On Venture Capital Fund Returns: The Impact of Sector and Geographic Diversification

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Using rich United States venture capital (VC) investment allocations and returns data from PitchBook, we study the effects of US VC sector and geographic portfolio company investment diversifications on funds' returns during 1999-2013 and through four public equity markets and two economic cycles. We find evidence of increasing diversification trends for VC investments over time. This study also reveals that VC funds' returns are positively related with sector and geographic diversifications. We find that investment diversification produces enhanced returns especially during economic and public market booms and diversifications reduce or insignificantly affect funds' returns during busts.

INTRODUCTION

As the U.S. public equity markets exhibit increased volatility, investors have increasingly become concerned with the cyclical nature of their equity investments. This is not unique, however; investors have also seen tremendous volatility of returns in the private capital markets, including venture capital. Based on our sample, the standard deviation and the mean of the internal rate of returns (IRR) for venture capital (VC) from 1999 to 2013 are 30.55 percent and 5.28 percent respectively (see Table 3). Ang et al. (2014) also demonstrates that the volatility of cash flows for VC is 3.4 times larger than the volatility estimated from the VC indices. This information clearly indicates that both returns and cash flows from venture capital have experienced a great deal of volatility. Additionally, we find that there has been an increasing trend of sector and regional diversifications from 1999 to 2013 (see Table 4). Naturally, this raises the question of whether diversifications in VC portfolio investments offer superior or inferior returns.

In this study, we examine the impact of investment diversification strategies on VC funds' returns. Our study specifically focuses on how VC fund managers in the US choose their investment portfolio

companies during large cyclicality swings (changes) of the public equity markets and economic growth in the United States. We examine the impact of sectoral and regional (global) diversifications on VC funds' returns during these changes in economic and public equity market cycles in the US.

Robinson and Sensoy (2013) find that VC funds' cash flows are pro-cyclical. They point out that because the fund inflows are pro-cyclical, their performance tends to be lower (higher) during economic expansion (recession) due to over (under) investment relative to the public equity market.

While most existing studies have discovered the persistence and cyclicality of VC funds flows and performance, there are only limited studies that examine the impact of funds' portfolio diversifications across different sectors and geographies on their performance persistence. Our study examines the VC funds' portfolio at GPs, LPs, and funds level data. Our study investigates the VC funds' diversifications across seven different sectors and five different regions on funds' returns. More importantly, we investigate whether investment portfolios sectors and regions diversifications during expansions (booms) and contractions (busts) have any significant impact on funds' performance.

We hypothesize that when public market and economic cycles change, the supply and demand for funds are also changing (Gompers and Lerner, 1998). If changes in the US market and economic conditions bring more favorable investment opportunities across different industries or sectors (boom period), then the demand for funds across different sectors increases. Thus, they will be able to diversify their investments across different sectors in such that their performance will be maximized. Also, during this boom period, the supply for funds usually increases. This increase in supply of funds allows the VC funds to diversify their investments geographically (globally). Therefore, during expansion periods, the funds will be able to increase both sectoral and geographic diversifications that will increase funds' returns. However, when changes in the US public market and economic cycles are unfavorable (bust period), the demand for funds is more likely to decrease across all industries (sectors) within the United States. All the funds in the market are now facing limited choices of domestic investments. The contraction period also reduces the funds' supply. In this bust period, we expect that sector diversification has little or no (negative) impact on funds' returns and diversification across different regions outside of the US may or may not help the funds' returns depending on whether the contraction is widespread across different countries or not. Our hypotheses are also consistent with the regime switching theory from modern portfolio (mean-variance) literature which indicates that equity returns during bust (bear) periods exhibit higher correlations among each other than during boom (bull) periods (Hamilton 1989, Ang and Bekaert 2002, 2004). Therefore, the impact of sector and regional diversifications on portfolio returns during a bear market is less effective than a bull market (Dou et al., 2014).

Using the largest quarterly returns database from PitchBook on: number of investment allocations for VC general partners (GPs), limited partners (LPs); and funds level returns, we examine closely how VC funds' sectoral and regional diversifications affect funds' returns when macroeconomics and public equity markets change during 1999 to 2013. To our knowledge, our study is the first study that utilizes PitchBook data and our comparative analysis presented in Table 1 shows that PitchBook data is more robust than other VC funds databases (i.e., Burgiss, TVE, Preqin, and Cambridge Associates).

We examine our hypotheses based on changes in four public market and two economic cycles. The main implication of our study is to provide a better understanding of how the diversifications in VC funds affect their portfolios returns during changes in economic conditions and public equity market. By examining funds' portfolio diversifications across seven different sectors and across five different regions, our study provides new insights on how the portfolio allocations across different sectors and regions affect the funds' returns when economic and public market conditions change.

The remainder of the paper is organized into the following. In the next section, we briefly review the literature on VC fund flows, performance, persistence, and diversifications. Next, we develop our hypotheses based on existing literature. Then we discuss our data and sample. We follow with the discussions on univariate and multivariate regression results. Finally, we summarize our findings and contribution of our study in the conclusion section.

LITERATURE REVIEW

Research studies on venture capital fund flows and performance have gained significant attention. Gompers and Lerner (1998, 1999) examine the VC fund raising in the U.S. during 1972 to 1994 and find that regulatory changes affecting pension funds, capital gains tax rates, economic growth, and research and development expense, as well as funds' performance and reputation, affect venture capital fundraising. Metrick and Yasuda (2010) analyze the performance and fee structure of venture capital. They find that venture capital fund managers cannot scale up their investment funds since investment in each private firm require specific experience and knowledge.

Extant literature also examines the persistence of fund flows and performance for venture capital funds. Gompers et al. (2008) examine the impact of changes in public market signals on venture capital investing during 1975 to 1998. They find that VCs with more industry experience will increase their investment the most when the public equity market is favorable. However, they find that increases in investment rates for VCs with the most industry experience do not translate into the success of their investments. They find that the success rate during a hot public equity market is lower than a cold market. However, experienced VCs perform slightly better in a hot market while less experienced VCs do worse. They argue that volatility in the VCs investments is driven more by economic fundamentals than overreaction.

Most of existing studies utilize the Thomson Venture Economics (TVE) database. Stucke (2011) indicates that there is a downward bias on fund performance reported in the TVE database. Thus, recent studies have begun to examine the VC funds with unique datasets. Harris et al. (2014a) find that VC funds outperform the public market prior to 2000 and underperform by 5 percent after 2000. Based on the Preqin data from 1980 to 2000, Chung (2012) finds that VC funds' performance persistence does not last beyond two years and is mostly driven by underperforming funds.

Harris et al. (2014b) examines the persistence of VC investment performance during pre-and-post 2000 using the Burgiss data. They find persistence in VC performance during pre-2000 and post-2000. VC funds with below (above) the median return for their vintage year tend to stay below (above) median and have lower (higher) return than S&P500.

There are limited existing studies that examine the impact of portfolio diversifications on venture capital portfolio returns. Knill (2009) examine the impact of diversifications across different regions in the US (domestic diversification) and across international regions (international diversification), industry diversification, and investment stages diversification on VC growth and exits in the US. She finds that all different types of diversifications increase VC funds growth but reduce the time to exit. Humphery-Jenner (2011, 2013) examine the impact of industry and geographic diversifications on US funds' returns and find positive relations between diversifications and fund returns. However, Humphery-Jenner (2013) finds that both industry and regional diversifications reduce the funds' returns if they spread their resources too thinly. He also finds that diversification across regions increases returns for funds that make seed investments. Our study extends this strand of literature by examining the impact of industry and geographic diversifications for VC funds in the US, especially when the US public equity market and economic conditions were experiencing high volatilities.

We argue that the public equity cycle usually occurs over an extended period of time. Therefore, studies that examine a single year (Harris et al. 2014b, Robinson and Sensoy, 2013) are most likely to miss the periods at which VCs adjust their investment portfolios across different cycles. Existing studies also have not examined the relationship between funds' sectors and regional diversifications and funds' returns during dramatic changes in a public market. Our study extends these studies by examining four public equity market booms and busts and two economic downturns using quarterly data from PitchBook database. We also bring the regime switching theory from modern portfolio literature to support our empirical findings on the impact of VCs portfolio diversifications on funds' performance (returns) during the peaks and the troughs of public market and economic cycles.

HYPOTHESIS AND EMPIRICAL MODEL

The underpinning theory in our study is based on Gompers and Lerner (1998) who argued that changes in public equity market and macroeconomic factors affect the supply and demand for VCs funding. More importantly, they indicate that changes in macroeconomic factors and differences in systematic shocks across regions such as the changes in growth of gross domestic product (GDP) and returns on public equity market are more likely to affect the supply and demand for VCs funds.[1] They argue that during economic and public market expansions, there may be more opportunities for entrepreneurs to start new firms. It also may stimulate firms to invest more in research and development expenditures as both are proxies for the shift in demand conditions. Additionally, during economic expansion or public equity booms, the capital fundraising may be easier compared to the economic contraction or public equity bust periods. Thus, changes in economic and public equity markets may also affect the supply of capital by the funds.

In this study, we attempt to provide additional answers to these literatures on funds' portfolio diversifications by examining changes in the relationship between funds' diversification and performance due to changes in public equity market and economic cycles. We utilize the S&P500 index and the US real gross domestic product (GDP) growth to identify the cyclicality of public equity market and economic conditions. Figure 1 shows a cyclical (up and down) pattern of the US public equity market measured by the S&P500 index. We can see that from the beginning (first quarter) of 2000 to mid (end of second quarter) of 2002, the US public market was experiencing a downturn (BUST2000). Starting from the beginning (first quarter) of 2003 until about mid (second quarter) of 2007, the public market reached a boom period (BOOM2003) and was immediately followed by a bust starting from the third quarter of 2007 to the first quarter of 2009 (BUST2007). The public market again is experiencing a boom period from the second quarter of 2009 until the end of 2013 (BOOM2009).[2]

FIGURE 1
S&P 500 INDEX FROM 1998 – 2014

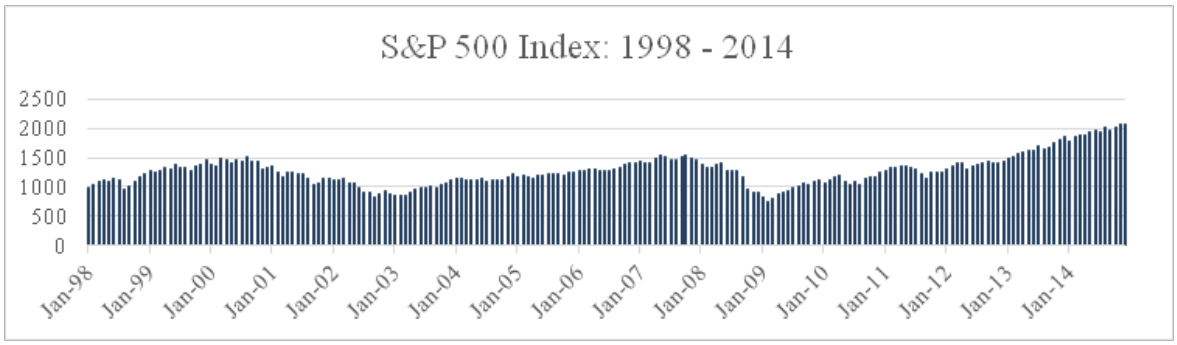
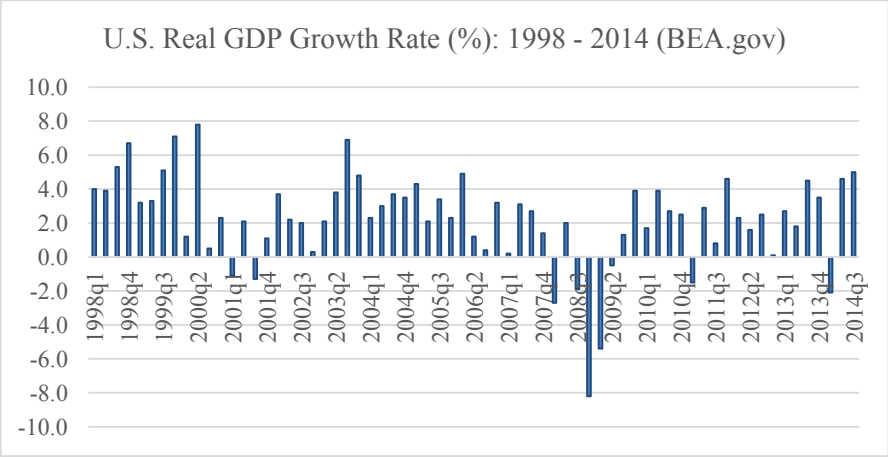


Figure 2 shows a cyclical (up and down) pattern of the US economic condition measured by the real GDP growth. We observe less persistent patterns of economic cyclicality relative to the US public equity market. Thus, we pick the periods at which there were dramatic decreases in US economic growth. We find that during the third quarter of 2000 to the third quarter of 2001, the US economy was experiencing an economic bust (ECOBUST2000). We also find an even larger economic bust during the fourth quarter of 2007 to the second quarter of 2009 (ECOBUST2007).[3]

FIGURE 2
U.S. REAL GDP GROWTH FROM 1998 – 2014



Based on the funds' demand side, we argue that portfolio investment opportunities for VC funds may have changed when business and public market conditions change. For instance, during the public equity market boom in the first quarter of 2003 until the second quarter of 2007, we expect that the demand for funds increases across different sectors. Therefore, during this period, the funds have more opportunity to diversify across sectors. We also expect the supply of funds to increase during this period. Therefore, in equilibrium, the funds have the ability to invest across different geographic regions. The positive impact of the public market boom allows the funds to diversify their investment across different sectors and regions, which produce higher returns. In equilibrium, we expect a positive relation between diversification and funds' returns during this boom period. In contrast, during the public equity market bust in the first quarter of 2000 to the second quarter of 2002, we expect that both the supply and demand of funds to shrink.[4] Therefore, the funds have less investment opportunities and face a significant challenge to raise capital. Thus, in equilibrium, we expect that the funds have less opportunity to diversify their investment portfolios and therefore we expect the relationship between diversifications and funds' returns to be insignificant or even negative if diversification makes the funds spread limited resources too thinly (Humphery-Jenner, 2013).

Literature in modern portfolio theory under regime switching market conditions also argues that the effectiveness of portfolio diversifications depend on the 'regime' or namely market cycles (Hamilton, 1989). Ang and Bekaert (2002) find that the correlation among investments in equity markets increases during the bad (bust) market condition. Ang and Bekaert (2004) indicate that dynamic diversifications when the regime (market cycle) changes can potentially provide a superior portfolio return. Dou et al. (2014) find that both sector and regional diversifications during the boom period provide superior returns relative to the bust period. Thus, modern portfolio theory under regime switching conditions has argued that effectiveness of diversifications across different sectors and regions (countries) to enhance portfolios' returns depend on the type of cycle (boom or bust).

Based on both the supply and demand theory and modern portfolio under regime switching theory, we state our hypotheses as the following:

H1: Portfolio diversification across different sectors and regions is positively related with funds' returns when the public market and economic conditions are favorable (boom).

H2: Portfolio diversification across different sectors and regions may be less or negatively related with funds' returns when the public market and economic conditions are unfavorable (bust).

Our study measures two types of diversifications: sectoral and regional diversifications. Sectoral diversification (SECTORDIV) is diversification of the funds' investments across seven different sectors: business-to-business (B2B), business-to-consumer (B2C), energy (ENER), financial (FIN), health (HLTH), information technology (IT), and materials and natural resources (MAT). These seven sectors are based on the PitchBook database categorizations. PitchBook also categorizes funds' investments across six different regional classifications: North America (NA), European (EURO), South America (SA), Asia/Oceania/Middle East (ASIA), Africa (AFR), and other regions (OTHER). We use a heterogeneity index that is commonly used in demographic research (e.g., Gibbs and Martin 1962, Blau 2000). We measure VC funds' sector and regional diversifications. The Blau measure in demographic research created by Gibbs and Martin (1962) and later referred to by Blau (2000) can be defined as the following:

$$\text{DIV} = 1 - \sum_{i=1}^{N} p_i^2 , \quad (1)$$

The p is the proportion of investment in each sector or region, and i represents the number of sectors or regions. Our diversification measure is also similar to the measures of Herfindahl index used in Ljungvist and Richardson (2003), Herfindahl-Hirchmann-Indices (HHI) in Lossen (2007), and altered Herfindahl index in Knill (2009). Our index of diversity of 1 (0) indicates that the population is perfectly heterogeneous (homogeneous). As the number of categories increases, the maximum value of DIV also increases. For example, the maximum value of REGIONDIV is 0.833 if the fund's portfolio has six regions (with equal representation in each category);[5] and it increases to 0.857 if we apply for fund's portfolio with equal representation across seven different sectors (SECTORDIV). We calculate the PCTB2B, PCTB2C, PCTENER, PCTFIN, PCTHLTH, PCTIT, and PCTMAT as percentages of investments across seven sectors calculated as the number of investments in each sector divided by the total number of investments in all seven sectors. PCTNA, PCTEURO, PCTSA, PCTASIA, PCTAFR, and PCTOTHER represent percentages of investment across six different geographic regions calculated as the number of investments in each region (country) divided by the total number of investments in all six regions.

We measure funds' returns using standard measures of funds' internal rate of return (IRR) and total value to paid in (TVPI) calculated as the ratio of the current value of remaining investments within a fund, plus the total value of all distributions to date, relative to the total amount of capital paid into the fund. We include the lag of funds' returns (lag IRR or lag TVPI) to control for funds' persistence that has been documented in the previous studies (Harris et al. 2014a, 2014b, Kaplan and Schoar 2005, Chung 2012). Based on the existing literature, we also control for various public debt and equity markets, valuation, liquidity, and priced risk measures through LN(P/D), LNSPREAD, VOLUME, and FIRSTDAY.[6] We use FIRMAGE and LNSIZE to control for funds' age and size, respectively. Several studies find that funds' experience significantly affects funds' returns (Gompers et al. 2008, Lerner et al. 2007). Therefore we include the sectoral prior experience (SECTOREXP) and regional prior experience (REGIONEXP) as control variables. Finally, we also control for vintage year of funds dummies.[7]

DATA AND SAMPLE STATISTICS

Harris et al. (2014a) indicates that it is possible for a general partner (GP) to strategically (intentionally) stop reporting to enhance fund performance, thus it suffers from a sample selection bias. Harris et al. (2010) suggests that reliance on voluntary reporting may create both a survivorship bias and a

backfill bias. A positive survivorship bias occurs when poor performing funds cease to report and therefore are not included in return calculations. A positive backfill bias occurs when funds only volunteer their information after experiencing good returns.

We utilize quarterly data from PitchBook to examine our hypotheses. PitchBook's fund performance data is collected on a quarterly basis and is provided to clients in a completely transparent and detailed way since it is not bound by non-disclosure requirements like other providers. It has returns data on over 5,800 GP/Private Debt/Infrastructure funds globally, totaling $4.1 trillion. PitchBook collects its data from daily systematic review of thousands of news and public filing sources. Then, the research teams at PitchBook confirm, clarify, and refine this data through direct communication with key contacts at target companies, investors, limited partners, and professional service providers. This ongoing contact ensures that the data is accurate, up-to-date, and less likely to suffer from both positive survival and backfill biases. To our knowledge, our study is the first study that utilizes the PitchBook data.

Since our study is the first that utilizes PitchBook data, we provide a comparison between PitchBook data and other databases (i.e., Burgiss, TVE, Preqin, and Cambridge Associates) and other unique funds data that are used in existing literature in Table 1.[8] PitchBook data's coverage on funds is relatively limited before 1993 compared to Cambridge Associates, Venture Economics, and Robinson and Sensoy

TABLE 1
NUMBER OF VENTURE CAPITAL FUNDS ACROSS DATABASES

Venture Capital Funds							
Vintage Year	PitchBook	Burgiss	Thomson Venture Economics	Preqin	Cambridge Associates	Kaplan-Schoar	Robinson-Sensoy
1984	11	18	63	17	32	57	6
1985	11	20	46	23	25	37	5
1986	11	12	41	19	30	36	3
1987	19	17	64	21	34	63	6
1988	15	16	44	24	26	42	9
1989	20	18	50	38	37	45	10
1990	14	13	21	20	16	20	1
1991	7	6	18	12	17	11	
1992	16	17	27	22	23	18	4
1993	24	13	41	32	37	45	5
1994	25	20	36	31	42	49	7
1995	26	18	49	29	34	43	13
1996	31	20	36	35	40		13
1997	64	33	64	54	73		19
1998	72	46	78	59	81		36
1999	100	65	107	78	112		40
2000	142	80	122	115	156		55
2001	81	48	59	66	52		18
2002	60	18	20	47	32		7
2003	40	25	17	37	35		
2004	54	32	22	51	64		
2005	66	48	20	58	58		1
2006	71	62	37	77	69		
2007	83	65	18	71	52		2
2008	83	45	14	57	55		
2009	39						
2010	43						
2011	47						
2012	43						
2013	36						
Total	1354	775	1114	1093	1232	466	260
Total 2009-2013	208						
Total 2000-08	680	423	329	579	573		
Total 1990-99	379	251	477	372	475	186	138
Total 1984-89	87	101	308	142	184	280	39

(2013) single fund investor database. Since PitchBook primarily relies on disclosure of returns from Limited Partners its data does have a nearly six month lag as compared to the four month lag of LP service providers like Burgiss and Cambridge Associates. Its coverage of European funds also lags that of Preqin's.

Table 1 presents the PitchBook coverage for venture capital funds and shows that PitchBook has more coverage after 2000 relative to other databases. We notice that Venture Economics has more coverage in earlier years and that PitchBook has generally had more coverage than Burgiss since 1993. Relative to PitchBook and Preqin, Cambridge Associates appears to have more coverage prior to 2001.
PitchBook classifies the number of investments for VC funds across seven different sectors: Business-to-Business (B2B), Business-to-Consumer (B2C), Energy (ENER), Healthcare (HLTH), Information Technology (IT), Financial (FIN), and Materials and Natural Resources (MAT). PitchBook also classifies the number of investments for VC funds across six different regions: North America (NA), European (EURO), South America (SA), Asia/Oceania/Middle East (ASIA), Africa (AFR), and Other Regions (OTH). We examine the funds' portfolio percentages of allocations in each quarter across these seven sectors and across six regions.

TABLE 2
VENTURE CAPITAL FUNDS' PERFORMANCE IN PITCHBOOK DATABASE

			Internal Rate of Return			Investment Multiple		
Vintage year	Number of Funds	Median % Realized	Average	Median	Weighted average	Average	Median	Weighted average
1984	11	100%	11.0%	12.6%	15.9%	1.90	2.05	1.58
1985	11	100%	11.9%	10.6%	13.2%	2.72	2.54	2.62
1986	11	100%	7.0%	7.2%	8.5%	1.55	1.55	1.66
1987	19	100%	9.9%	7.6%	11.4%	1.87	1.48	2.26
1988	15	100%	20.0%	20.8%	23.3%	2.23	1.91	2.49
1989	20	100%	11.5%	11.6%	19.3%	2.56	2.29	3.35
1990	14	100%	15.6%	17.3%	30.2%	2.83	2.16	3.63
1991	7	100%	18.4%	17.7%	18.1%	2.43	2.21	2.43
1992	16	100%	33.7%	25.0%	40.1%	3.77	2.40	3.70
1993	24	100%	38.4%	39.0%	39.9%	4.79	3.12	3.90
1994	25	100%	35.4%	27.1%	46.8%	4.52	2.16	6.74
1995	26	100%	32.3%	26.8%	43.6%	2.04	1.48	3.16
1996	31	100%	47.7%	14.5%	44.0%	4.10	1.95	3.87
1997	64	100%	49.3%	11.2%	67.8%	2.38	1.13	2.69
1998	72	92%	7.7%	2.8%	12.4%	1.17	1.04	1.22
1999	100	62%	-2.6%	-2.4%	-3.8%	0.92	0.82	0.87
2000	142	65%	-2.4%	-0.7%	-0.2%	0.98	0.92	1.03
2001	81	69%	-0.6%	1.5%	6.2%	1.11	1.08	1.36
2002	60	48%	-0.2%	3.7%	-0.3%	1.14	0.95	1.19
2003	40	46%	0.5%	3.7%	3.6%	1.15	1.20	1.37
2004	54	31%	-2.7%	-3.4%	-1.5%	1.08	0.90	1.09
2005	66	36%	5.7%	4.6%	8.0%	1.40	1.10	1.42
2006	71	34%	2.0%	5.7%	4.7%	1.17	1.17	1.37
2007	83	26%	8.4%	7.0%	8.6%	1.35	1.31	1.43
2008	83	23%	11.8%	11.1%	9.8%	1.40	1.21	1.39
2009	39	6%	13.4%	12.6%	16.0%	1.32	1.30	1.44
2010	43	5%	16.2%	12.1%	20.9%	1.29	1.19	1.39
2011	47	0%	17.3%	14.0%	21.5%	1.18	1.12	1.16
2012	43	0%	8.6%	8.4%	8.2%	1.05	1.00	1.06
2013	36	0%	2.4%	-0.2%	-8.3%	0.91	0.94	0.91
	Mean all periods	109.22%	14.26%	10.98%	17.59%	1.94	1.52	2.13
	Mean 2010s	1.13%	11.15%	8.57%	10.57%	1.11	1.06	1.13
	Mean 2000s	38.25%	3.60%	4.58%	5.49%	1.21	1.11	1.31
	Mean 1990s	183.75%	27.59%	17.89%	33.90%	2.89	1.85	3.22
	Mean 1980s	175.33%	11.89%	11.73%	15.26%	2.14	1.97	2.33

Table 2 displays the funds' performance from 1984 - 2013. Comparing our studies to Harris et al. (2014a), we find that the averages IRR performance for VC funds in PitchBook data seem to be higher during 1990s and 2000s and lower in 1980s relative to Burgiss. However, the averages of investment multiples for VC funds in PitchBook data seems to be higher during the 1980s and 2000s but lower during the 1990s relative to Burgiss. Overall, we observe some differences in average returns measured by IRR and investment multiples between PitchBook and Burgiss. We believe that these differences are due to differences in funds' coverage and time lags between these two databases.

Sample Formation

We create our sample by combining PitchBook data for portfolio company investments by fund general partners (GP) with fund commitments from limited partners (LPs). The LP investments are matched at the fund (GP) level and traced to specific portfolio companies on a quarterly basis. The GP level data contains investors' types, geographic location, founding year, and portfolio allocations counts across 7 different sectors (B2B, B2C, energy, financial, health, information technology, materials and natural resources) and allocation counts across 6 different regions (North America, Europe, South America, Asia/Oceana/Middle East, Africa, and Other regions). The fund commitment level data consists of a funds' vintage year, funds' size, funds' returns measures (IRR and TVPI), contribution, distribution, remaining value, committed, and unfunded committed. Also, the LP level data consists of LP's country locations and committed amount.

After merging these three levels of data, our sample size consists of 145,959 GPs' quarters, 118,594 observations are U.S. LPs and GPs, 33,290 are Venture Capital (VC) funds, and 4,170 are growth/expansion funds. We focus on VC funds and after deleting missing observations (mostly missing funds' performance), our final sample consists of 12,559 VC funds-quarters from 1999 to 2013. We merge the data with our control variables such as the Standard and Poor's (S&P) 500 index and dividends[9], corporate bond spreads between Baa and Aaa[10], number of IPOs (net IPO volume), and the average first day return for IPOs to represent public market performance.[11]

Sample Statistics

Sample statistics were generated for several variables for Venture Capital, and reported in Table 3.[12]

TABLE 3
SAMPLE STATISTICS

Variable	Obs	Mean	Std. Dev.	10 Pctile	25 Pctile	50 Pctile	75 Pctile	90 Pctile
IRR	12559	5.277	30.555	-18.3	-8.7	0.3	8.99	30.06
TVPI	12559	1.393	2.160	0.59	0.79	1	1.31	1.97
SECTORDIV	12559	0.515	0.209	0.179	0.390	0.583	0.686	0.721
REGIONDIV	12559	0.119	0.125	0	0	0.077	0.194	0.288
LN(P/D)	12559	3.945	0.136	3.818	3.851	3.916	4.017	4.109
LNSPREAD	12559	0.040	0.234	-0.274	-0.117	-0.020	0.278	0.322
VOLUME	12559	16.689	8.896	8	10	15	23	28
FIRSTDAY	12559	15.948	12.826	1.8	8.7	13.8	24.1	29.6
FIRMAGE	12559	19.227	10.273	7	11	17	28	34
LNSIZE	12559	5.852	0.958	4.682	5.220	5.858	6.477	6.985
SECTOREXP	12559	5.481	1.765	3.219	4.290	5.416	6.692	7.811
REGIONEXP	12559	11.783	1.170	10.126	10.956	12.121	12.606	12.927

The VC category includes 12,559 observations. The average IRR reported is 5.277% and the average TVPI is 1.393 for VC.[13] SECTORDIV, the variable used to determine the level of sector diversification averages 0.515 for VC. REGIONDIV is the variable used to determine the level of geographic distribution. Geographic diversification for VC is at 0.119. FIRMAGE represents the number of years

lapsed since the year founded. The average age of VC firms is 19.227 years. Average funds' size (LNSIZE) for VC is 5.852. This translates to an average fund size of $348 million.

Table 4 provides averages for VC variables for each year from 1999 to 2013. We observe that VC funds' returns vary from year to year. Distribution statistics are provided for overall diversification measures (SECTORDIV and REGIONDIV) as well as individual geographies and sectors.

TABLE 4
YEAR BY YEAR CHANGES IN FUNDS PERFORMANCE AND DIVERSIFICATIONS

Variable	1999	2000	2001	2002	2003	2004	2005
IRR	37.058	22.856	17.069	-2.298	-2.330	0.609	4.046
TVPI	2.267	2.187	2.095	1.698	1.584	1.473	1.456
SECTORDIV	0.475	0.476	0.434	0.447	0.438	0.433	0.445
REGIONDIV	0.040	0.079	0.077	0.077	0.075	0.081	0.086
PCTB2B	0.104	0.099	0.103	0.101	0.102	0.105	0.110
PCTB2C	0.138	0.085	0.082	0.070	0.062	0.061	0.058
PCTENER	0.013	0.010	0.006	0.006	0.007	0.008	0.009
PCTFIN	0.018	0.037	0.032	0.026	0.021	0.027	0.029
PCTHLTH	0.153	0.162	0.174	0.218	0.231	0.233	0.239
PCTIT	0.569	0.604	0.600	0.573	0.571	0.560	0.548
PCTMAT	0.005	0.004	0.003	0.005	0.006	0.006	0.007
PCTNA	0.954	0.948	0.931	0.934	0.940	0.934	0.941
PCTEURO	0.004	0.014	0.018	0.024	0.021	0.022	0.025
PCTSA	0	0	0.001	0.001	0	0	0
PCTASIA	0	0.009	0.006	0.008	0.008	0.009	0.010
PCTAFR	0	0	0	0	0	0	0
PCTOTHER	0.042	0.029	0.043	0.034	0.031	0.035	0.024
Sample (N)	102	116	156	263	521	632	658

Variable	2006	2007	2008	2009	2010	2011	2012	2013
IRR	4.244	4.797	5.072	0.239	2.919	5.610	6.194	8.312
TVPI	1.406	1.330	1.374	1.219	1.231	1.295	1.315	1.408
SECTORDIV	0.468	0.499	0.509	0.535	0.544	0.539	0.547	0.552
REGIONDIV	0.101	0.112	0.116	0.120	0.126	0.131	0.139	0.150
PCTB2B	0.113	0.114	0.117	0.124	0.130	0.135	0.131	0.134
PCTB2C	0.072	0.085	0.096	0.104	0.106	0.112	0.118	0.122
PCTENER	0.013	0.018	0.025	0.032	0.040	0.039	0.038	0.036
PCTFIN	0.019	0.023	0.021	0.027	0.028	0.027	0.027	0.029
PCTHLTH	0.254	0.265	0.262	0.273	0.284	0.289	0.292	0.284
PCTIT	0.524	0.487	0.468	0.431	0.404	0.389	0.384	0.386
PCTMAT	0.006	0.009	0.010	0.010	0.009	0.009	0.008	0.009
PCTNA	0.941	0.934	0.932	0.930	0.924	0.921	0.916	0.910
PCTEURO	0.026	0.028	0.027	0.027	0.027	0.029	0.030	0.031
PCTSA	0	0.000	0.000	0.000	0.001	0.001	0.003	0.004
PCTASIA	0.019	0.028	0.031	0.033	0.038	0.037	0.040	0.043
PCTAFR	0	0	0	0	0.0001	0.0001	0.001	0.001
PCTOTHER	0.014	0.011	0.009	0.009	0.010	0.011	0.011	0.011
Sample (N)	837	958	378	1349	1582	1261	1903	1843

Table 4 indicates that there is an increasing sector diversification (SECTORDIV) for VC funds from 0.475 in 1999 to 0.552 in 2013. We observe that VC investments in B2B slowly increased from 0.104 in 1999 to 0.134 in 2013. During BUST2000 and ECOBUST2000 (2000-2001), we observed declining diversifications and also declining VC funds' returns. In contrast, the BOOM2003 (2003-2007) period shows that the increasing diversification in VC funds was accompanied with higher funds' returns. During the BUST2007 and ECOBUST2007 (2008-2009), the VC funds' diversifications were accompanied by lower funds' returns. During the BOOM2009 (2009-2013), we observe that an increasing trend of regional diversification was accompanied by higher VC funds' returns.

There are increasing VC investments in health sectors while VC investments in the information technology sector decreased during our sample period. Venture capital funds investments in B2C, energy, financial, and material and natural resources have fluctuated during our sample period. The regional

diversification for VC has increased over threefold from 0.04 in 1999 to 0.15 in 2013 with the most notable increase occurred during 2000. The North American investment category (PCTNA) declined from 0.954 in 1999 to 0.91 in 2013 while investments in Europe (PCTEURO) and Asia/Oceania/Middle East (PCTASIA) have increased during our sample period. VC investments in South America (PCTSA) and Africa (PCTAFR) started in 2007 and 2010 respectively but their percentages remain relatively low throughout our sample period. VC investments for other regions (PCTOTHER) have generally declined over the period of our sample. Overall, we observe an increasing trend of VC investments in health and B2C sectors and Europe and Asia/Oceania/Middle East regions.

TABLE 5
CORRELATION COEFFICIENTS

No	Variables	1	2	3	4	5	6	7	8	9	10	11
1	IRR	1										
2	TVPI	0.650*	1									
3	SECTORDIV	0.059*	0.045*	1								
4	REGIONDIV	0.136*	0.103*	0.141*	1							
5	LN(P/D)	0.124*	0.096*	-0.134*	-0.131*	1						
6	LNSPREAD	-0.080*	-0.046*	0.048*	0.018	-0.567*	1					
7	VOLUME	0.058*	0.040*	-0.095*	-0.082*	0.600*	-0.560*	1				
8	FIRSTDAY	0.109*	0.041*	0.010	0.014	0.152*	-0.257*	0.102*	1			
9	FIRMAGE	0.097*	0.098*	0.308*	0.054*	-0.128*	0.004	-0.057*	0.015	1		
10	LNFUNDSIZE	-0.183*	-0.154*	0.146*	0.213*	-0.104*	0.039*	-0.060*	-0.049*	0.348*	1	
11	SECTOREXP	0.091*	0.032*	0.396*	0.196*	-0.248*	0.048*	-0.129*	-0.044*	0.593*	0.582*	1
12	REGIONEXP	0.064*	0.087*	0.181*	0.183*	-0.732*	0.174*	-0.437*	-0.107*	0.175*	0.112*	0.338*

* significant at 1% or less.

Table 5 shows correlation coefficients for VC returns, diversification measures and control variables that are used in the multivariate regression analysis. We find positive and significant correlations between sector and regional diversification measures (SECTORDIV and REGIONDIV) and funds' performance measures (IRR and TVPI) for VC. We find various control variables for public debt and equity markets, valuation, liquidity, risk, funds' age, and fund size with funds' returns for VC funds.

We also find significant and positive correlations between sector prior experience (SECTOREXP) for VC funds. We find both returns measures for VC funds are positively and significantly correlated with VC funds' regional prior experience (REGIONEXP). Additionally, there are high correlations among spread (LNSPREAD), VOLUME, LN(P/D), SECTOREXP, and REGIONEXP which indicate potential multicollinearity among the independent variables. Thus, we conduct robustness checks by dropping some control variables that are highly correlated with one another to avoid the potential multicollinearity problem.[14]

MULTIVARIATE REGRESSION RESULTS

Preliminary Regression for Sector and Regional Diversifications

As a preliminary analysis, we conduct multivariate regression of sectoral and regional diversifications (SECTORDIV and REGIONDIV) and percentages of investments in each sector and region for all sample periods ignoring public market and economic cycles. Table 6 presents our preliminary regression results. We find that both sector and regional diversifications positively and significantly affect VC funds' returns, except for TVPI return measure. This implies that sectoral and regional diversifications tend to enhance VC funds' returns. The magnitudes for the impact of sectoral diversification on VC funds are small while the magnitudes of regional diversification on VC funds returns are large. This implies that the regional diversifications seem to have large economic significance for enhancing VC funds' returns.

TABLE 6
THE IMPACT OF PORTFOLIO DIVERSIFICATIONS ON VENTURE CAPITAL FUND RETURNS

	IRR	TVPI	IRR	TVPI
LAG(IRR)	0.888		0.882	
	(31.0)***		(31.3)***	
LAG(TVP)		1.0047		1.0046
		(113.3)***		(113.5)***
SECTORDIV	0.815	0.0015		
	(1.99)**	(0.13)		
REGIONDIV	3.8809	0.0320		
	(5.96)***	(1.65)*		
PCTB2B			3.3787	-0.0341
			(1.01)	(0.44)
PCTB2C			3.3295	-0.0075
			(1.04)	(0.10)
PCTENER			2.0465	-0.1052
			(0.64)	(1.32)
PCTHLTH			3.1830	0.0183
			(1.76)*	(0.23)
PCTIT			3.6885	0.0124
			(2.01)**	(0.15)
PCTMAT			2.9038	0.0079
			(0.63)	(0.08)
PCTEURO			5.4983	0.1318
			(3.45)***	(2.89)***
PCTSA			2.1275	0.1004
			(0.35)	(0.49)
PCTASIA			3.1562	0.0045
			(2.55)**	(0.11)
PCTAFR			-50.0117	-1.4399
			(1.58)	(1.35)
PCTOTHER			5.3615	-0.0193
			(2.36)**	(0.52)
LN(P/D)	7.2677	0.1172	7.1517	0.1199
	(3.63)***	(1.96)**	(3.83)***	(3.29)***
LNSPREAD	0.3916	-0.0243	0.3876	-0.0236
	(0.55)	(1.14)	(0.71)	(1.56)
VOLUME	0.0473	-0.0004	0.0469	-0.0004
	(3.05)***	(0.96)	(2.49)**	(0.78)
FIRSTDAY	0.0615	0.0009	0.0610	0.0009
	(5.53)***	(2.70)***	(2.52)**	(2.38)**
FIRMAGE	-0.0139	-0.0004	-0.0225	-0.0004
	(1.37)	(1.24)	(2.00)**	(1.35)
LNFUNDSIZE	0.1945	0.0024	0.2664	0.0026
	(1.62)	(0.67)	(1.79)*	(0.47)
SECTORSEXP	0.1366	0.00003	0.1489	-0.0001
	(1.90)*	(1.00)	(1.09)	(0.06)
REGIONEXP	1.3507	0.0189	1.3813	0.0190
	(3.67)***	(1.72)*	(2.82)***	(1.60)
Intercept	-28.1637	-0.3078	-35.7732	-0.2891
	(3.08)***	(1.13)	(2.04)**	(1.24)
Vintage Year Dummies	Yes	Yes	Yes	Yes
Year Recorded Dummies	Yes	Yes	Yes	Yes
Observations	12559	12559	12559	12559
R-squared	0.9241	0.9865	0.9242	0.9865

Robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

When we look more closely across different sectors, we find evidence that VC investments in health and information technology are positively related to VC funds' IRR return. We also find that VC investments in Europe (PCTEURO), Asia/Oceania/Middle East (PCTASIA), and Other regions (PCTOTHER) are positively related to VC funds' returns. Again, we find evidence that regional diversification seems to be more important for enhancing VC funds' returns than sectoral diversification.

We examine the impact of control variables on VC funds and find that the S&P500 dividend yield (LN(P/D)), trading volume in public equity markets (VOLUME), and the first day stock return in companies that went through initial public offering (FIRSTDAY) are positively related to funds' returns. This may indicate that higher yield and more favorable conditions (i.e., liquidity and returns) in the public equity market also leads to higher return in the private capital market. We find evidence that both sector and regional prior experience (SECTOREXP and REGIONEXP) positively and significantly affect VC funds returns. Overall, the impacts of control variables on funds' returns are consistent with existing studies.

TABLE 7
PORTFOLIO DIVERSIFICATIONS AND FUNDS RETURNS DURING PUBLIC MARKET AND ECONOMIC CYCLES

Panel A

BUST2000			BOOM2003		
	IRR	TVPI		IRR	TVPI
LAG(IRR)	0.9240		LAG(IRR)	0.9203	
	(45.57)***			(45.40)***	
LAG(TVPI)		1.0071	LAG(TVPI)		1.0070
		(141.43)***			(144.24)***
BUST2000 x	*-12.3245*	*-0.0632*	*BOOM2003 x*	*0.7135*	*0.0227*
SECTORDIV	*(3.76)****	*(1.81)**	*SECTORDIV*	*(0.90)*	*(0.82)*
BUST2000 x	*7.4997*	*0.1735*	*BOOM2003 x*	*4.3772*	*0.0247*
REGIONDIV	*(0.79)*	*(1.60)*	*REGIONDIV*	*(2.49)***	*(1.82)**
Intercept	-29.9039	-0.8429	Intercept	-27.8942	-0.3464
	(4.78)***	(4.99)***		(2.71)***	(1.52)
Observations	12559	12559	Observations	12559	12559
R-squared	0.9193	0.9861	R-squared	0.9208	0.9864

Panel B

BUST2007			BOOM2009		
	IRR	TVPI		IRR	TVPI
LAG(IRR)	0.9205		LAG(IRR)	0.9192	
	(45.57)***			(42.71)***	
LAG(TVPI)		1.0072	LAG(TVPI)		1.0068
		(142.42)***			(138.38)***
BUST2007 x	*-1.2968*	*-0.0218*	*BOOM2009 x*	*0.7145*	*0.0352*
SECTORDIV	*(1.69)**	*(1.94)**	*SECTORDIV*	*(1.54)*	*(2.99)****
BUST2007 x	*3.0318*	*-0.0051*	*BOOM2009 x*	*3.1175*	*0.0332*
REGIONDIV	*(2.12)***	*(0.16)*	*REGIONDIV*	*(3.35)***	*(1.67)**
Intercept	-27.646	-0.3279	Intercept	-9.312	-0.6929
	(3.00)***	(1.45)		(1.45)	(3.67)***
Observations	12559	12559	Observations	12559	12559
R-squared	0.9206	0.9865	R-squared	0.9195	0.9861

Panel C

ECOBUST2000			ECOBUST2007		
	IRR	TVPI		IRR	TVPI
LAG(IRR)	0.9238		LAG(IRR)	0.9204	
	(46.26)***			(45.60)***	
LAG(TVPI)		1.0068	LAG(TVPI)		1.0069
		(146.47)***			(144.46)***
ECOBUST2000 x	*-12.1682*	*0.1952*	*ECOBUST2007 x*	*-0.6369*	*0.0198*
SECTORDIV	*(2.61)****	*(0.55)*	*SECTORDIV*	*(0.72)*	*(1.57)*
ECOBUST2000 x	*11.1409*	*0.5309*	*ECOBUST2007 x*	*3.8857*	*0.0168*
REGIONDIV	*(2.52)***	*(1.69)**	*REGIONDIV*	*(2.28)***	*(0.50)*
Intercept	-27.5401	-0.3245	Intercept	-27.4903	-0.3456
	(4.43)***	(1.43)		(2.68)***	(1.53
Observations	12559	12559	Observations	12559	12559
R-squared	0.9191	0.9864	R-squared	0.9207	0.9864

All regressions include the same control variables as Table 6. See Appendix A for variables definitions.

Robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Multivariate Regression across Different Market and Economic Cycles

Next, we examine the impact of sector and regional diversifications on funds' returns during four different public market cycles: BUST2000, BOOM2003, BUST2007, BOOM2009, and two different economic cycles: ECOBUST2000 and ECOBUST2007. Table 7 presents the impact of sector and regional diversity measures (SECTORDIV and REGIONDIV) on funds' returns. First, we find that during the Dot-Com public market bust (BUST2000), sectoral diversification reduces VC funds' returns while the regional diversification does not significantly affect funds' returns. This finding is consistent with our second hypothesis (H2), which indicates that during the market bust, diversification across different sectors was costly and reduced funds' returns while regional diversification also did not enhance (affect) the funds' returns.

During the public market boom 2003 (BOOM2003), we find evidence that only regional diversification positive affect VC funds' returns. This finding supports our first hypothesis (H1) which argues that during favorable market conditions, VC funds are able to take advantage of increased supply and demand of funds by increasing their sectoral and regional diversifications (indicated in Table 4), and these diversifications increase funds' returns.

During the public market and economic bust 2007 (BUST2007 and ECOBUST2007), we find that sector diversification is negatively related to VC funds' returns. However, we find some evidence that regional diversification is positively related to VC internal rate of return (IRR), which is not consistent with our second hypothesis (H2). We also find similar evidence during the ECOBUST2000 for VC funds. This implies that during the economic and public market bust 2007, and economic bust 2000, VC funds would have benefited from diversifying their investment across different countries.

And last but not least, during the 2009 public market boom (BOOM2009), we observe that regional diversification is more positively and more strongly related to VC returns than the sectoral diversification.

TABLE 8
SECTOR AND REGIONAL COMPONENTS ON FUNDS RETURNS DURING PUBLIC MARKET AND ECONOMIC CYCLES

Panel A

BUST2000			BOOM2003		
	IRR	TVPI		IRR	TVPI
BUST2000 x PCTB2B	-3.7427 (1.38)	-0.3258 (2.02)**	BOOM2003 x PCTB2B	3.9878 (2.29)**	0.0428 (0.84)
BUST2000 x PCTB2C	-15.582 (2.30)**	-0.35844 (2.15)**	BOOM2003 x PCTB2C	0.6722 (0.25)	0.0379 (0.49)
BUST2000 x PCTENER	14.2769 (0.31)	0.8497 ;(1.10)	BOOM2003 x PCTENER	11.9623 (1.49)	-0.0335 (0.14)
BUST2000 x PCTHLTH	-3.4727 (1.13)	0.0444 (0.81)	BOOM2003 x PCTHLTH	0.5853 (0.72)	0.0306 (1.29)
BUST2000 x PCTIT	-5.8790 (-3.31)***	-0.0304 (0.79)	BOOM2003 x PCTIT	1.4443 (1.77)*	0.0227 (0.95)
BUST2000 x PCTMAT	0.5358 (1.08)	2.2928 (0.99)	BOOM2003 x PCTMAT	9.4677 (2.77)***	0.0851 (0.27)
BUST2000 x PCTEURO	-0.9035 (0.09)	0.6610 (0.95)	BOOM2003 x PCTEURO	3.7325 (1.18)	0.0569 (0.61)
BUST2000 x PCTSA	8.5126 (2.03)**	-0.6226 (0.14)	BOOM2003 x PCTSA		
BUST2000 x PCTASIA	6.7907 (0.74)	1.9769 (1.01)	BOOM2003 x PCTASIA	11.9947 (2.08)**	0.0679 (1.90)*
BUST2000 x PCTAFR			BOOM2003 x PCTAFR		
BUST2000 x PCTOTHER	6.9043 (2.16)**	-0.1039 (0.55)	BOOM2003 x PCTOTHER	3.7799 (2.12)**	0.0093 (0.18)
Intercept	-25.6388 (5.91)***	-0.9161 (5.39)***	Intercept	-33.6578 (3.67)***	-0.4607 (1.71)*
Observations	12559	12559	Observations	12559	12559
R-squared	0.913	0.9861	R-squared	0.9210	0.9864

Panel B

BUST2007			BOOM2009		
	IRR	TVPI		IRR	TVPI
BUST2007 x PCTB2B	0.8895 (0.45)	0.0481 (0.82)	BOOM2009 x PCTB2B	1.0046 (0.84)	0.0442 (1.73)*
BUST2007 x PCTB2C	8.4193 (0.84)	0.1044 (1.47)	BOOM2009 x PCTB2C	2.2932 (2.45)**	0.0853 (3.70)***
BUST2007 x PCTENER	7.8112 (1.54)	0.0442 (0.35)	BOOM2009 x PCTENER	1.1676 (0.69)	0.0447 (1.43)
BUST2007 x PCTHLTH	0.5923 (1.24)	0.0148 (1.02)	BOOM2009 x PCTHLTH	0.6165 (1.13)	0.0459 (2.85)***
BUST2007 x PCTIT	-0.7304 (1.45)	-0.0027 (0.14)	BOOM2009 x PCTIT	0.9040 (0.45)	0.0601 (3.95)***
BUST2007 x PCTMAT	0.6712 (0.06)	0.0089 (0.03)	BOOM2009 x PCTMAT	6.7135 (1.95)*	0.0527 (0.79)
BUST2007 x PCTEURO	5.5815 (2.58)***	.0910 (0.96)	BOOM2009 x PCTEURO	4.6015 (3.27)***	0.1396 (1.98)**
BUST2007 x PCTSA	-20.1437 (1.54)	0.1055 (0.07)	BOOM2009 x PCTSA	0.0491 (0.01)	-0.0076 (0.04)
BUST2007 x PCTASIA	1.5515 (0.61)	-0.0648 (0.69)	BOOM2009 x PCTASIA	1.7792 (1.62)	-0.0376 (1.02)
BUST2007 x PCTAFR			BOOM2009 x PCTAFR	9.8481 (0.29)	-1.3203 (1.72)*
BUST2007 x PCTOTHER	9.892 (1.19)	.0240 (0.12)	BOOM2009 x PCTOTHER	1.5249 (0.85)	-0.0300 (1.03)
Intercept	-27.9227 (3.38)***	-1.0110 (5.77)***	Intercept	-11.2430 (1.89*	-0.5912 (3.55)***
Observations	12559	12559	Observations	12559	12559
R-squared	0.9190	0.9861	R-squared	0.9188	0.9862

Panel C

ECOBUST2000			ECOBUST2007		
	IRR	TVPI		IRR	TVPI
ECOBUST2000 x PCTB2B	-2.7945 (1.27)	-0.4284 (2.27)**	ECOBUST2007 x PCTB2B	-1.6428 (0.82)	0.0451 (0.70)
ECOBUST2000 x PCTB2C	-6.4604 (2.38)**	-0.5838 (3.05)***	ECOBUST2007 x PCTB2C	-1.6428 (3.58)***	0.1015 (1.37)
ECOBUST2000 x PCTENER	3.6082 (1.64)	0.4900 (1.72)*	ECOBUST2007 x PCTENER	-8.8636 (1.72)*	0.0394 (0.30)
ECOBUST2000 x PCTHLTH	-4.8209 (0.94)	0.0716 (1.10)	ECOBUST2007 x PCTHLTH	-1.3989 (2.48)**	-0.0365 (2.35)**
ECOBUST2000 x PCTIT	3.4753 (0.60)	0.0359 (0.78)	ECOBUST2007 x PCTIT	0.5590 (0.98)	0.0295 (1.35)
ECOBUST2000 x PCTMAT	0.5410 (1.44)	2.7926 (0.97)	ECOBUST2007 x PCTMAT	2.9553 (0.22)	0.0183 (0.06)
ECOBUST2000 x PCTEURO	0.9540 (3.81)***	1.4892 (3.17)***	ECOBUST2007 x PCTEURO	6.1834 (2.65)***	0.1046 (1.01)
ECOBUST2000 x PCTSA	9.6999 (1.28)	-4.7211 (0.97)	ECOBUST2007 x PCTSA	6.65792 (1.97)**	-0.0283 (0.02)
ECOBUST2000 x PCTASIA	-9.7339 (0.24)	2.8578 (3.72)***	ECOBUST2007 x PCTASIA	1.2283 (0.47)	-0.0551 (0.55)
ECOBUST2000 x PCTAFR			ECOBUST2007 x PCTAFR		
ECOBUST2000 x PCTOTHER	11.2477 (1.74)*	-0.19033 (1.45)	ECOBUST2007 x PCTOTHER	11.1091 (1.31)	0.035 (0.17)
Intercept	-29.9039 (4.78)***	-0.7929 (4.64)***	Intercept	-32.5968 (3.48)***	-1.1992 (6.78)***
Observations	12559	12559	Observations	12559	12559
R-squared	0.9193	0.9862	R-squared	0.9191	0.9861

All regressions include the same control variables as Table 6. See Appendix A for variables definitions.

Robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

We continue our multivariate regression analysis by examining the impact of each sector and regional diversification on VC returns across these different cycles. Table 8 shows that during BUST2000, VC funds' returns were adversely affected by B2C and IT. The rest of the sectors do not significantly affect VC returns. We also find that investments in different regions do not statistically affect VC returns, except for investment in South America (PCTSA), which is positively related to VC funds' IRR. Overall, we find supporting evidence that during the BUST2000, the funds' diversifications either negatively or insignificantly affect funds' returns.

During public market boom 2003 (BOOM2003), we find that VC investments in material and natural resources (PCTMAT) enhance the funds' returns. There is some evidence that investments in Asia/Oceania/Middle East (PCTASIA) and other regions (PCTOTHER) enhance VC funds' IRR. Overall, we find evidence that during BOOM2003, there are positive relationships between investments across different sectors and regions and funds' returns.

In the period of public market bust in 2007 (BUST2007) presented in Panel B of Table 8, we observe a positive relationship between investments in Europe and VC funds' returns. Thus, the impact of regional diversification on funds' returns during BUST2007 is positive while the impact of sector diversification is either negative or insignificant.

We find that investments in B2B, B2C, health, IT, and material and natural resources sectors and investment in European region generally increase VC returns during the public market boom in 2009 and thereafter (BOOM2009). There is some evidence that investments in Africa reduce VC funds' TVPI. Overall, during this BOOM2009 period, we generally find that sector and geographic diversifications boost funds' returns.

Examining the economic bust in 2000 (ECOBUST2000) in Panel C of Table 8, we find that investments in B2B and B2C reduce VC funds' returns. We find some evidence that diversification of investments in Europe, Asia/Oceania/Middle East, and other regions increase VC funds' returns. And last but not least, we find that investments across different sectors generally adversely affect VC returns during the 2007 economic bust (ECOBUST2007). We find that investments in Europe and South America enhance VC funds' returns. Overall, we find mixed evidence for the impact of diversifications on funds' returns during ECOBUST2007.

Robustness Checks

The funds' portfolio holdings may have a lag effect on funds' returns. We check our results using a one-quarter lag and then one-year lag of diversification measures separately on current funds' returns. Our untabulated results are consistent with reported results. We also conduct a fixed-effect panel data regression and clustering of standard error based on GPs (in addition to vintage year and year of reported data) and the untabulated results are similar to the results reported in this study.

The correlation Table 5 indicates that there are high correlations between diversification measures (SECTORDIV and REGIONDIV) and funds' size (LNFUNDSIZE) and VC firms' age (FIRMAGE). We re-estimate our regression analyses by excluding funds' size (LNFUNDSIZE) and VC firms' age (FIRMAGE) and the results are consistent with our reported results. We also re-estimate the regressions by excluding diversification measures (SECTORDIV and REGIONDIV) and find that the impact of funds' size (LNFUNDSIZE) and VC firms' age (FIRMAGE) are still weakly significant similar to the results presented. Also, there are high correlations among independent variables LN(P/D), LNSPREAD, and VOLUME. We again re-estimate our regression analyses by including only one of these three independent variables at the time and the results are also consistent with our reported results. Therefore, we believe that our results are not driven by multicollinearity problems.

The quarterly data interval is most likely to suffer from a serial correlation for both dependent and independent variables. Therefore, we re-estimate our regression analyses using only the fourth quarter data every year and the untabulated results indicate that our results remain robust using the annual (fourth quarter) data. And lastly, we also winsorize the returns data at 10 percentile and 90 percentile to eliminate outliers in funds' returns data. The results from winsorized data are also consistent with the results presented in our tables.

CONCLUSIONS

In the venture capital communities and with limited partners, there is a long-standing debate as to whether specialist or generalist investment strategies produce better returns. Using rich VC data from PitchBook, we document that there has been an increasing trend of diversification of US venture capital (VC) funds' investments across different sectors and geographic regions outside of the US during 1999 to 2013. Our study examines whether diversification strategies of VC funds affect the funds' returns.

We specifically focus on the impact of US venture funds' investment diversifications across different sectors and geographic regions on their funds' returns. Based on existing VC literature, we argue that when public equity market and economic conditions change, the supply and demand for VC funds also change. The asset allocation and diversification literature also indicate that changes in market and economic conditions (boom and bust) influence the effectiveness of portfolio diversifications to improve investments' returns. Therefore, changes in public equity market and economic conditions provide a perfect opportunity to empirically examine the impact of diversification on VC funds' returns. Thus, we examine the impact of investments across seven sectors and six regions (countries) from US venture capital firms on their returns when the US economic and public equity markets were experiencing booms and busts.

First, we find that VC funds with more diversified portfolios across sectors and regions have higher returns throughout the entire period of our sample. More importantly, we find that sector and regional diversifications provide favorable returns during the boom periods and diversifications adversely or insignificantly affect funds' returns during the downturns (busts). This is consistent with supply and demand theory and modern portfolio theory under regime switching conditions. Furthermore, geographically, investments in Europe provide enhanced returns relative to North America, while investments in Asia/Oceania/Middle East and Africa are negatively related to funds' returns during the downturns.

Our study has implications for limited partners investing in venture capital funds as well as for general partners formulating investment strategies when anticipating changes in public equity market and economic cycles. Our conclusions also add new information to contribute to the debate about whether specialist or generalist fund strategies produce superior economic outcomes. What remains unanswered is what motivates funds to invest away from their sector and geographic preferences and diversify their holdings. Are they lured by opportunistic risk and return (pricing) imbalances or are they seeking a deliberate diversification plan in accordance with their charters? This represents an area that is ripe for future study.

ENDNOTES

1. Gompers and Lerner (1998) indicate that the supply of capital is determined by investors' expected rate of return on funds' investments while the demand for funds is based on the number of entrepreneurial firms who are seeking financing that can deliver investors' expected returns. They show that the regulatory changes related to the "prudent man" rule that allows pension funds to invest in venture funds and lower capital gain tax on limited partners positively affect the supply of funds while firms' research and development expense positively affect the demand for venture funds.
2. The time spans that we use to identify the booms and busts of the US public equity market are consistent with the periods identified in recent literature (Nyberg 2012).
3. Our time frames of economic busts are also consistent with time frames that have been documented in recent studies (Segal 2011, Morley and Piger 2012, Nyberg 2012).
4. We expect similar results during two economic downturns (bust) in 2000-2001 and 2007-2009.
5. For a group of seven sectors with equal distribution of 1/7 on each sector or region, the maximum value of $DIV= (1 - ((1/6)^2+(1/6)^2+(1/6)^2+(1/6)^2+(1/6)^2+(1/6)^2)) = 0.833$ (assuming the fund has equal distribution across all six region).
6. These control variables are consistent with control variables from existing literature (Robinson and Sensoy 2013, Lossen 2007, Ang et al. 2013).

7. See Appendix A for variables definitions.
8. We report information for other non-PitchBook databases from Harris et al. (2014a). All data presented in Table 1 are annual data counts.
9. Standard and Poor's data is collected from Robert Shiller's website at http://www.econ.yale.edu/~shiller/data.htm
10. The Moody's corporate bond spreads is collected from the Federal Reserve Bank data at http://www.federalreserve.gov/releases/h15/data.htm.
11. The IPO data is collected from Jay Ritter's website at http://bear.warrington.ufl.edu/ritter/ipodata.htm
12. See Appendix A for variables definitions.
13. Variable definitions are included in Appendix A.
14. We conduct robustness checks by eliminating some independent variables that are highly correlated to one another and the results are discussed on the Robustness Checks section. High correlations among LN (P/D), LNSPREAD, and VOLUME are also reported in Robinson and Sensoy (2013).

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APPENDIX A

Variables Definitions

Variables	Definitions
IRR	Internal Rate of Return of the fund (%)
TVPI	Total Value to Paid In. The ratio of the current value of remaining investments within a fund, plus the total value of all distributions to date, relative to the total amount of capital paid into the fund.
SECTORDIV	Diversification or Blau heterogeneity index as a measure of portfolio diversification across 7 sectors. Blau index is calculated as = 1 – $\sum_1^7 Si^2$, where Si is the percentage of portfolio investment in 7 sectors (PCTB2B, PCTB2C, PCTENER, PCTFIN, PCTHLTH, PCTIT, and PCTMAT)
REGIONDIV	Diversification or heterogeneity Blau index as a measure of portfolio diversification across 6 regions. Blau index is calculated as = 1 – $\sum_1^6 Ri^2$, where Ri is the percentage of portfolio investment in 6 regions (North America, Europe, South America, Asia/Oceania/Middle East, Africa, and Other regions)
LN(P/D)	Natural log of the price/dividend ratio of the S&P 500 (source: http://www.econ.yale.edu/~shiller/data.htm)
LNSPREAD	Natural logarithm of the Baa-Aaa corporate bond yield spread (source: http://www.federalreserve.gov/releases/h15/data.htm)
VOLUME	Net IPO volume in each period (source: http://bear.warrington.ufl.edu/ritter/ipodata.htm)
FIRSTDAY	The average of first day IPO returns during the period (source: http://bear.warrington.ufl.edu/ritter/ipodata.htm)
SECTOREXP	Sector prior experience measured by the natural log of the largest number of investments made by VC firm in a sector prior to the current period.
REGIONEXP	Region prior experience measured by the natural log of the largest number of investments made by VC firm in a region prior to the current period.
FIRMAGE	General Partners age since founding year
LNSIZE	Natural log of fund's size (fund size is stated in US Dollar)
PCTB2B	Number of investments in business to business (B2B) sector divided by total number of investments in all sectors.
PCTB2C	Number of investments in business to consumer (B2C) sector divided by total number of investments in all sectors.
PCTENER	Number of investments in energy sector divided by total number of investments in all sectors.
PCTFIN	Number of investments in financial sector divided by total number of investments in all sectors.
PCTHLTH	Number of investments in health sector divided by total number of investments in all sectors.
PCTIT	Number of investments in information technology sector divided by total number of investments in all sectors.
PCTMAT	Number of investments in material or natural resources sector divided by total number of investments in all sectors.
PCTNA	Number of investments in North America region divided by total number of investments in all regions
PCTEURO	Number of investments in European region divided by total number of investments in all regions
PCTSA	Number of investments in South America region divided by total number of investments in all regions
PCTASIA	Number of investments in Asia/Oceania/Middle East region divided by total number of investments in all regions
PCTAFR	Number of investments in Africa region divided by total number of investments in all regions
PCTOTHER	Number of investments in other regions (other than North America, European, South America, Asia/Oceania/Middle East, or Africa) divided by total number of investments in all regions
BUST2000	A dummy variable equals one if the period is between Jan 2000 – June 2002 (Q1 2000 to Q2 of 2002)
BOOM2007	A dummy variable equals one if the period is between Jan 2003 – June 2007 (Q1 2003 to Q2 2007)
BUST2007	A dummy variable equals one if the period is between July 2007 – Mar 2009 (Q3 2007 to Q1 2009)
BOOM2007	A dummy variable equals one if the period is between June 2009 – present (Q2 2009 and after)
ECOBUST2000	A dummy variable equals one if the period is between July 2000 – Sep 2001 (Q3 2000 to Q3 2001)
ECOBUST2007	A dummy variable equals one if the period is between Oct 2007 – June 2009 (Q4 2007 to Q2 2009)