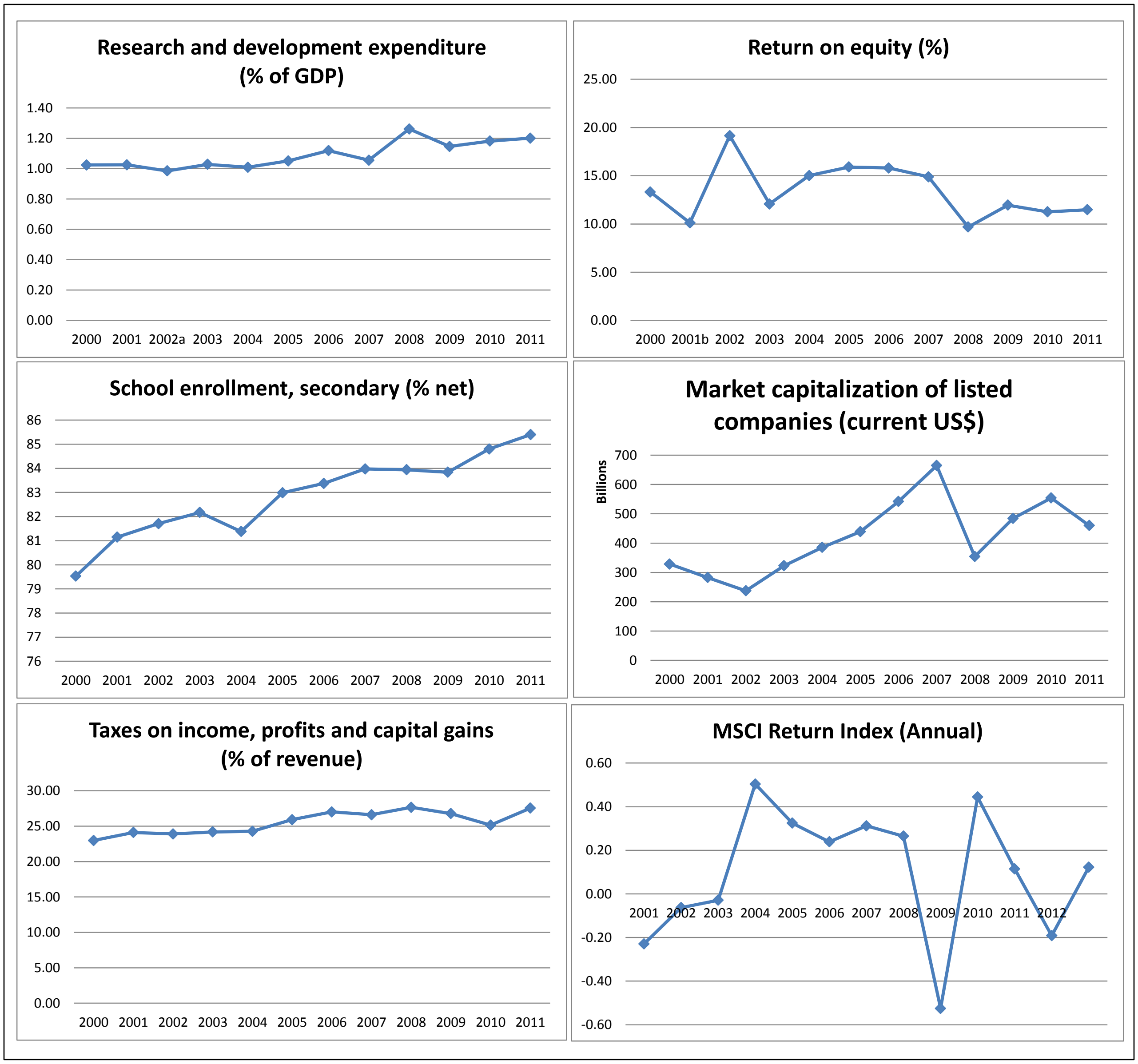


Figure 5.3: Historical trends of the country-based indices (continued)

Table 5.4: Pairwise correlation between all country-based variables

	ID	*Index (Variable)*	1	2	3	4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Main list of Macroeconomic Variables	1	Business extent of disclosure index	1																				
	2	Political Stability and Absence of Violence	-0.138	1																			
	3	Intellectual Property Rights (IPR) Index	0.1217	0.7292	1																		
	4	Regularity Quality	0.06	0.8014	0.8327	1																	
	5	GDP per capita (current US$)	-0.155	0.6202	0.5956	0.6129	1																
	6	Labor force with secondary education (% of total)	-0.111	0.1832	0.0064	0.0605	0.0311	1															
	7	Business entry rate (new registrations as % of total)	0.1699	0.0958	0.3079	0.2601	0.1673	-0.203	1														
	8	Research and development expenditure (% of GDP)	0.0739	0.3606	0.6494	0.5384	0.4275	0.0334	0.1925	1													
	9	Return on equity (%)	-0.028	-0.152	-0.149	-0.234	-0.182	-0.039	0.124	-0.183	1												
	10	School enrollment, secondary (% net)	0.1165	0.5384	0.5831	0.5264	0.3283	0.2214	0.0832	0.5719	-0.145	1											
	11	Market capitalization of listed companies (current US$)	0.1327	0.0594	0.2174	0.1932	0.1718	-0.076	0.1454	0.3086	-0.089	0.173	1										
	12	Taxes on income, profits and capital gains (% of revenue)	0.2167	0.1486	0.4238	0.3132	0.2067	-0.349	0.4494	0.2465	-0.05	0.1508	0.2863	1									
	13	MSCI Return Index (Annual)	0.1621	-0.446	-0.457	-0.387	-0.319	0.0015	-0.192	-0.359	0.1753	-0.424	-0.196	-0.128	1								
Not included in the main list	14	New Legal Variables: Limited Government Powers	0.0461	0.517	0.6706	0.6726	0.4118	0.0577	0.1081	0.5547	-0.132	0.4679	0.1845	0.3191	-0.226	1							
	15	New Legal Variables: Absence of Corruption	0.0388	0.6155	0.7412	0.7015	0.4574	0.1161	0.193	0.6019	-0.122	0.5369	0.2167	0.2747	-0.334	0.881	1						
	16	New Legal Variables: Order and Security	0.0125	0.5782	0.479	0.503	0.3627	0.2291	0.0594	0.4277	-0.172	0.4539	0.1439	0.1016	-0.309	0.753	0.798	1					
	17	New Legal Variables: Fundamental Rights	0.001	0.5132	0.5428	0.6127	0.3569	0.1462	0.0438	0.5089	-0.139	0.4814	0.1327	0.1846	-0.219	0.92	0.83	0.751	1				
	18	New Legal Variables: Open Government	0.1132	0.5209	0.6791	0.6651	0.4246	0.0841	0.1265	0.6352	-0.165	0.5163	0.2606	0.3101	-0.242	0.926	0.9	0.748	0.886	1			
	19	New Legal Variables: Regulatory Enforcement	0.0792	0.5417	0.6504	0.6534	0.4304	0.1094	0.1179	0.5819	-0.094	0.4563	0.2128	0.234	-0.215	0.908	0.935	0.798	0.856	0.937	1		
	20	New Legal Variables: Civil Justice	-0.004	0.5189	0.5811	0.5868	0.3928	0.13	0.1335	0.5483	-0.066	0.4608	0.1556	0.1529	-0.256	0.876	0.905	0.829	0.844	0.897	0.95	1	
	21	New Legal Variables: Criminal Justice	0.0553	0.5646	0.6634	0.6521	0.4227	0.1767	0.1553	0.5686	-0.19	0.4942	0.1608	0.2197	-0.253	0.877	0.934	0.841	0.842	0.861	0.901	0.889	1

5.2. Regression/Hypotheses Testing Results

5.2.1. VC and Firms' Innovation

The results of our regression analysis for testing the main theoretical hypotheses are provided in Tables 5.6 and 5.7. In the first hypothesis, we test the effects of VC investment on a firms' patenting in different intellectual property support environments. In the second part, we test whether VC investment impact is significant in different legal systems and countries. In the third part, this test is extended to different industries. Our variables of interest are VC investment, the Intellectual Property Right (IPR) index and their interaction term, controlling for other firm-level as well as country-level variables.

Model selection is conducted using multiple negative binomial regression. As discussed earlier in Chapter 4 (§ 4.2.3), in order to select either Fixed Effects or Random Effects model in our panel data analysis, we complete the DWH test. As the results shown in Table 5.5, p-value=0.000. Thus, we can reject the null hypothesis and conclude that the Fixed Effects model is more consistent than the Random Effects model for our balanced panel data.

The number of patents in each year is the response variable through a log-link function, and we examine potential explanatory variables. Tables 5.6 and 5.7 demonstrate the key models of our analyses. All models in Table 5.6 are based on zero-inflated negative binomial regression (clustered and not clustered) for the panel data, but in Table 5.7, we demonstrate the results of using other applicable regression methods (i.e., logistic regression and a zero inflated Poisson for both clustered and not clustered panel data).

Results of these analyses show that VC investment, IPR, and their interaction term have significant impacts on a firm's patenting, with a 95% confidence level, controlling for other factors. Since the VC investment value ($) for some VC deals are not available in the database, and we do not have enough information about the distribution of VC funds in each year after investment, we assign a dummy variable to the VC investment variable. This variable is 1 for 1 to 5 years after investment, and 0 for other times and for all non VC-backed firms in the panel data. IPR is a continuous variable showing the score of intellectual protection.

In Model 1 of Table 5.6, we illustrate the impacts of just VC investment and IPR variables with no interaction term and no control variables. This model shows that both VC investment and IPR have positive impacts on the patenting rate, with a 99% confidence level and regression coefficients 0.54 and 0.39, respectively. That means VC investment has greater impacts than IPR. If we add country-based or control variables to Model 1 to create Model 2, the results for VC investment and IPR are still valid, but with small changes in their regression coefficients. If, however, we add the interaction term of VC investment and IPR to Model 1 and establish Model 3, we can see a significant but negative impact of their interaction on firms' patenting, with a regression coefficient of -0.34. The regression coefficients of both VC investment and IPR variables increase from 0.54 and 0.39 in Model 1 to 2.40 and 0.51 in Model 3, respectively. When we add country-based control variables to Model 3 and create Model 4, the results are still consistent, but there are a few reductions in the coefficients[1]. In Model 4, all three key parameters (the VC dummy, IPR and their interaction) are significant, at a 99% confidence level, but the coefficient of the interaction term (IPR*VC) is still negative, with a smaller absolute value (-0.33) than those of VC investment and IPR variables (2.40 and 0.47). Therefore, both VC investment and IPR have significant and positive impacts on a firm's patenting rate, and in those areas where intellectual property rights are weaker; VC investment affects a firm's

[1] We also changed the VC dummy variable to the VC value ($), distributed equally from 1 to 5 years after investment and we obtained a consistent result for VC, IPR and their interaction impacts. Additionally, we changed the VC dummy variable from a 5-year to 4-year and 1-year time period after investment. Again, we received consistent results that VC and IPR are positively significant (their interaction coefficient is still negative with an absolute value less than its two main variables).

innovation more. Measuring the effects of changes in these parameters can be done through the log-link function of the negative binomial model.

Model 4 is the full model, in which we can see the impact of control variables on the model, including the legal systems parameter. In addition, this model has the highest log-likelihood regression value than other nested models (models 1, 2, 3, and 5). In this model, Labor Force with Secondary Education, School Enrollment (Secondary), and MSCI Return indices do not have significant effects on a firm's patenting, but all other country-based indices have an important role on a firm's patenting. For these indices, positive coefficients mean positive impacts, and negative coefficients mean negative impacts on the patenting rate. In Model 5, we test only the effects of control variables, regardless of the VC and IPR variables. Model 6 is similar to Model 4, but instead of legal systems parameter, we add all 82 SIC codes dummy variables. The general results of VC investment, IPR and their interaction term is consistent with other models; however, there are a few changes in the list of significant control indices. The main issue in Model 6 is that the convergence is not achieved, due to the many dummies existing in this model.

Another standard approach for obtaining an optimum regression model is stepwise regression, by applying forward selection and backward elimination to our negative binomial regression and testing the models in each step using F-test and the log-likelihood results. At each step, the least significant variable is removed and a new model is tested against the previous model using the LR test at $\alpha = .05$. If the more complete model is not a better fit to the data, the reduced model is retained and the procedure is repeated, eliminating the next least significant variable. We continue this process until a model is obtained in which (a) all explanatory variables are significant, or (b) the reduced model is not a better fit to the data than a more complete model. Our resulting model is retained and demonstrated in Appendix D. This final model is nested in Model 4, but its log-likelihood is lower than that of Model 4. Therefore, our focus will be on Model 4, as the most consistent negative binomial model, with the best likelihood ratio.

In Table 5.7, we use additional methods to verify the robustness of our outcomes. Based on these results, both VC investment and IPR have significant and positive impacts on the patenting rate in all logistic and Poisson regression models too. The interaction term also has a significant but negative impact on patenting, with a smaller coefficient than the VC investment and IPR ones in all of these models. These results are consistent with the results shown in Table 5.6.

Based on these initial results, p-value and log-likelihood estimations for the models in Table 5.6 and 5.7, we can simply reject the null hypotheses (hypotheses 1a and 1b in Chapter 4- § 4.1.1) and conclude that both VC investment and IPR variables have significant impacts on a firm's innovation. VC investment impact is greater in the areas with weaker intellectual property protection and support. In order to provide a clear picture about the effects of VC investment in different IPR environments, we have measured and demonstrated the effects of VC investment change versus IPR score change on the explanatory variable simultaneously in Figure 5.4 for 12 countries with the highest sample size in the dataset through the following equations:

$$\log(\mu) = \beta_0 + \beta_{VC}X_{VC} + \beta_{IPR}X_{IPR} + \beta_{VC.IPR}X_{VC}X_{IPR} + \beta_i X_i + \cdots + \beta_n X_n \qquad (24)$$

If we call $\log(\mu) = Z$, then

$$Change\ in\ Z\ by\ change\ in\ X_{VC} vs.by\ change\ in\ X_{IPR} = \frac{\frac{\partial(Z)}{\partial(IV)}}{\frac{\partial(Z)}{\partial(IPR)}} = \frac{\partial(Z)}{\partial(IV)} * \frac{\partial(IPR)}{\partial(Z)} = \frac{\partial(IPR)}{\partial(IV)} =$$

$$(\beta_{VC} + \beta_{VC.IPR}X_{IPR})/(\beta_{IPR} + \beta_{VC.IPR}X_{VC}) \qquad (25)$$

Based on our results which is demonstrated in Figure 5.4, the impact of VC investment on the total patent numbers (through the log-link function) is higher in weaker intellectual property protection environments.

It is also necessary to complete our regression analyses by checking robustness by clustering standard errors of time (year) and legal systems, as the key components of the constructed panel data. In addition, if there is any endogeneity concern, we need to use appropriate methods to address this concern and finalize our results.

The following section discusses other hypothesis tests mentioned in Chapter 4 (§ 4.1.2), regarding the effects of VC investment on different legal systems and industries.

Table 5.5: DWH Test for Random Effects vs. Fixed Effects Models

Step 1: Negative Binomial Regression for Panel Data- Random Effects (Using Key Variables)

Response Variable- Patent	*Regression Coefficient*	*Std. Error*	*Z*	*P>|Z|*	*[95% Conf. Interval]*	
vc1	2.580	0.177	14.61	0	2.234	2.927
new_ipr	0.559	0.022	24.97	0	0.515	0.603
vc1_ipr	-0.353	0.032	-11.01	0	-0.416	-0.290
_cons	-3.533	0.122	-28.89	0	-3.772	-3.293

Observations = 567720
Wald chi2(1) = 2815
Log pseudolikelihood=-121045 & Prob > chi2 = 0.000

Step 2: Negative Binomial Regression for Panel Data- Fixed Effects (Using Key Variables)

Response Variable- Patent	*Regression Coefficient*	*Std. Error*	*Z*	*P>|Z|*	*[95% Conf. Interval]*	
vc1	2.406	0.181	13.27	0	2.050	2.761
new_ipr	0.515	0.024	21.58	0	0.468	0.562
vc1_ipr	-0.340	0.033	-10.31	0	-0.404	-0.275
_cons	-3.265	0.130	-25.1	0	-3.520	-3.010

Observations = 92628 (475092 obs. dropped because of all zero outcomes)
Wald chi2(1) = 2029
Log pseudolikelihood=-75857 & Prob > chi2 = 0.000

Step 3: DWH Test (Random vs. Fixed Effects)

Response Variable- Patent	*Random (b)*	*Fixed (B)*	*Difference (b-B)*	*sqrt(diag(V_b-V_B)) S.E.*
vc1	2.580	2.406	0.175	0
new_ipr	0.559	0.515	0.044	0
vc1_ipr	-0.353	0.340	-0.014	0

b = consistent under Ho and Ha; obtained from xtnbreg
B = inconsistent under Ha, efficient under Ho; obtained from xtnbreg
chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 11663.54 & Prob>chi2= 0.0000

Prob>chi2=0.0000⇒ Reject Ho ⇒ NB- Fixed Effects model is more consistent than NB- Random Effects

Table 5.6: Regression analysis results using negative binomial for panel data- fixed effects

	Regression Results						Clustering Standard Errors		
Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
VC Investment (dummy for 1-5 years)	0.5399***	0.5939***	2.4057***	2.3981***	NO	2.5384***	1.8096***	1.5606***	1.5606***
Intellectual Property Rights (IPR)	0.3911***	0.3410***	0.5148***	0.4704***	NO	0.4818***	0.3632***	0.2363***	0.2363**
IPR*VC Investment (interaction term)	NO	NO	-0.339***	-0.328***	NO	-0.3510**	-0.1025*	-0.0509	-0.0509
Controls:	NO	YES	NO	YES	YES	YES	NO	YES	YES
Business Extent of Disclosure	---	-0.0278**	---	-0.0320***	0.0117	-0.0743***	---	-0.061***	-0.061*
Political Stability & Absence of Violence	---	-0.1457***	---	-0.1476***	-0.1449***	-0.0630***	---	0.1082	0.1082
GDP per Capita (current US$)	---	-1.2E-05***	---	-1.1E-05***	-7.8E-07	-8.9E-06***	---	-9.8E-06***	-9.8E-06*
Labor Force with Secondary Education (% of total)	---	0.0015	---	0.0018	-0.0010	-0.0001	---	0.0137**	0.0137**
Business Entry Rate (new registrations as % of total)	---	-0.0099***	---	-0.0129***	-0.0124***	-0.0189***	---	-0.0120*	-0.0120
Research and Development Expenditure (% of GDP)	---	0.0929***	---	0.0911***	0.1227***	0.1024**	---	0.2961***	0.2961***
Return on Equity (%)	---	-0.0045***	---	-0.0045***	-0.0036***	-0.0044***	---	-0.0048**	-0.0048
School Enrollment, Secondary (% net)	---	-0.0016	---	0.00004	0.0036	0.0102***	---	-0.0304***	-0.0304
Market Capitalization of Listed Co. (current US$)	---	6.3E-15**	---	5.7E-15**	7.6E-15***	-2.08E-15	---	-1.20E-15	-1.20E-15
Taxes on Income, Profits & Capital Gains (% of rev)	---	0.0072***	---	0.0073***	0.0071***	0.0049***	---	0.0190***	0.0190***
MSCI Return Index (annual)	---	-0.0217	---	-0.0140	0.0468	0.0257	---	0.1602*	0.1602*
Legal System (dummy)	NO	YES***(all)	NO	YES***(all)	YES***(all)	NO	NO	NO	NO
Industry (dummy)	NO	NO	NO	NO	NO	YES*(some)	NO	NO	NO
Clustering of Standard Errors	NO	NO	NO	NO	NO	NO	YES(YEAR)	YES (YEAR)	YES (LEGAL)
Wald Chi2	1976	--	2029	---	---	---	1984	--	--
Prob>Chi2 (p-value)	0.0000	--	0.0000	---	---	---	0.000	--	--
Log Likelihood (log pseudolikelihood for clustering)	-75910	-75626	-75857	-75578	-76540	-75308	-170904	-169831	-169831
Number of Observations	92628	92628	92628	92628	92628	92628	567720	567720	567720

*,**,*** indicate significance levels of 10%, 5%, and 1%

In non-clustered analysis, 39649 groups (475788 observations) dropped because of all zero outcomes

The Regulation Quality index removed because of its strong correlation with another index (Political Stability & Absence of Violence)

The software does not run the model that includes all SIC and legal dummy variables together (message: convergence is not achieved)

Table 5.7: Result of regression analysis using logistic, negative binomial and Poisson regressions for panel data- Fixed Effects

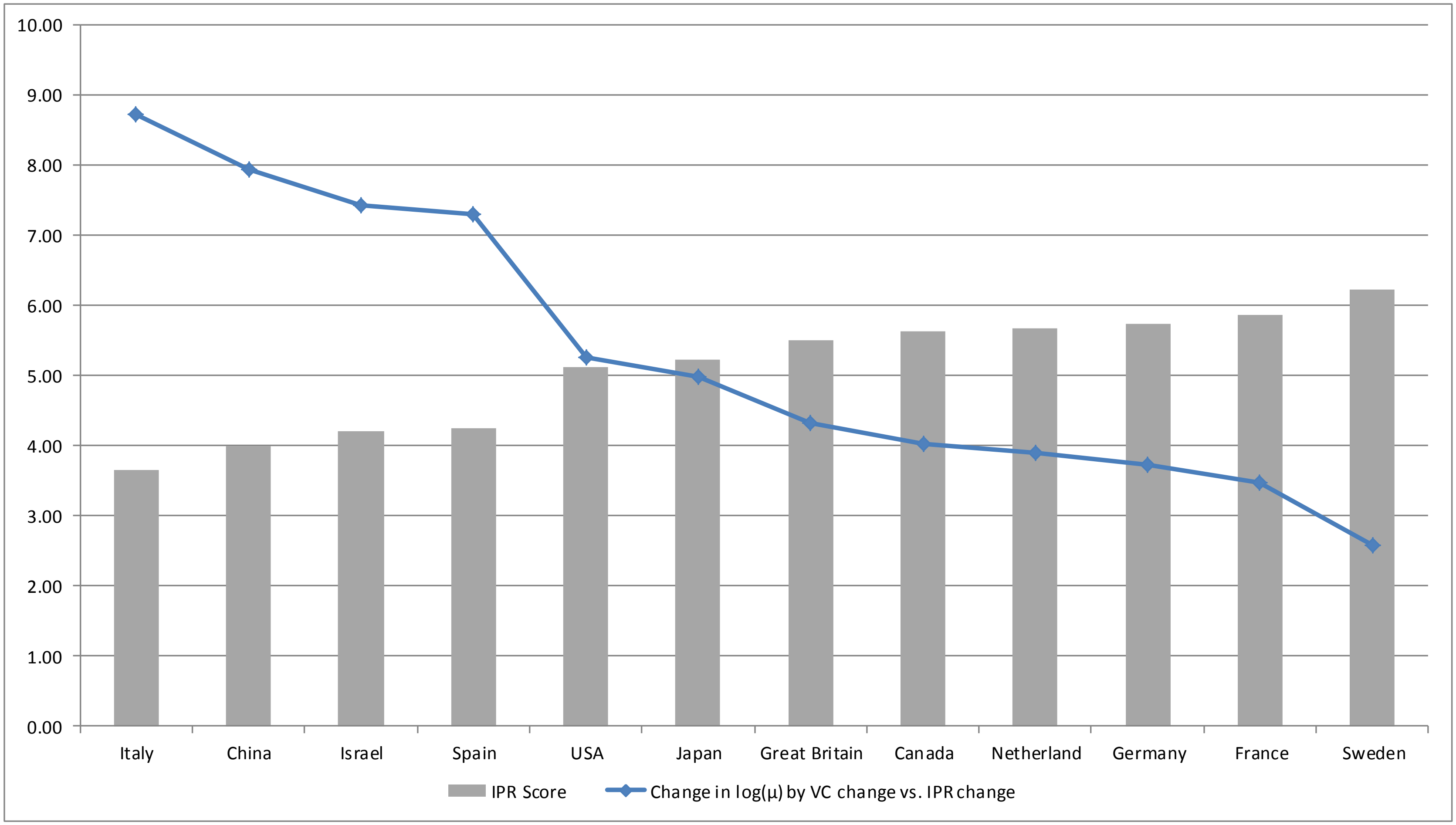
Parameter	Panel Logistic Regression Results				Panel Data		
	Model 1	Model 2	Model 3	Model 4 Clustering SE	Model 5 (Zero-Inf. NB)	Model 6 (Poisson)	Model 7 (Poisson)
VC Investment (dummy for 1-5 years)	3.5801***	3.5396***	3.5396***	1.5446***	2.4527***	2.2746***	2.3054***
Intellectual Property Rights (IPR)	0.9480***	0.8466***	0.8466***	0.2375**	0.5524***	0.3721***	0.3116***
IPR*VC Investment (interaction term)	-0.5008***	-0.4783***	-0.4783***	-0.0324	-0.3471***	-0.3043***	-0.3054***
Controls:	NO	YES	YES	YES	NO	NO	YES
Business Extent of Disclosure	---	Omitted†	Omitted†	0.0642***	---	---	Dropped†
Political Stability & Absence of Violence	---	-0.3095***	-0.3095***	0.1144	---	---	-0.1812***
GDP per Capita (current US$)	---	-0.00002***	-0.00002***	-0.00001***	---	---	-2.9E-06
Labor Force with Secondary Educ. (% of total)	---	0.0051***	0.0051***	0.0142**	---	---	0.0068***
Business Entry Rate (new registrations as % of total)	---	-0.0068	-0.0068	-0.0125*	---	---	-0.0106***
R&D Expenditure (% of GDP)	---	0.1523***	0.1523***	0.3158***	---	---	0.1867***
Return on Equity (%)	---	-0.0022	-0.0022	-0.0048**	---	---	-0.0063***
School Enrollment, Secondary (% net)	---	0.0004	0.0004	0.3169***	---	---	-0.0146***
Market Capitalization of Listed Co. (current US$)	---	1.69E-14***	1.69E-14***	-1.7E-15	---	---	6.6E-15***
Taxes on Income, Profits & Capital Gains (% of reven)	---	0.0045**	0.0045**	0.1996	---	---	0.0029***
MSCI Return Index (annual)	---	-0.0970**	-0.0970**	0.1707**	---	---	0.1938***
Legal System Variables	NO	NO	YES	NO	YES	NO	YES
• Limited Government Powers	---	---	Omitted†	---	-2.93***	---	Dropped†
• Absence of Corruption	---	---	Omitted	---	-2.188**	---	Dropped
• Order and Security	---	---	Omitted	---	4.932***	---	Dropped
• Fundamental Rights	---	---	Omitted	---	10.316***	---	Dropped
• Open Government	---	---	Omitted	---	-2.892***	---	Dropped
• Regulatory Enforcement	---	---	Omitted	---	-0.539	---	Dropped
• Civil Justice	---	---	Omitted	---	1.452**	---	Dropped
• Criminal Justice	---	---	Omitted	---	-7.435***	---	Dropped
Industry (dummy)	NO	NO	NO	NO	NO	NO	NO
Clustering of Standard Errors	NO	NO	NO	YES (Year)	NO	NO	NO
LR Chi2 (for panel Wald Chi2)	2131	2435	2435	--	2246 (Wald)	5343	__
Prob>Chi2 (p-value)	0.0000	0.000	0.000	--	0.000	0.000	__
Log Likelihood	-32205	-32053	-32053	-104767	-75722	-114437	-113453
Number of Observations	89796	89796	89796	567720	92628	92628	92628

*,**,*** indicate significance levels of 10%, 5%, and 1%

† Dropped/omitted: variable is dropped because it is constant within the group. Omitted means no variance within the group.

The Regulation Quality index removed because of its strong correlation with another index (Political Stability & Absence of Violence)

The applications do not run models that include all SIC and legal dummy variables together (message: convergence is not achieved)



Country	***Italy***	***China***	***Israel***	***Spain***	***USA***	***Japan***	***Great Britain***	***Canada***	***Netherland***	***Germany***	***France***	***Sweden***
IPR Score	3.66	3.99	4.20	4.26	5.11	5.22	5.50	5.63	5.68	5.75	5.86	6.23
Change in log(μ) by VC change vs. IPR change	8.72	7.94	7.43	7.30	5.25	4.99	4.33	4.02	3.91	3.74	3.47	2.58

Figure 5.4: Changes in explanatory variable (log(μ)) by VC change versus IPR change

5.2.2. Legal Systems and VC Outcomes

As mentioned earlier, countries can be categorized under different legal systems: Common law (British law), Civil law (Roman law) and others. Civil law is comprised of three families: French, German and Scandinavian (La Porta et al., 1998). Civil law gives investors weaker legal rights and protection than Common law (La Porta et. al, 1998).

As a part of this research, we test the impact of VC investment on a firm's patenting under different legal systems. This analysis helps us to determine the effects of rights of investors, quality of enforcement of legal rules, and other countries' legal system attributes. The hypothesis (asserted in § 4.1.2) is

H_0: VC investment impact is not significant and does not vary by legal system or country.

or on a more detailed level, we can say

H_0: Patenting rates before and after VC investment in legal system i are not significantly different.

Our analysis in Models 2, 4 and 5 in Table 5.6 show that the legal systems, including all British and Civil laws have significant impacts in the relationship between VC investment and a firm's patenting at a 99.9% confidence level. The six legal systems are added to the models as five dummy variables.

If we use the reverse causality effect method (discussed in Chapter 4- § 4.2.5.1), as a robust approach for examining this effect, we can see again that all legal systems are positively effective in firms' patenting, and the British and French Civil legal systems, in that order, provide the most effective support for innovation and firms' patenting, followed by the German and Scandinavian. Details are provided in Table 5.8. In this method, we compare and test firms' patenting rates before and after VC investment for patent owners in the VC-backed dataset. Based on the elements of the legal system parameter, these results illustrate that countries with stronger rights of investors and quality of enforcement of legal rules have higher rates of innovation. Since countries can be categorized under different legal systems (La Porta, 1998), this valuable achievement is extendable to different world regions and countries, based on their legal system. These outcomes are also supported by detailed analyses on countries in Table 5.9 for all active countries that have a sample size of at least 10 firms in the treatment group and active in patenting (they held at least one patent during the 15 year period 1995-2012). The results show that the United States, France, Canada, Great Britain, Switzerland, Germany, Israel, Belgium, the Netherlands and China, in that order, are the most effective countries for firms' patenting after VC investment, followed by Ireland, Denmark, Sweden, Italy, Spain and Finland. There is not enough evidence to show this effectiveness in four countries that have a very low sample size: Austria (with 16 VC-backed firms in the list), Australia (23 VC-backed firms), Japan (31 VC-backed firms), and Norway (22 VC-backed firms).

5.2.3. Industry and VC Outcomes

It is important to investigate and compare the impacts of VC investment on patenting in different industries. In order to test the influence of VC investment on a firm's patenting in different industries (the hypothesis test of Chapter 4-§ 4.1.3), we utilize 83 two-digit SIC codes in our analysis to investigate this effect on different industries. These 83 codes and their definitions are listed in Appendix C. As indicated in section 4.1.3, our hypothesis is

H_0: *VC investment impact is not significant and does not vary by industry* or on a more detailed level, we can say

H_0: *The patenting rate before and after VC investment in industry i are not significantly different*

Based on 83 SIC codes, 82 dummy variables are defined and added to Model 6, as a zero-inflated negative binomial regression model in Table 5.6. According to the results, some industry types have significant influences on firms' patenting. In order to measure the details of industry impacts and achieve more reliable results, we can use causality effect method for each industry. Our focus is on those industries that have a sample size of at least 10 in the treatment group (VC-backed firms) and active in patenting. Using this method, we are able to compare and test a firm's patenting rate before and after VC investment for each industry (method described in Chapter 4-§ 4.2.5.1). In this test, we utilize a Student's t-test for a sample size less than 30 firms and a Z-test statistic for a sample size of 30 or more. The results of these tests are summarized in Table 5.10 (Panel 1) and show that the effects of VC investment are significant in most industries, consisting of 28 (Chemicals and Allied Products), 30 (Rubber and Miscellaneous Plastics Products), 34 (Fabricated Metal Products, Except Machinery and Transportation Equipment), 35 (Industrial, Commercial Machinery and Computer Equipment), 36 (Electronic and Other Electrical Equipment and Components, Except Computer Equipment), 37 (Transportation Equipment), 38 (Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks), 48 (Communications), 49 (Electric, Gas, and Sanitary Services), 50 (Wholesale Trade-durable Goods), 73 (Business Services), 87 (Engineering, Accounting, Research, Management, and Related Services), and 89 (Miscellaneous Services). There is not enough evidence to show the effectiveness of VC on patenting under industry codes 20 (Food and Kindred Products), 27 (Printing, Publishing, and Allied Industries), and 59 (Miscellaneous Retail). The same size of codes 20 and 59 are too small (i.e., 11 and 14, respectively). If we test the average differences in Table 5.10 (Panel 2), based on our existing data, we can see that the SIC codes 36, 37, 87, 35 and 28 are the most effective areas for VC investment effects on patent. According to Law of Large Numbers (LLN), when a sample size is significantly increased, the sample means converge to the true mean or expected value:

$$\overline{\mathrm{X}}_n = \frac{1}{n}(X_1 + X_2 + \cdots + X_n)$$

converges to the expected value:

$$\overline{\mathrm{X}}_n \overset{P}{\to} \mu \text{ for } n \to \infty$$

where *X1*, *X2*, ... is an infinite sequence of i.i.d random variables and their expected values and variances are:

$$\mathrm{E}(X_i) = \mu \text{ for } \mathrm{i} = 1,2, \dots, \mathrm{n}$$

$$Var(X_i) = \sigma^2 < \infty$$

If our samples are heterokedastic (but independent), then:

$$Var(X_i) = \sigma_i^2 < \infty \text{ and } \lim_{n\to\infty} \frac{1}{n^2} \sum_{i=1}^{n} \sigma_i^2 = 0$$

Therefore, we can see better results when the number of samples for each SIC code increases. Based on above results, patenting is understandably more critical in some industries like IT, electric, electronic and measurement systems, industrial materials and equipment, due to rapid technological changes in these areas It is also important to recognize that venture capitalists are effective in increasing patenting rate in the service industry as well as in trading, including business, engineering, management and accounting services, and durable good wholesale trading.

Table 5.8: Causality test for all (average treatment)

Type of Test	*VC-Backed Firms (patent owners)*	*Average of θ **	*Std. Error of θ **	*Z or t-test Value***	*P-value*	*Result (95% Conf. Level)*
Test for all VC-backed firms	16774	0.192	1.156	21.476	0.0000	H0 Rejected-Significant
All VC-backed firms with zero patent before VC invest	13434	0.130	0.586	25.808	0.0000	H0 Rejected-Significant
British Legal System	4441	0.626	2.054	20.308	0.0000	H0 Rejected-Significant
French Legal System	385	0.444	1.126	7.738	<0.00001	H0 Rejected-Significant
German Legal System	411	0.329	1.512	4.409	<0.00001	H0 Rejected-Significant
Scandinavian Legal System	247	0.320	1.571	3.203	<0.00001	H0 Rejected-Significant

$*\ \bar{\theta}$ is the average of θ in the main model
** One-tail test. Student's t-test for small sample sizes (<30)
*** Testing average Θ's (µ1-µ2) by Z-test, British and French legal systems, in order, are the most effective environments than others.

Table 5.9: Test for different legal systems (country effects)

Test for Countries	*VC-Backed Firms (patent owners)*	*Average of θ*	*Std. Error of θ*	*Z or t-test Value*	*P-value*	*Result (95% Conf. Level)*
Austria (AT)	16	0.251	1.065	0.942	>0.1	
Australia (AU)	23	0.377	1.575	1.149	>0.1	
Belgium (BE)	38	0.630	1.022	3.798	<0.0001	H0 Rejected- Significant
Canada (CA)	148	0.450	0.968	5.654	<0.00001	H0 Rejected- Significant
Switzerland (CH)	55	0.461	0.756	4.519	<0.00001	H0 Rejected- Significant
China (CN)	25	2.059	3.398	3.029	<0.005	H0 Rejected- Significant
Germany (DE)	297	0.363	1.492	4.192	<0.00001	H0 Rejected- Significant
Denmark (DK)	56	0.342	1.072	2.387	<0.009	H0 Rejected- Significant
Spain (ES)	33	0.308	1.185	1.492	<0.07	H0 Rejected (at 93%)
Finland (FI)	54	0.411	2.169	1.392	<0.08	H0 Rejected (at 92%)
France (FR)	239	0.478	1.227	6.022	<0.001	H0 Rejected- Significant
Great Britain (GB)	546	0.664	3.284	4.723	<0.001	H0 Rejected- Significant
Ireland (IE)	29	0.311	0.571	2.937	<0.03	H0 Rejected- Significant
Israel (IL)	224	0.323	1.214	3.980	<0.002	H0 Rejected- Significant
Italy (IT)	29	0.184	0.654	1.516	<0.07	H0 Rejected (at 93%)
Japan (JP)	31	0.093	1.334	0.390	>0.1	
Netherlands (NL)	44	0.382	0.814	3.118	<0.005	H0 Rejected- Significant
Norway (NO)	22	0.232	1.341	0.812	>0.1	
Sweden (SE)	115	0.284	1.499	2.031	<0.04	H0 Rejected- Significant
United States (US)	3462	0.65192	1.882	20.366	<0.0001	H0 Rejected- Significant

Table 5.10: Test for different industries or SIC codes (average effects)

Panel 1: Z-test (t-test) for each SIC code

Test for Industries Based on SIC	*VC-Backed Firms (patent owners)*	*Avg. of θ*	*Std. Error of θ*	*Z or t-test Value*	*P-value*	*Result (95% Conf. Level)*
SIC- 20	11	0.216	0.989	0.724	>0.1	
SIC- 27	51	-0.092	1.445	-0.452	>0.1	
SIC- 28	343	0.671	2.123	5.850	<0.00001	H0 Rejected-Sign.
SIC- 30	11	0.526	0.990	1.762	<0.06	H0 Rejected (at 94%)
SIC- 34	13	0.573	1.021	2.022	<0.03	H0 Rejected-Sign.
SIC- 35	172	1.082	2.381	5.959	<0.00001	H0 Rejected-Sign.
SIC- 36	736	1.087	2.922	10.096	<0.00001	H0 Rejected-Sign.
SIC- 37	20	1.721	3.116	2.470	<0.02	H0 Rejected-Sign
SIC- 38	522	0.508	1.560	7.435	<0.00001	H0 Rejected-Sign.
SIC- 48	76	0.357	0.767	4.055	<0.00001	H0 Rejected-Sign.
SIC- 49	22	0.993	1.479	3.150	<0.005	H0 Rejected-Sign.
SIC- 50	15	0.366	1.038	1.367	<0.09	H0 Rejected (at 91%)
SIC- 59	14	0.384	1.312	1.096	>0.1	
SIC- 73	2228	0.269	0.878	14.483	0.0000	H0 Rejected-Sign.
SIC- 87	1120	0.852	2.655	10.746	<0.001	H0 Rejected-Sign.
SIC- 89	15	1.551	4.066	1.478	<0.08	H0 Rejected (at 92%)
All SIC Codes	5518	0.583	1.958	22.104	0.0000	H0 Rejected-Significant

Panel 2: Z-value for testing average differences between 16 SIC codes

	SIC-20	**SIC-27**	**SIC-28**	**SIC-30**	**SIC-34**	**SIC-35**	**SIC-36**	**SIC-37**	**SIC-38**	**SIC-48**	**SIC-49**	**SIC-50**	**SIC-59**	**SIC-73**	**SIC-87**	**SIC-89**
SIC-20																
SIC-27	0.85															
SIC-28	-1.42	-9.52														
SIC-30	-0.73	-3.00	0.45													
SIC-34	-0.87	-3.20	0.32	-0.11												
SIC-35	-2.48	-9.10	-1.91	-1.59	-1.51											
SIC-36	-2.75	-13.15	-2.64	-1.77	-1.70	-0.02										
SIC-37	-1.99	-4.42	-1.49	-1.58	-1.53	-0.89	-0.90									
SIC-38	-0.95	-7.74	1.22	0.06	0.22	2.96	4.54	1.73								
SIC-48	-0.45	-3.89	2.17	0.54	0.73	3.59	5.25	1.94	1.36							
SIC-49	-1.79	-4.19	-0.96	-1.08	-0.99	0.24	0.28	0.95	-1.50	-1.94						
SIC-50	-0.37	-3.36	1.05	0.40	0.53	2.21	2.50	1.82	0.51	-0.03	1.52					
SIC-59	-0.36	-3.47	0.78	0.31	0.42	1.77	1.92	1.71	0.35	-0.07	1.29	-0.04				
SIC-73	-0.18	-4.77	3.46	0.86	1.07	4.45	7.48	2.08	3.38	0.98	2.29	0.36	0.33			
SIC-87	-2.06	-12.64	-1.30	-1.06	-0.95	1.16	1.76	1.24	-3.29	-4.18	0.43	-1.74	-1.30	-7.15		
SIC-89	-1.22	-3.89	-0.83	-0.94	-0.90	-0.44	-0.44	0.13	-0.99	-1.13	-0.51	-1.09	-1.05	-1.22	-0.66	

5.3. Robustness Check

To check for robustness, we utilize clustering standard error methods and run additional regression models, as reported in Tables 5.6 and 5.7. Along with the panel data analysis by negative binomial regression, standard errors of the time (year) and legal systems parameters are clustered and the results are shown in Models 7, 8 and 9 in Table 5.6, and Model 4 in Table 5.7. Based on these results, our initial models are valid and robust in general, in case of heterokedasticity and correlation within the groups. VC investment has positive and significant impacts in all clustered and non-clustered models. The regression coefficients of VC investment and IPR in Models 7, 8 and 9 are very close to their coefficients in the corresponding non-clustered models (Models 3 and 4). The standard errors of these two variables, using both clustered and non-clustered methods are small. If we cluster standard errors by year, there is a small lift in the standard errors of the regression parameters (e.g. the standard errors are changed from 0.28 and 0.030 in Model 3 to 0.55 and 0.040 in Model 7 for VC and IPR variables). If we conduct an additional test and cluster standard errors by firms (ID), then all regression coefficients as well as standard errors of clustered models are very close to the non-cluster results (e.g. standard errors are changed from 0.28 and 0.030 in Model 3 to 0.29 and 0.033). Details of the new robustness and clustering analysis are provided in Appendix D.

5.4. Test of Endogenity

5.4.1. Reverse Causality Test

In order to test for endogeneity between VC investment, as the key explanatory variable, and a firm's patenting, as the response variable, first we utilize a reverse causality test. As explained in Chapter 4 (§ 4.4), the two key parameters for this test are the annual patenting rates of the VC-backed firms before and after VC investment in a five-year window. As a reminder, the null hypothesis for this test is

H_0*: The patenting rates before and after VC investments are not significantly different*

We measure and test the difference in the patenting rates before and after investment, using the aforementioned equation (10) in section 4.2.5:

$$\bar{\theta} = E\left(\bar{Y}_i^{(1)} - \bar{Y}_i^{(0)} \middle| VC = 1\right) = E\left(\left(\bar{Y}_i^{(1)} \middle| VC = 1\right) - E\left(\bar{Y}_i^{(0)} \middle| VC = 1\right)\right.$$

Since the behavior of the $\bar{\theta}$ parameter is approximately normal (details in Appendix B); we can apply the Z-statistic method.

According to the summary of the causality analysis provided in Table 5.8, the rate of patenting after VC investment is much larger than before the investment, with a 99.99% confidence level for all 16,774 VC-backed firms. If we focus only on those VC-backed firms that have zero patents before first VC investment (13,434 firms), we still see that VC investment has significant impacts on firms' patenting with a 99.99% confidence level. As indicated earlier, if we continue this test for different legal systems, the results show that in all legal systems, the patenting rate after VC investment is much greater than before investment. Tables 5.8 and 5.9 summarize this analysis. Based on these results, we can conclude that the causality runs mainly from VC investment to a firm's patenting, not vice versa. We extended this method to test the impact of VC investment in different industries and locations in previous sections (§ 5.2.2 and 5.2.3).

5.4.2. Instrumental Variables Method

In order to address endogeneity concerns between VC investment (the explanatory variable) and patenting (the response variable) from a different perspective, the Ease to Do Business index is used as an instrumental variable. This index is created by the World Bank and is based on the comparative study of laws and regulations worldwide. The Ease of Doing Business index provides the ranking of 185 economies periodically based on the inputs and verification of more than 9,600 government officials, lawyers, accountants, business advisors, and other professionals in these economies who continuously provide consulting or legal and regulatory administration support (World Bank, 2013). A high ranking (e.g., 185) on this index means that a regulatory environment is more conducive and supportive to new business startups, a situation directly correlated with VC activities focusing on start-up businesses.

The Ease of Doing Business index, IV, has zero correlation with the regression error terms, but negative (non-zero) correlation with VC investment. The results of two-step negative binomial regression and tobit analysis using the instrumental variable are presented in Table 5.11. In the first step of this analysis, we apply the tobit model because of non-negative and many zero-valued observations in the VC investment variable in the panel data. We use the IV variable and compute the predicted values of VC from the tobit equation then apply it in the negative binomial regression-fixed effects model in the second step to complete the analysis. Since we do not know the form of error distribution in the second step, we use bootstrapping methods for standard errors of the negative binomial model to ensure our results are robust.

The final results of this IV analysis support our previous outcomes for the VC investment variable that it has a significant impact on a firm's patenting, but its coefficient is 22.15 with standard errors 3.72. This coefficient is about 10 times larger than its coefficient in our general negative binomial models (e.g., β_{VC}=1.76 in Model 4 in Table 5.6). In this analysis, the regression coefficient of IPR is -8.73 (with standard errors 1.38). Despite our previous discussions about IPR literature (in Chapter 2) and the fact that stronger property support increases firm's innovation and patenting, this result shows that IPR has a negative impact on patenting, which means that patenting activities decreases in stronger property protection and support areas. The negative sign for the interaction (VC*IPR) coefficient is consistent with the previous regression models (-3.84 with standard error 0.58), and its absolute value is smaller than VC and IPR ones. In this IV analysis, both IPR and the interaction term have negative effects, which mean VC investment is more effective in weak property support environments.

At the end of the IV analysis, we need to apply the DWH test (Hausman, 1978) discussed in section 4.4.2 to compare the general negative binomial (previous results) and IV methods and identify the most consistent solution. Using a proprietary software to complete this complicated test, we obtain DWH= 154.34. Since DWH has approximately Chi-square (χ^2) distribution, the corresponding p-value≈ 0. Therefore, we reject the null hypothesis and conclude that the current general negative binomial model (with no IV) is a more consistent estimator than the IV model for our panel data. In the next step, we use the Heckman Selection Model for the endogeneity test from different perspective.

Table 5.11: Instrumental variable method results- IV: Ease of Doing Business (start_bus)

Step 1: Tobit regression (for predicting VC investment variable)

Response Variable- VC Investment (vc1)	*Regression Coefficient*	*Std. Error*	*Z-test*	*P>|t|*	*[95% Conf.*	*Interval]*
start_bus	-0.003	0.0004	-6.42	0	-0.003	-0.002
_cons	-2.304	0.0149	-155.01	0	-2.332	-2.274

Number of groups= 47310

Obs per group: min=12, avg= 12.0, max= 12

Wald chi2(1) =41.21

Log likelihood = -219530.61 & Prob > chi2 = 0.0000

Observation summary: 497,640 left-censored observations

70080 uncensored 0 right-censored

Step 2: Negative binomial regression (FE- final model- bootstrap replications (50) based on predicted VC variable)

Response Variable- Patent	*Regression Coefficient*	*Std. Error*	*t-test*	*P>|t|*	*[95% Conf.*	*Interval]*
vhat	22.148	3.719	5.96	0	14.859	29.438
new_ipr	-8.732	1.385	-6.3	0	-11.446	-6.017
vhat_ipr	-3.840	0.582	-6.6	0	-4.980	-2.700
disclose	-0.036	0.018	-1.95	0.052	-0.072	0.0003
labor_educ	-0.003	0.001	-3.58	0	-0.005	-0.002
bus_entry	-0.014	0.004	-3.42	0.001	-0.023	-0.006
rd_country	0.147	0.021	7.01	0	0.106	0.189
roe_mkt	-0.003	0.001	-2.28	0.023	-0.005	-0.0004
ss_enroll	0.015	0.003	4.16	0	0.008	0.022
market_cap	3.39E-15	4.08E-15	0.83	0.406	-4.61E-15	1.14E-14
tax	0.005	0.001	4.5	0	0.003	0.008
msci	0.081	0.027	2.97	0.003	0.027	0.134
_cons	48.281	9.130	5.29	0	30.385	66.177

Observations = 92700, Number of groups = 7725

Obs per group: min = 12, avg= 12.0, max=12

Wald chi2(1) =9.52

Log likelihood= -76872.793 & Prob > chi2 = 0.0020

Step 3: DWH Test

βiv = consistent under Ho and Ha; obtained from xtnbreg
βnb = inconsistent under Ha, efficient under Ho; obtained from xtnbreg
chi2(1) = (βiv-βnb)'[(V_iv-V_nb)^(-1)](βiv-βnb)= 154.34⇒ Prob>chi2=0.0000⇒
Test: Ho: difference in coefficients not systematic⇒ general NB model is more consistent than IV

5.4.3. Heckman Selection Model

We apply the two–step estimation of the Heckman Selection model in this study. This two-step method provides a correction for potential endogeneity and selection bias in our models. Table 5.12 presents the results of the first and second stages of the Heckman Selection model in our study. The predicted value obtained from the first stage regression model is incorporated as an additional regressor in the second-stage negative binomial regression to control for potential endogeneity and to examine the effects of inflation-adjusted VC investment on patenting. Based on this result, both VC investment and IPR have significant and positive impacts on a firms' patenting, with regression coefficients of 10.10 and 0.62, and standard errors of 1.79 and 0.04, respectively. Their interaction term (VC*IPR) is still significant, with a negative coefficient (-1.77 with standard errors 0.33), but the absolute value of this coefficient is higher than the coefficient of IPR. Thus, VC investment is more effective in weak intellectual property support areas. This result is consistent with the previous regression outcomes provided in the main negative binomial regression models in Tables 5.6 and 5.7, and results of IV method, in which we found that VC investment is more effective in a climate of weak intellectual property protection and support. Therefore, we can conclude that there is no selection bias in the data and it rejects any criticism that VC only accepts specific firms with higher priori abilities to patent their innovations.

Similar to the IV method, we need to apply a robust statistic test to compare the Heckman Selection model and the original negative binomial methods applied and discussed in section 5.2. The DWH test (Hausman, 1978) is used again here to complete this test. Based on the results demonstrated in Table 5.12 (Step 3), DWH= 14.82. Since DWH has approximately Chi-square (χ^2) distribution, the corresponding p-value≈ 0. Therefore, we reject the null hypothesis and conclude that the original negative binomial models are more consistent estimator than the Heckman Selection model for our panel data. Thus, we focus on the results of the previous models provided in Tables 5.6 and 5.7 (especially Model 4) moving forward.

Table 5.12: Heckman Selection model analysis

Step 1: Selection Equation

Fitting VC Investment variable (vc1=1 for 1-5th year of VC inv., zero otherwise)- Panel Logistic

Response- VC Invest. (vc1)	*Regression Coefficient*	*Std. Error*	*Z*	*P>|Z|*	*[95% Conf. Interval]*	
disclose	(omitted)					
stability	-1.517	0.026	-57.85	0	-1.568	-1.466
gdp	0.000	0.000	36.75	0	0.000	0.000
labor_educ	0.016	0.001	13.57	0	0.013	0.018
bus_entry	0.103	0.003	35.57	0	0.097	0.109
rd_country	-0.340	0.018	-18.7	0	-0.376	-0.304
roe_mkt	0.008	0.001	10.84	0	0.006	0.009
ss_enroll	0.022	0.002	9.12	0	0.017	0.026
market_cap	0.000	0.000	-3.79	0	0.000	0.000
tax	0.064	0.002	36.47	0	0.061	0.068
msci	0.070	0.024	2.89	0.004	0.023	0.118

Number of observation= 200,100

LR Chi2(10)= 19,778

Log likelihood= -93,699

Prob > Chi2 =0.000 (similar result if using NB in Step1)

Step 2: Outcome Equation

Using fitted value of VC Investment variable as a regressor (conditional FE negative binomial)

Response Variable- Patent	*Regression Coefficient*	*Std. Error*	*Z*	*P>|Z|*	*[95% Conf. Interval]*	
vhat	10.105	1.786	5.66	0	6.604	13.605
new_ipr	0.616	0.035	17.35	0	0.546	0.685
vhat_ipr	-1.770	0.328	-5.4	0	-2.413	-1.127
_cons	-3.752	0.195	-19.24	0	-4.134	-3.370

Number of observation= 92628

Wald chi2(3)=518

Log likelihood = -76615 & Prob > chi2 = 0.0000

Step 3: DWH Test

Using covariance matrix of step 2 (Heckman) and cov matrix with the same elements in NBl

βheckman = consistent under Ho and Ha; obtained from xtnbreg

βnb = inconsistent under Ha, efficient under Ho; obtained from xtnbreg

chi2(1) = (βheckman-βnb)'[(V_heckman-V_nb)^(-1)](βheckman-βnb)=14.82

Prob>chi2=0.0001$\Rightarrow$Reject Ho: difference in coefficients not systematic$\Rightarrow$general NB model is more consistent than Heckman

CHAPTER 6: CONCLUSIONS

6.1. Summary of Findings

Given the emerging nature of research on VC investment, and this investment's roles in enabling new start-up firms to increase their internal knowledge and innovation, this research has systematically examined some fundamental questions through different theoretical hypotheses and developed an extensive and holistic framework for this phenomenon that covers different industries and legal and socioeconomic patterns. This thesis contributes to the literature on VC and IPR by highlighting their critical roles in technological innovation in different cultural, legal and economic regimes, from weak to strong, or under enforced business support and protection. Our contribution also extends the literature by focusing on wider economic areas, including agriculture; manufacturing; mining; transportation; and retail, personal and business services, at firm level, using large datasets.

This research empirically examines different hypotheses about the relationship between VC investment and portfolio firms' innovation in various intellectual protection environments across all industries worldwide. We set up a large balanced panel data for the period 2000-2011, and started with zero-inflated negative binomial regression models. According to the first hypothesis analysis, the impacts of our key underlying parameters, including VC investment and Intellectual Property Rights (IPR), on business innovation, are strongly positive in all our regression models. In addition, based on the coefficient of their interaction term, VC investment clearly has more influence on a firm's patenting in areas with weaker intellectual support and protection.

Using large panel data for VC-backed and non VC-backed firms for 99 countries and 83 industries, we examined and measured the details of the VC investment and IPR influences on a firm's patenting rate under different legal systems and industries. Our negative binomials as well as logistic regression models of the panel data present the significant impacts of VC investment and IPR parameters on increasing business patenting rates under all legal systems, by controlling for cultural, regulatory, and economic and market conditions of the business environment. These rates vary by area. Details of our analysis show that British law is more effective than other legal platform. French Civil law is the second most-effective legal platform, following by the German and Scandinavian varieties. This finding is consistent with La Porta et al. (1998), who state that the British legal system provides stronger business support and protection than others. Based on the elements of the legal system parameter, these results show that those countries that established stronger support for investors and quality of enforcement of legal rules can increase national rates of innovation. Since countries can be categorized under different legal systems (La Porta, 1998), this valuable achievement is extendable to different world regions and countries, based on their legal system. These outcomes are also supported by detailed analyses on countries. In those countries for which enough samples (more than 30 samples) exist, VC investment significantly and positively affects firms' patenting increase.

The magnitude of VC influence differs in response to the industry involved. This effect is larger in those high-technology industries in which technological innovation is critical for success. Ultimately, VC investors have highly strategic roles and responsibilities in improving the internal knowledge and innovative activities of such firms.

In order to test and address endogeneity concerns about the relationship between dependent and key independent parameters, we use reverse causality, instrumental variables and the Heckman Selection model. In the reverse causality test, we adopt Granger causality to test the impact of VC investment before and after investment. This test supports our analysis to ensure that causality runs mainly from X (the explanatory variable) to Y (the response variable), or more specifically that VC investment causes a firm to be more innovative. This test is conducted for all VC-backed firms, and our findings show that the rate of a firm's patenting is higher after VC investment than before, at a 97% level of confidence. The reverse causality method is applied at a more-detailed level to test VC investment effects in all legal systems, countries and industries. The summarized results are explained later in this section.

The instrumental variables method is also used for testing the endogeneity between the key explanatory and response variables. Our instrument for VC investment is the Ease of Doing Business index. In the first step, the VC investment variable is predicted by the instrument and added as a regressor to the main regression model. The DWH test shows that the initial regression analysis is more consistent than the instrumental variables method.

In addition, we applied a two-step Heckman Selection model as an additional endogeneity test for testing selection bias. There is a criticism that VC only focuses on those firms with higher priori abilities to innovate. The Heckman Selection model helps to conduct this analysis. In this model, the predicted value of VC investment obtained from the first step regression is incorporated as an additional regressor in the second step of negative binomial regression to control for selection bias and to examine the effects of inflation-adjusted VC investment on patenting. Based on this result, both VC investment and IPR have significant and positive impacts on firms' patenting, and their interaction term (VC*IPR) is still significant, with a negative coefficient. Thus, VC investment is more effective in weak intellectual property support areas. This result is consistent with the initial regression outcomes in which we found that VC investment is more effective in weak intellectual property protection environments and it rejects above criticism regarding the VC selection concerns. Using DWH testing method, we conclude again that the initial regression parameters are more consistent estimate than the Heckman Selection model. Finally, to test whether our results are robust and unbiased, robust regression and clustering standard errors are completed and show that the main results of the negative binomial regression are consistent.

In the next part of our analysis, we use the reverse causality method at a more detailed level for testing VC investment effects in all legal systems and even for different countries across the world. As asserted earlier, VC investment impact is much stronger in British legal systems, such as in the US, Great Britain and Canada, than all Civil laws. French Civil law is the second most effective legal platform, following by the German and Scandinavian ones.

In terms of country-level, the statistical test is completed for those countries that have a sample size of at least 10 to obtain unbiased estimates. Based on the test outcomes illustrated in Table 5.9, with a confidence level of around 95%, we can say that a firm's patenting rate is greater after VC investment than before in 16 countries; thus VC investment is an effective factor for firms' patenting in these locations: the United States, France, Canada, Great Britain, Switzerland, Germany, Israel, Belgium, the Netherlands, China, Ireland, Denmark, Sweden, Italy, Spain and Finland. As indicated earlier, our results in ranking the legal systems' impacts are extendable to different world regions and countries.

This analysis is continued for those industries with a sample of at least 10 firms in the treatment group. Based on our analysis and our sample size, VC investment is very effective in the following industries: SIC-73 (Business Services), 87 (Engineering, Accounting, Research, Management, and Related Services) and 36 (Electronic and Other Electrical Equipment and Components, Except Computer Equipment). Out of 16 industries in two-digit SIC categories, in 13 of them, VC investment has significant impacts on firms' patenting rates. These industries are SIC codes 28 (Chemicals and Allied Products), 30 (Rubber and Miscellaneous Plastics Products), 34 (Fabricated Metal Products, Except Machinery and Transportation Equipment), 35 (Industrial, Commercial Machinery and Computer Equipment), 36 (Electronic and Other Electrical Equipment and Components, Except Computer Equipment), 37 (Transportation Equipment), 38 (Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks), 48 (Communications), 49 (Electric, Gas, and Sanitary Services), 50 (Wholesale Trade-durable Goods), 73 (Business Services), 87 (Engineering, Accounting, Research, Management, and Related Services), and 89 (Miscellaneous Services). According to the detailed outcomes, innovation and patenting are understandably critical in most industries, however, VC investment impacts are more critical in some industries like information technology, communications, electric, electronic and measurement systems, industrial materials, and equipment, due to rapid technological changes in these areas. It is also important to recognize the effects of venture capitalists in patenting in the service industry as well as in trading, including business, engineering, management and accounting services, and durable good wholesale trading. Testing the average differences between SIC codes, we can find that the codes 36, 37, 87, 35 and 28 are the most effective environments for VC investment impacts on patenting rates.

6.2. Future Work

This research examines the relationship between an external source of knowledge-venture capital-and firms' innovation worldwide. VC has significant impact on startup firms by providing different kinds of value-added support from the early stage to the exit stage.

Some other external sources, such as private equity, alliances and joint ventures support and influence firms financially and non-financially. Therefore, an avenue of future research would be to examine the relationship between private equity, for example, and innovation. Similar to VCs, private equity firms provide working capital to their target firms to nurture expansion, new-product development, or restructuring of the firms' operations, management, or ownership. In addition to VC, other common private equity strategies are leveraged buyouts, management buyouts, distressed investments, and mezzanine capital.

Another avenue for future research would be to study, at a detailed level, other value-added efforts of VC and private equity on target firms (e.g., productivity, quality, and business expansion) and measure their impacts in various industries worldwide. As discussed in Chapter 2 (§ 2.2.2), VC contribution to firms' activities is based on three main dimensions: the industry of target firms, the stage of VC investment, and firms' geographic location (Boue, 2002). Any new study can consider this diversity and quantify results in each category.

Finally, further research within the current dataset could be applied to industry-level innovative activities instead of firm-level, by using the country-based indices associated with industry/country behavior. In such a study, it would be worthwhile to measure and compare innovation efforts in different industries across countries/regions, while controlling for other socio-economic factors.

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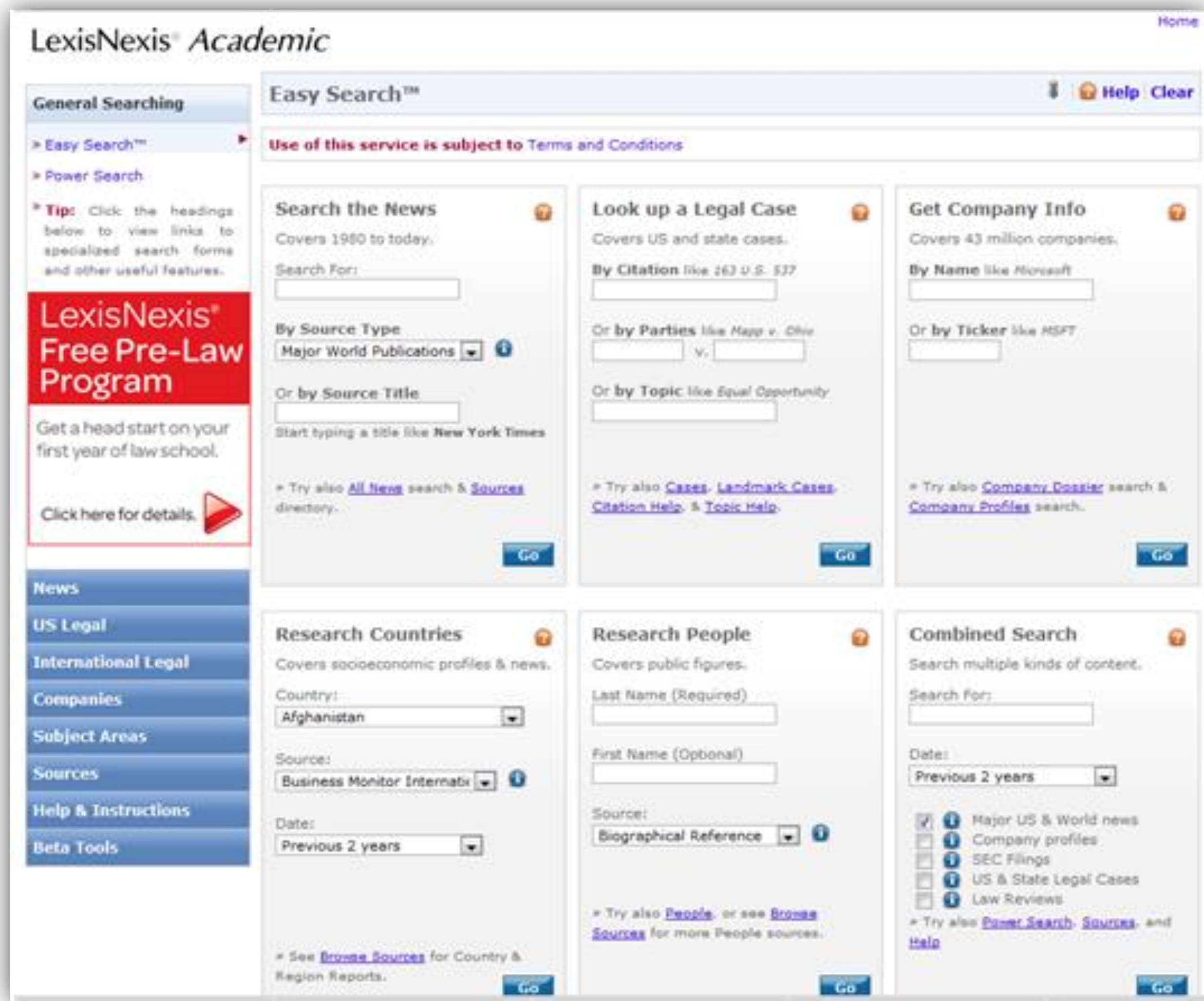
APPENDIX

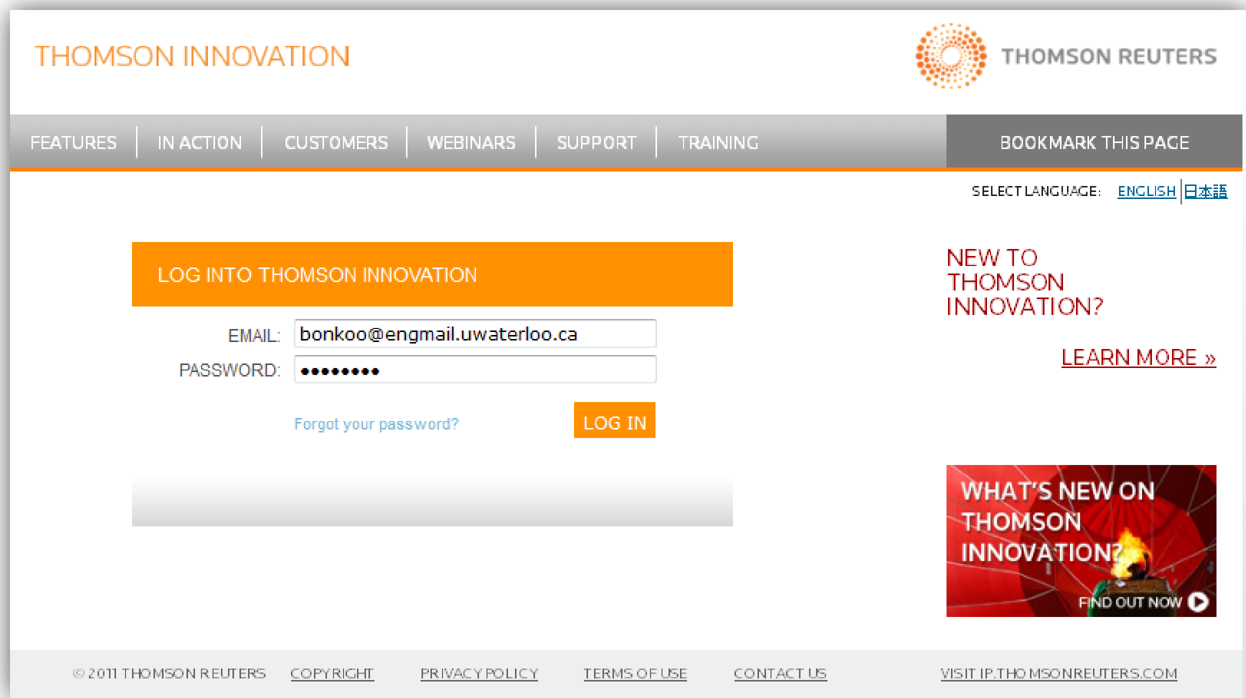
Appendix A: Main Databases

A.1. Zephyr Database

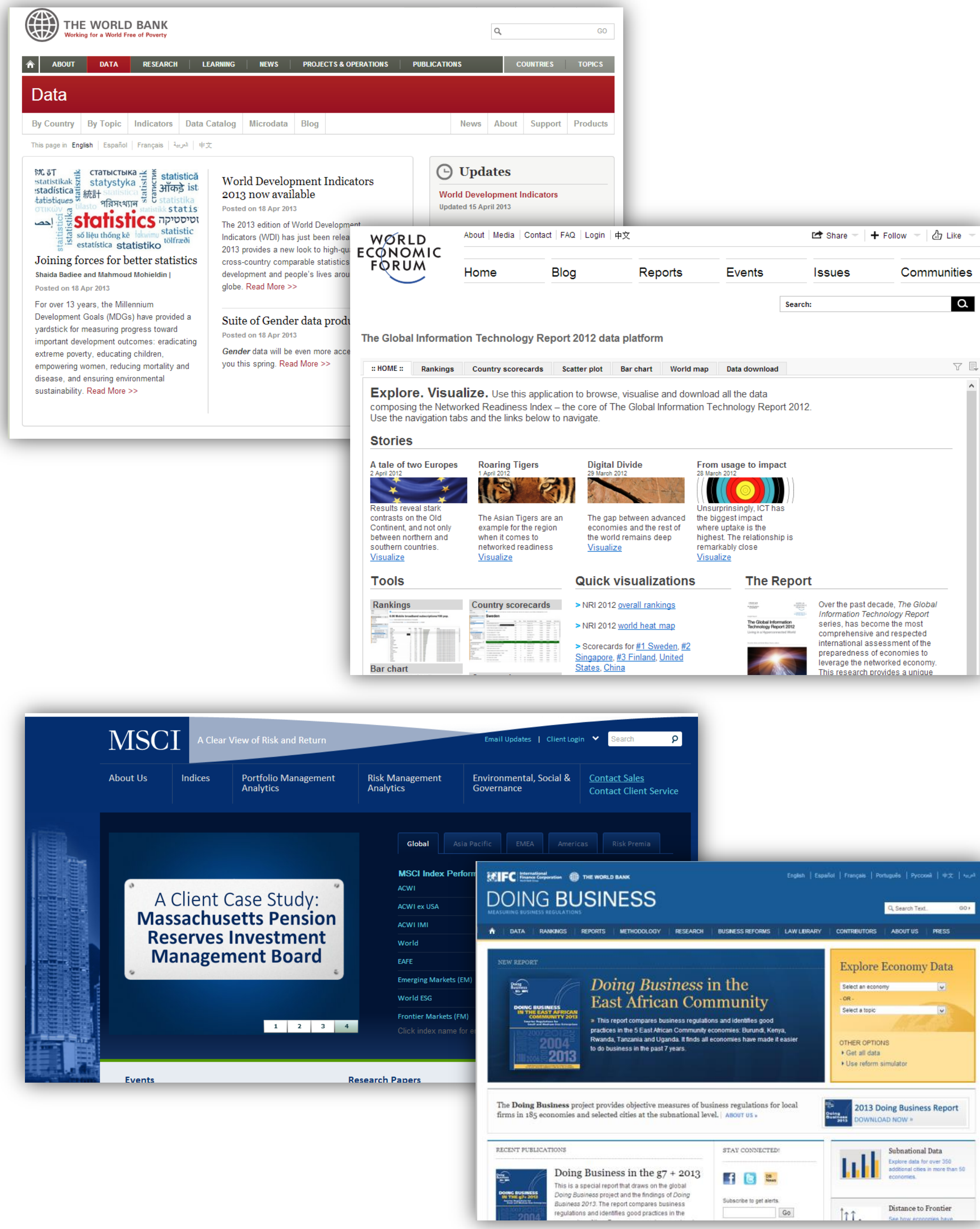
A.2. LexisNexis Application



A.3. Thomson Innovation



A.4. World Bank Databank, World Economic Forum Data Platform, MSCI and Doing Business Project (for Country-Based Indices)



Appendix B: Test of Normality for Reverse Causality Parameter ($\overline{\theta}$)

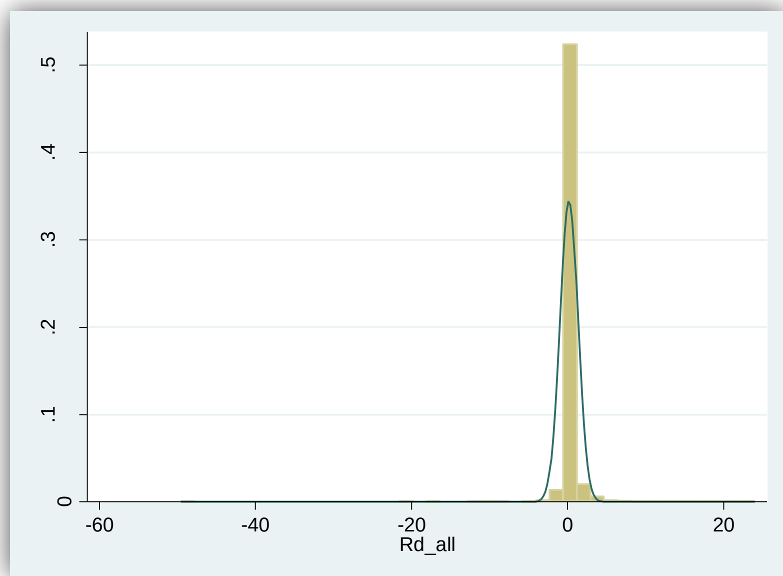
1. **Summary of $\overline{\theta}$ parameter (for all VC-backed firms):**

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
rd_all	*16797*	*.1908353*	*1.15873*	*-49.57284*	*23.98686*

2. **Shapiro-Francia Test (for large sample size):**

Variable	*Obs*	*W'*	*V'*	*z*	*Prob>z*
rd_all	*16797*	*0.40876*	*519.355*	*0.412*	*0.34031*

3. **Histogram of $\overline{\theta}$ (16797 data points)**



Appendix C- Two- digit SIC codes and Industry Types

INDUSTRY CODE (2-DIGIT SIC)	INDUSTRY TYPE	INDUSTRY CODE (2-DIGIT SIC)	INDUSTRY TYPE
Group 01	Agricultural Production Crops	Group 50	Wholesale Trade-durable Goods
Group 02	Agricultural Production Livestock And Animal Specialties	Group 51	Wholesale Trade-non-durable Goods
Group 07	Agricultural Services	Group 52	Building Materials, Hardware, Garden Supply, And Mobile Home Dealers
Group 08	Forestry	Group 53	General Merchandise Stores
Group 09	Fishing, Hunting, And Trapping	Group 54	Food Stores
Group 10	Metal Mining	Group 55	Automotive Dealers And Gasoline Service Stations
Group 12	Coal Mining	Group 56	Apparel And Accessory Stores
Group 13	Oil And Gas Extraction	Group 57	Home Furniture, Furnishings, And Equipment Stores
Group 14	Mining And Quarrying Of Nonmetallic Minerals, Except Fuels	Group 58	Eating And Drinking Places
Group 15	Building Construction General Contractors And Operative Builders	Group 59	Miscellaneous Retail
Group 16	Heavy Construction Other Than Building Construction Contractors	Group 60	Depository Institutions
Group 17	Construction Special Trade Contractors	Group 61	Non-depository Credit Institutions
Group 20	Food And Kindred Products	Group 62	Security And Commodity Brokers, Dealers, Exchanges, And Services
Group 21	Tobacco Products	Group 63	Insurance Carriers
Group 22	Textile Mill Products	Group 64	Insurance Agents, Brokers, And Service
Group 23	Apparel And Other Finished Products Made Fro	Group 65	Real Estate
Group 24	Lumber And Wood Products, Except Furniture	Group 67	Holding And Other Investment Offices
Group 25	Furniture And Fixtures	Group 70	Hotels, Rooming Houses, Camps, And Other Lodging Places
Group 26	Paper And Allied Products	Group 72	Personal Services
Group 27	Printing, Publishing, And Allied Industries	Group 73	Business Services
Group 28	Chemicals And Allied Products	Group 75	Automotive Repair, Services, And Parking
Group 29	Petroleum Refining And Related Industries	Group 76	Miscellaneous Repair Services
Group 30	Rubber And Miscellaneous Plastics Products	Group 78	Motion Pictures
Group 31	Leather And Leather Products	Group 79	Amusement And Recreation Services
Group 32	Stone, Clay, Glass, And Concrete Products	Group 80	Health Services
Group 33	Primary Metal Industries	Group 81	Legal Services
Group 34	Fabricated Metal Products, Except Machinery And Transportation Equipment	Group 82	Educational Services
Group 35	Industrial And Commercial Machinery And Computer Equipment	Group 83	Social Services
Group 36	Electronic And Other Electrical Equipment And C	Group 84	Museums, Art Galleries, And Botanical And Zoological Gardens
Group 37	Transportation Equipment	Group 86	Membership Organizations
Group 38	Measuring, Analyzing, And Controlling Instrume	Group 87	Engineering, Accounting, Research, Management, And Related Services
Group 39	Miscellaneous Manufacturing Industries	Group 88	Private Households
Group 40	Railroad Transportation	Group 89	Miscellaneous services
Group 41	Local And Suburban Transit And Interurban Hig	Group 91	Executive, Legislative, And General Government, Except Finance
Group 42	Motor Freight Transportation And Warehousing	Group 92	Justice, Public Order, And Safety
Group 43	United States Postal Service	Group 93	Public Finance, Taxation, And Monetary Policy
Group 44	Water Transportation	Group 94	Administration Of Human Resource Programs
Group 45	Transportation By Air	Group 95	Administration Of Environmental Quality And Housing Programs
Group 46	Pipelines, Except Natural Gas	Group 96	Administration Of Economic Programs
Group 47	Transportation Services	Group 97	National Security And International Affairs
Group 48	Communications	Group 99	Nonclassifiable Establishments
Group 49	Electric, Gas, And Sanitary Services		

Source: US Government, 2013 (http://www.osha.gov/pls/imis/sic_manual.html)

Appendix D: Additional Analysis for Negative Binomial Regression

1. Stepwise Regression- Final Model for Negative Binomial Panel Data
2. Additional Analysis for Clustering Standard Errors

	Stepwise NB Regression Results- Final Model of This Method	Clustering Standard Errors	
Parameter	Model 10†	Model 11	Model 12
VC Investment (dummy for 1-5 years)	2.392***	2.300***	1.801***
Intellectual Property Rights (IPR)	0.464***	0.362***	0.344***
IPR*VC Investment (interaction term)	-0.327***	-0.139***	-0.063
Controls:	YES	NO	YES
Business Extent of Disclosure	-0.033***	---	-0.063***
Political Stability & Absence of Violence	-0.123***	---	0.006
GDP per Capita (current US$)	-1.1E-05***	---	-1E-05***
Labor Force with Secondary Education (% of total)	Not Sign. (Excluded)	---	0.015***
Business Entry Rate (new registrations as % of total)	-0.013***	---	-0.019***
Research and Development Expenditure (% of GDP)	0.096***	---	0.259***
Return on Equity (%)	-0.005***	---	-0.006***
School Enrollment, Secondary (% net)	Not Sign. (Excluded)	---	-0.032***
Market Capitalization of Listed Co. (current US$)	5.7E-15*	---	-1.20E-15
Taxes on Income, Profits & Capital Gains (% of rev)	0.007***	---	0.017***
MSCI Return (Annual)	Not Sign. (Excluded)	---	0.110***
Legal System (dummy)	YES***(all)	NO	NO
Industry (dummy)	NO	NO	NO
Clustering of Standard Errors	NO	Firm:ID	Firm:ID
Wald Chi2	---	3431	--
Prob>Chi2 (p-value)	0.000	0.000	--
Log Likelihood (log pseudolikelihood for clustering)	-75580	-170917	-169807
Number of Observations	92628	567720	567720

*,**,*** indicate significance levels of 10%, 5%, and 1%

†Three variables are eliminated during stepwise regression: Labor force with secondary education, School Enrollment-Secondary, and MSCI Return Indices.