Macroeconomic and Capital Market Determinants of Venture Capital Investment

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April 14, 2017

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Honors thesis submitted in partial fulfillment of the requirements for Graduation with Distinction in Economics in Trinity College of Arts and Sciences at Duke University.

Acknowledgements

I would like to express my sincerest gratitude to Dr. Michelle Connolly for her tremendous assistance and contribution to this paper. Without her support, time, knowledge and patience this thesis would not have been possible. I am also extremely grateful for the advice and guidance provided by my faculty advisor, Dr. Mary Beth Fisher, seminar advisor, Dr. Kent Kimbrough and fellow honors student, Matthew Van Liedekerke.

Dedicated to my parents, Christine and Mitchell.

Abstract

This thesis explores the impact of macroeconomic, equity and credit market conditions on venture capital investment. The theoretical methodology outlines the logical foundation that supports the relationships between each explanatory variable and the supply and demand of venture financing. The hypotheses suggested by theory are tested using five multi-vector ordinary least squares regression that analyze the impact of the macroeconomic and capital market variables, after adjustment for multicollinaerity and overspecification bias, on each stage of venture capital investment. The next empirical strategy uses category variables and interaction terms to vastly expand the number of observations in the dataset and provide a more robust analysis of select variables. The results show that macroeconomic conditions associated with increased economic activity and productivity growth cause an increase in venture capital investment at all development stages, though early and late stage investments are the most sensitive to growth and productivity advances. In addition, strong public equity market valuations and initial public offering successes are positively associated with venture capital investments. Finally, optimism in credit markets are found to have an indirect impact on venture capital investment, through confounding factors related to investor and entrepreneurial confidence.

JEL Classification: G2, G24, E44
Keywords: venture capital, macroeconomics, capital markets

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1 Introduction

Venture capital (VC) is a private equity investment in which investors exchange capital for an equity interest in startups and small- to medium-sized private enterprises with strong growth potential. This class of growth investors has developed as an important financial intermediary that provides financing to young, risky businesses may otherwise be unable to obtain it due to high levels of uncertainty, few or no securable assets, or asymmetric information between entrepreneurs and investors (Gompers & Lerner, 2001). The paper contributes to the literature studying the variation and driving forces of venture capital investment by analyzing the relationship between macroeconomic, equity and credit market conditions, and investment levels at various stages of company development. Understanding the impact both short- and long-term macroeconomic and capital market conditions have on venture capital investment has strategic implications for institutional investors, venture capitalists, business owners and entrepreneurs. This study finds that healthy economic conditions, rising Nasdaq valuations and strong IPO investor appetite are associated with increases in venture capital investment. Increases in investor confidence, represented by reduced investment grade risk premiums, are found to be associated with increases in venture capital investment.

The literature review establishes context for this paper by briefly describing relevant previous studies on venture capital. The theoretical methodology delineates the individual impact of each variable on the supply and demand of venture capital investment followed by a summary and description of the explanatory and response variables. The empirical strategy outlines two ordinary least squares regression models that measure the *net impact* of three macroeconomic, equity and credit market variable vectors on VC activity by investment stage from 1985 to 2016, followed by a discussion and interpretation of the results.

Venture capital firms are generally composed of a team of professional investors funded by institutional asset managers such as pension funds, insurance companies, endowments, sovereign wealth funds, family offices, etc. Venture capitalists take an active role in the development of their portfolio companies by providing mentorship, network access, strategic guidance and operational experience (Strebulaev & Gornall, 2015). After a typical investment horizon of three to seven years, venture capital investors create liquidity for their equity interests by selling the company through an initial public offering or an M&A transaction (getting acquired). This process of raising funds from institutional investors, investing in and adding value to portfolio companies, and liquidating investments through an IPO or M&A is known as the "venture cycle."

Venture capital has been vital to the development and modernization of the U.S. economy. Dominant companies such as Google, Starbucks and FedEx were all supported by venture capital. In 1979, a regulatory change allowed pension funds to invest with venture capital firms caused the industry's size, scope and assets under management to expand by orders of magnitude. Of companies founded between 1979 and 2013, 43% of public U.S. companies has received venture financing. These companies possess a 57% of the cumulative market capitalization, compose 42% of all research and development spending, and employ 38% of the workforce of public U.S. companies (Strebulaev & Gornall, 2015). VC is not only a potentially lucrative investment, but also has positive impact on the innovation, productivity, employment and overall economy activity (Kortum & Lerner, 2000; Füss & Schweizer, 2011).

Nascent companies seek venture capital at different stages of development and often undergo multiple fundraising rounds as the business matures. The classification of private companies raising capital is segmented into four categories: seed/start-up stage, early stage,

expansion stage and late stage. Seed/start-up stage companies are the least mature and are characterized by comparatively modest amounts of invested capital used for concept or product development, market research, building a management team and developing a business plan. These companies are usually in existence for less than 18 months. Early stage financing refers to investments in companies that have begun operations and have a product or service in testing or pilot production but have not yet achieved commercial manufacturing and sales. Some companies may require capital to support further product development and marketing to generate initial revenues. Other companies have begun to generate revenue, but are yet to turn a profit, and are looking for capital to begin commercial manufacturing and sales. These companies have usually been in business for three years or less. Expansion stage companies have demonstrated significant revenue growth by offering a product or service in production and commercially available, but may or may not be profitable. Capital at this stage is used for aggressive market expansion and product diversification. These companies have existed for more than three years. Late stage companies have products or services that are widely available, have generated reoccurring revenue, and are likely to be profitable or cash flow generative but not necessarily. These companies have usually been in business for more than three years and may be in preparation for their sale through a merger, acquisition or initial public offering. Successful investments will generate a high return on investment for venture capitalists that have provided financing during these any of these rounds. Earlier stage investments are expected to provide higher rates of return, commiserate with the higher risks inherited upon early investment.

2 Literature Review

Previous studies have focused on venture capital investment and performance from a microeconomic and firm-level, analyzing firms' governance, structures, networks and relationships with entrepreneurs. Some have investigated the driving forces of success of companies by comparing VC-financed and non-VC financed firms (Puri & Zarutskie, 2012), the strengths, risks and decisions of venture capital investments (Kaplan and Stromberg 2004), as well as the individual impact different venture capital firms have on portfolio company performance (Nahata, 2008; Croce, Grilli, & Murtinu, 2013). Studies have tended to focus on the impact of firm-level decisions, both from investors and entrepreneurs. Research investigating the relationship between macroeconomic conditions, the capital market and venture capital investment has been less frequent and robust (Ning, Wang, & Yu, 2014).

One study by Black and Gilson (1998) established the foundational work for the analysis in this paper that focuses on the relationship between venture capital and the capital markets. Their study discusses how bank or stock market-centered capital markets differ in efficiency with respect to venture capital investments. They find that the success of the U.S. venture capital industry is partially explained by the ability to exit an investment rapidly through IPO. The relationship between equity markets and venture capital investment is intuitive; approximately 1 of 6 venture capital financed companies sell shares to the public through an initial public offering when early investors seek liquidity for their stake in a private business. Volatility in the venture capital industry has been documented through fundraising, investment levels and performance, and much this volatility can be related to shifting valuations and conditions in public equity markets. As IPO valuations increase and equity market conditions appears propitious, venture capital firms, specifically more experienced general partners, increase the frequency and value of

their investments (Gompers et al., 2008). This is consistent with a casual relationship between equity market conditions and venture capital fundraising and investment.

Füss and Schweizer (2011) outline a methodology for analyzing VC investment value by determining the general equilibrium between supply and demand for venture financing. Füss and Schweizer consider VC supply to be the willingness of asset managers to supply funds to entrepreneurs and business owners, while demand is the desire to obtain such financing. Venture capitalists exist at the general equilibrium, connecting capital seekers to capital providers in an efficient way. Both supply and demand are measured as a function of an investment's profitability, the existence and efficiency of an exit channel, short and long-term interest rates, inflation and economic activity. They find that the rate of industrial production, Nasdaq, and long-term interest rates are positively related to the value of VC investments, while short-term interest rates are negatively related. My analysis builds upon their theoretical methodology to establish a relationship between the macroeconomic environment, capital market conditions, and venture capital investment.

Ning, Wang, & Yu (2014) examine the volatility and macroeconomic drivers of venture capital investments. Their study shows that macroeconomic factors influence the aggregate amount of capital invested through venture capitalists, as well as the number of deals and average deal size. Their paper also finds that the 2000 dot-com bubble and 2008 global financial crisis both materially changed the risk preferences and investment strategies of venture capitalists following the crises. This paper contributes to the existing literature on venture capital determinants by expanding the explanatory scope into equity and credit market conditions, analyzing VC investment variance between development stages, and employing a new empirical methodology that expands the model's number observations and power of estimation.

3 Theoretical Methodology

3.1 Overview

Venture capital is classified as an alternative investment strategy due to the low correlation its returns share with traditional asset classes such as stocks, bonds or cash. Regardless, there are a number of confounding factors that can be considered driving forces of both alternative and traditional investments. This section outlines the theory that explains why and how each variable included in this analysis should impact the supply and/or demand of venture capital. These macroeconomic and capital market variables can be categorized in two ways. The first set of variables have a direct impact on the supply and demand of venture capital, while the second set of variables, though are reflective of greater conditions and sentiment, have very little direct impact on the process or strategy of venture capitalists or entrepreneurs looking to raise capital. Both types of variables are valuable to this analysis, but the distinction between the two is important to consider.

3.2 Macroeconomic Theory

Increasing economic activity and industry growth have been shown to increase the number of start-ups, which subsequently proliferates both innovation and demand for venture capital (Acs and Audretsch, 1991). In addition, the growth in consumer demand and optimism associated with healthy macroeconomic conditions causes entrepreneurs to pursue potentially lucrative ventures and business owners to expand their companies, consequently increasing the demand for venture capital (Füss & Schweizer, 2011). During these periods of growth, investors are more optimistic in their investment considerations, causing more capital to be put to work by intuitional investors and venture capitalists, increasing the supply of venture funds. The

combined increases in supply and demand of venture capital is the basis for the expected positive correlation between variables related to economic activity and venture capital investment. Measurements that reflect macroeconomic conditions, such as GDP, industrial production, corporate profit, as well as the federal funds rate and the unemployment rate are all expected to impact supply and demand in accordance with this theory.

Interest rates have a more complex impact on the supply and demand for venture capital. The Federal Reserve sets a target for the federal funds rate as a function of broader economic conditions; when the U.S. approaches full employment, macroeconomic conditions have a positive outlook and financing markets heat up, the central bank raises rates to prevent excessive inflation. Conversely, as the economy slows, unemployment rises and inflation is under control, the federal funds rate target is dropped to stimulate the economy. From a macroeconomic perspective, this relationship causes the federal funds rate to reflect broad economic conditions and therefore have a positive expected correlation with VC investment. The implication of interest rates on cost of capital is discussed further in the credit market theory section.

3.3 Equity Market Theory

Equity capital markets are particularly important to private equity investors because they often are a source of liquidity for the ownership interests they hold in private companies. Healthy equity market conditions are important to venture capitalists that invest in high-risk startups and businesses as these investors understand the pivotal role equity markets play in generating a high return. Market indices such as Nasdaq and S&P 500 reflect the market's valuation of publicly traded companies and can be used as a proxy for determining potential value in privately held VC backed companies. When market index prices are high, potential investment returns are also

optimistically inflated. This confidence increase in investors and entrepreneurs stimulates demand and supply of venture funds; therefore the existence of a functioning and profitable exit channel would increase both supply and demand for venture capital (Ning, Wang, & Yu, 2014). The supply-side impact, however, is expected to be greater than demand. Though venture capitalists keep a close eye on equity capital markets, entrepreneurs are more likely pursue business opportunities regardless of conditions in the financial markets.

Though the Nasdaq Composite Index depicts the market's valuation of public companies and is reflective of greater investor confidence, it does not provide specific insight into initial public offerings. To understand how IPOs impact venture capital, this study includes the number of IPOs per quarter and the first day return on those IPOs as explanatory variables to gauge equity market conditions. A high number of IPOs is expected to positively impact the level of venture capital investment at all stages, as this demonstrates the effectiveness of the equity markets to serve as an exit channel and increases venture capitalist confidence. First day return of newly public securities offered on exchanges such as Nasdaq measure the demand of the private businesses from market participants. This metric reflects the market sentiment and public equity investor appetite for owning private businesses brought to market for the first time. First day IPO returns are expected to be positively correlated with VC supply. Because venture capitalists only sell a portion of their investment in a business during an IPO, a high first day return would boost the VC's return, causing asset managers to commit more capital to the industry. In addition, when venture capitalists generate high returns, their response has been to invest capital more readily, as evidenced in the dot-com bubble.

3.3 Credit Market Conditions

Credit market conditions are frequently cited as a principal determinant of private equity investments such as leveraged buyouts and real estate due to the paramount role of leverage in such investments. The impact of debt markets on venture capital is less obvious, as the equity investments that venture capitalists provide do not directly use debt financing; regardless, there are still a number reasons why credit conditions can impact the supply and demand of venture capital. Investor confidence has been shown to be a principal determinant in the magnitude of risk premium charged for holding risky assets. These risk premiums are observed in the yield spread of investment grade debt over the risk-free ten-year treasury security. Tight yield spreads are demonstrative of optimistic market sentiment, greater risk-tolerance among investors as well as broad positive macroeconomic trends (Tang & Yan, 2010). In this case, optimistic market sentiment is the confounding factor that causes spreads to tighten, venture capitalists to invest more readily, and entrepreneurs to seek more capital, again increasing supply and demand of VC funds.

The federal funds rate and the 10-year treasury yield are used in this analysis as a representation of the cost of debt for companies. These rates and the prime rate, which usually hovers around three hundred basis points above the federal funds rate, are benchmarks for interest rates used for most companies who are issued credit by large financial institutions. Increased debt service costs are a financial burden on businesses that seek debt financing and incentivize entrepreneurs to choose venture funding rather than debt when raising capital. Therefore, changing interest rates impact the demand of venture capital investments from entrepreneurs and private business owners. Long term fixed income instruments like the 10 year treasury security also present an investment alternative to venture capital and should

consequentially change the supply of venture capital funds as this long term rate changes. As the risk-free rate increases, the cost of capital increases, giving capital allocated to venture investments a higher opportunity cost. The net impact of interest rates movement is determined by the quantity of supply or demand that changes with a given rate change (Füss & Schweizer, 2011). Two additional considerations with respect to interest rate changes are the confounding factors. Given the persistence of demand for venture capital and the strength of non-market related forces in determining venture capital demand, the supply effect is expected to be greater than the demand effect. Hence, increasing treasury yields should on net decrease the supply of venture capital funds, which will consequentially decrease overall levels of investment.

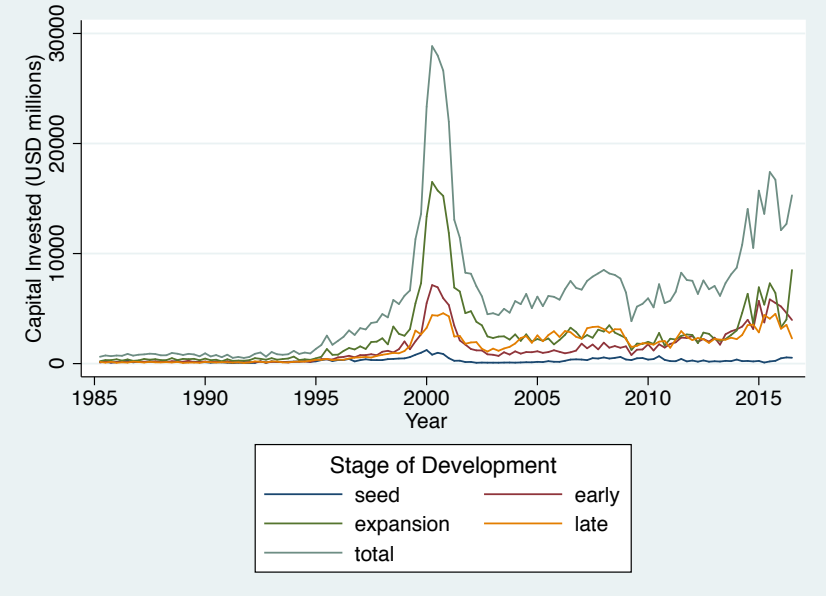
4 Data

4.1 Venture Capital Investment Data

The dependent variables in this analysis come from data released from the National Venture Capital Association (NVCA), a public policy organization composed of more than 450 member venture capital firms that publishes fundraising, investment and other data. The dataset used in this study provides the quarterly value of venture capital investments per stage of development (seed, early stage, expansion, late stage) from Q2 1985 to Q3 2016. These values have been converted to real 2016 dollars. The number of observations of the dependent variables is limited, as venture capital is by nature long-term investment, making monthly or more frequent measurements of investment data less illustrative than equivalent measurements of macroeconomic or financial market conditions. In addition, the fast-growing and relative youth of the venture capital industry has limited the amount of historical data available.

Figure 1

Venture Capital Invested by Stage per Year



4.2 Summary Statistics

Table 1

Variable	Mean	St. Dev.	Min	Max
Venture Capital Investment Variables				
Seed	383.8	275.8	81.2	1742.3
Early	1772.8	1895.5	173.8	10005.6
Expansion	3298.8	4040.3	373.9	23148
Late	1861.1	1524.6	101.1	6314.1
Total	7316.5	7278.5	898.1	40457.4
Macroeconomic Variables				
Real GDP	12213.2	2793.5	7537.9	16727.0
Federal Funds Rate	3.8%	2.8%	0.1%	9.7%
Unemployment Rate	6.1%	1.5%	3.9%	9.9%
Industrial Production	85.5	16.3	56.8	106.3
Corporate Profits	1361.6	581.8	573.1	2327.2
Equity Market Variables				
Nasdaq	1882.0	1314.9	286.2	5168.9
Number of IPOs	59.1	47.1	1.0	202.0
Average First-Day Return	48.1%	50.9%	-11.0%	291.2%
Credit Market Variables				
Ten Year Treasury Yield	5.3%	2.3%	1.6%	10.8%
Investment Grade Credit Spread	2.8%	1.5%	-0.1%	7.5%

3.3 Independent Variables

The independent variables are collected from the Federal Reserve Economic Database (FRED), published by the research division of the Federal Reserve Bank of St. Louis, as well as the online financial market and economic database, Quandl.

3.3.1 Macroeconomic Variables

Gross Domestic Product

- The monetary value of the goods and services produced by labor and property located in the United States, calculated on an annualized basis. This metric is often used as a broad measurement of the overall economic activity, including all private consumption, domestic investment, government expenditures and net exports. GDP is also used as a measurement of productivity in an economy. The real GDP data released by FRED is inflation-adjusted in 2009 dollars.

Federal Funds Rate

- The interest rate at which depository institutions such as banks and credit unions borrow and lend funds held at the Federal Reserve to each other overnight. This rate is one of the most widely impactful determinants and metrics of the broader economy, since it affects monetary and financial conditions that in turn have influence on employment, economic growth and inflation. The Federal Open Market Committee (FOMC) sets a target for this rate, which is responsive to greater economic conditions. That is, as the economy strengthens and inflation poses more risk than unemployment, the FOMC raises the target Federal Funds Rate, and when the economy needs stimulation such as during and after an economic or financial downturn, the Fed decreases its target rate. In this way, the Federal Funds Rate is reflective of the macroeconomic environment, while simultaneously influencing the economic and capital market conditions.

Unemployment Rate

- The percentage of the labor force that is jobless. Generally, the unemployment rate is a indicator of changing economic conditions; as the economy strengthens and economic activity increases, the unemployment rate decreases, and vice versa.

Industrial Production Index

- The measurement of the real output for all facilities located in the United States manufacturing, mining, and electric and gas utilities, measuring the raw volume of goods produced. This rate is often used as a depiction of productivity, and is another perspective of greater economic activity. In the wake of the financial crisis, although GDP was relatively quick to match pre-crisis levels, industrial production was much slower to rebound as the private sector was selling off existing inventory rather than producing new stock.

Corporate Earnings

- An economic indicator that depicts the net income of corporations in the National Income and Product Accounts. This measurement depicts the cumulative profitability of U.S. businesses and is reflective of general economic activity.

3.3.2 Equity Market Variables

Nasdaq Composite Index

- A market-capitalization weighted index of the approximately 3,000 companies listed on the technology-heavy Nasdaq stock exchange. Many VC-backed companies are brought through an initial public offering on the Nasdaq exchange.

Number of Initial Public Offerings

- Number of initial public offerings (excludes penny stocks, REITS, closed-end funds, acquisition companies, American depositary receipts, limited partnerships, banks and S&Ls).

Average First-Day Return of Initial Public Offering

- Average percent change in stock price of the previously described IPOs on the first day of trading. This metric represents investor demand for private, often VC-backed companies when they become available for public purchase.

3.3.3 Credit Market Variables

10-Year Treasury Yield

- The yield of the 10-year Treasury Security, a debt obligation issued by the U.S. government that matures in 10 years. The 10-year Treasury pays a fixed rate of interest to bond holders every six months, as well as the face value at maturity. The yield of this security is the percentage return on investment from purchasing a 10-Year Treasury. This yield changes based on the interest rate at which the bond is issued, as well as the price at which it is bought. These bonds are often considered to be the risk-free rate of return.

Investment Grade Yield Spread

- The difference between AAA-rated corporate bond yields and the risk free yield (10-Year Treasury). This figure represents the yield premium investors require to hold AAA-rated investment grade corporate debt, to compensate for the low but additional risk of holding these securities rather than the risk-free 10-Year Treasury Note.

5 Empirical Specification

5.1 Ordinary Least Squares Regression Model

The OLS Model is composed of three explanatory variable vectors outlined below.

OLS Regression Model

$$Investment_{t,stage} = \alpha + \overrightarrow{\beta_1}\overrightarrow{Macro} + \overrightarrow{\beta_2}\overrightarrow{Equity} + \overrightarrow{\beta_1}\overrightarrow{Credit} + \varepsilon \quad (1)$$

Macroeconomic Vector

$$\overrightarrow{Macro} = \begin{pmatrix} GDP_t \\ IndProduction_t \\ FedFunds_t \\ UnemploymentRate_t \\ CorpProfit_t \end{pmatrix} \quad (2)$$

Equity Market Vector

$$\overrightarrow{Equity} = \begin{pmatrix} Nasdaq_t \\ NumberIPO_t \\ ReturnIPO_t \end{pmatrix} \quad (3)$$

Credit Market Vector

$$\overrightarrow{Credit} = \begin{pmatrix} 10YrTbill_t \\ IGSpread_t \end{pmatrix} \quad (4)$$

The general equilibrium nature of the economy and financial markets results in high correlations between many variables used in this study to measure various attributes of the macroeconomic environment and capital markets. Though this does not change the theoretical basis that justifies the impact each variable has on VC investment, it does limit the ability to test each variable in the final OLS regression model, due to issues of multicollinearity and overspecification bias. For example, industrial production and real corporate profits have correlations with real gross domestic product of .9653 and .8928, respectively. The Nasdaq Composite Index is also highly correlated (.8724) with real GDP, and therefore is dropped in the final benchmark model. The capital market variables that do not cause collinearity issues include volatility, number and first-day return of IPOs, and investment grade yield spreads, and each variable is accordingly included in the final benchmark model. Analyses of the individual impact each variable has on total VC investment, including collinear variables, are included in Appendices A, B and C. Log transformations were applied to venture capital investment, GDP and the number of IPOs per quarter in order to account for skew, outliers and large differences in scale between variables. The final empirical strategy for this analysis is outlined in Equation 5.

Final Benchmark Regression

$$Investment_{t,stage} = \alpha + \beta_1 GDP_t + \beta_2 FedFunds_t + \beta_3 UnemploymentRate_t + \beta_4 NumberIPO_t + \beta_5 ReturnIPO_t + \beta_6 InvGradeSpread_t + \varepsilon \quad (5)$$

5.2 Category Variables with Interaction Terms

5.2 Category Variables with Interaction Terms

Empirical papers studying attributes of private equity investments are often limited in their number of observations due to relatively recent development of this investment class. Because a regulatory change in 1979 catalyzed the development of venture capital as a scalable investment strategy, a maximum of approximately 38 years of data exists on the subject in 2017. This industry youth is coupled with the long-term nature of the investment strategy, limiting the availability and usefulness of frequent observations. Previous studies on venture capital often cite less than 100 observations due to these data frequency limitations. In order to counteract this, a second empirical strategy is included in this study pools each stage of VC investment, increasing the number of observations to 480, allowing this model to generate a more robust estimation. This model adds 3 VC stage dummies with interaction terms to identify the intercept and slope impact of GDP and first day IPO return on each stage of VC investment. These variables are chosen because they have two of the more significant relationships with each stage of investment on both a statistical and theoretical basis. This empirical strategy expands on the previous section's analysis and should provide a more robust result given the increase in observations.

Interaction Model (GDP Example)

$$Investment_{t,stage} = \alpha + \beta_1 GDP_t + \ldots + \beta_2 earlydummy_t + \beta_3 earlydummy_t * GDP_t + \beta_4 expansiondummy_t + \beta_5 expansiondummy_t * GDP_t + \beta_6 latedummy_t + \beta_7 latedummy_t * GDP_t + \varepsilon \quad (6)$$

6 Results

6.1 Ordinary Least Squares Regression Model

Table 2 summarizes results of the five final regressions outlined in Equation 5.

Table 2

OLS Regression Per Stage of Development

LN(VC investment)	(1) Seed	(2) Early	(3) Expansion	(4) Late	(5) Total
LN(GDP)	1.689***	3.668***	2.252***	4.417***	3.031***
	(4.840)	(9.95)	(5.85)	(13.56)	(9.72)
Federal Funds Rate	0.196***	0.0546	-0.0353	0.0201	0.0151
	(6.03)	(1.59)	(-0.98)	(0.66)	(0.52)
Unemployment Rate	0.102*	-0.0862*	-0.264***	-0.165***	-0.174***
	(2.47)	(-1.98)	(-5.80)	(-4.28)	(-4.73)
LN(Number of IPOs)	0.293***	0.114*	0.0715	0.0780	0.0980*
	(6.01)	(2.22)	(1.33)	(1.72)	(2.25)
First Day Return of IPOs	0.363***	0.472***	0.462***	0.222**	0.382***
	(4.23)	(5.20)	(4.87)	(2.76)	(4.96)
Investment Grade Yield Spread	-0.551***	-0.338***	-0.334***	-0.346***	-0.353***
	(-6.97)	(-4.05)	(-3.83)	(-4.69)	(-5.00)
Constant	-13.37***	-28.17***	-12.63**	-34.29***	-19.91***
	(-3.76)	(-7.50)	(-3.22)	(-10.34)	(-6.27)
Observations	120	120	120	120	120
R^2	0.6	0.824	0.781	0.898	0.851
Adjusted R^2	0.579	0.815	0.769	0.893	0.843
F-statistic	28.25	88.4	67.17	166.5	107.8
Root Mean Squared Error	0.407	0.43	0.449	0.38	0.364

t-statistics in parentheses.

* Significant at the 5% confidence level.

** Significant at the 1% confidence level.

*** Significant at the .1% confidence level

VC Investment, GDP and # IPOs in natural logarithm.

Real GDP has a significant, positive relationship with venture capital investment at all stages of development. This is consistent with the theory that increased economic activity is stimulative for both supply of venture funds that are able to achieve higher rates of return during periods of increased economic activity, output and production. It also supports the idea that entrepreneurs demand a greater amount of venture funding to pursue potentially profitable endeavors during such periods. The federal funds rate does not have a statistically significant relationship with total venture capital investment, although it is positively associated with seed stage investment. This outcome can be explained by the fact that the federal funds rate target is held constant for long periods of time when VC investment changes every quarter. Although this rate is set by the Federal Reserve and theoretically should reflect economic conditions, it does not move frequently enough to be correlated with such environmental changes over the past 30 years. Unemployment was shown to have a significant inverse correlation with VC investment in the early, expansion and late stages, as well as with aggregate investment levels. This supports the theory that the unemployment rate is a strong indicator of greater economic health and confidence by both investors and entrepreneurs. When the economy is strengthening and the unemployment rate falls, supply and demand of venture capital funding rise.

The theoretical methodology delineates the importance of public equity markets such as the Nasdaq Exchange for providing an exit channel to venture capitalists. Though the value of the Nasdaq Composite Index could not be included in the regression to do collinearity with GDP, the number of IPOs per quarter and the average first day return of IPOs are included in the analysis. The number of IPOs is only significant for seed, early and total VC investment levels. One explanation for this outcome is that though broad IPO activity is heavily influenced by conditions in the economy and capital markets, the number of IPOs during any given quarter

may be somewhat arbitrary. This means that even though venture capitalists consider IPO activity when considering their investment strategy, the quarterly amount of IPOs may be less relevant than other factors. One such factor may be public investor confidence and appetite for owning private businesses, a sentiment gauged through the return of securities on their first day of public trading. This idea of confidence is also evidenced by the positive, significant relationship of first day initial public offering returns and VC investment. This variable shows the readiness of market participants to buy into private, often VC-backed, startups and businesses that go through an IPO. VC investors do not completely liquidate their stake in a business when they sell shares through an IPO. Therefore, as IPO returns fall, VCs become less confident in their ability to generate a high rate of return and become more parsimonious in their deployment of funds, and vice versa. This outcome provides evidence that private equity investors consider public market appetite and confidence when developing strategy for venture investing.

Credit conditions are infrequently considered to be a determinant of venture capital investment due to the lack of leverage in venture investments and consequently few studies exist analyzing the relationship between the credit markets and venture capital. This analysis attempts to build an indirect connection between credit markets and VC investment through the confounding factors of market sentiment and investor confidence. On a theoretical basis, there are a number of relationships that are likely to exist given the significance of the credit markets in global economic health, investor confidence, and the cost of capital. The final model includes only the investment grade yield spread due to collinearity restrictions. Appendix C addresses the individual impact of each credit variable on total venture capital investment. Yield spreads indicate the risk premium investors demand to hold interest-paying securities above the risk-free rate. These spreads decrease when investor are optimistic and risk tolerant, and increase when

investors are bearish and risk averse. Therefore, the significant negative coefficient for investment grade yield spreads supports is consistent with the theory that as public market participants gain confidence and risk appetite, causing risk premiums to fall, venture investors also become more confident in their ability to generate a return on investment. Therefore, institutional asset managers commit greater sums of capital to high-risk strategies like venture capital, and venture capitalists become more generous in their deployment of those funds.

Table 2 also demonstrates the variance between stages of VC investment that can be attributed to the independent variables. One of the more interesting findings is the difference in magnitude of each GDP coefficient in early, expansion and late stage regressions. Early and late stage investments were the most substantially impacted by changes in GDP with coefficients of 3.338*** and 4.417***, respectively, while expansion investments had a coefficient of 2.252***. We can see this pattern is consistent when GDP is replaced with its collinear counterpart, the Nasdaq Composite Index, as early and late stage coefficients are 1.284*** and 1.316***, respectively, and the expansion coefficient is .885***. The strength and direction of the monotonic relationship between these two variables provides evidence of Nasdaq's high rank order to GDP. This outcome is driven by the changes in venture capitalists' investment process and strategies during times of economic expansion. When the economy is healthy and output is strong, stock market indices gain in value as well. As equity prices rise, venture capitalists seek to take advantage lofty valuations in public markets by increasing their investments in late stage companies, which they hope to sell for a high price and relatively quick profit due to current positive market sentiment. Venture capitalists are equally opportunistic during periods of positive economic activity, as they begin to make investments in riskier but potentially more

lucrative earlier stage investments with newfound confidence that they will be able to grow into a healthy business and become substantially more valuable.

Another interesting outcome of this analysis is the unique and unexpected coefficient characteristics in seed stage investing. For example, the federal funds rate and unemployment both have correlation signs that oppose the theoretical assumptions of this paper, as well as the observed outcomes of all early, expansion, late stage and total investment. One justification of this outcome is that the amount of capital that is allocated to seed funding is much smaller and more consistent than other types of investment. A small number of firms focus on seed stage investments, and larger firms that have the ability to allocate more or less capital to one particular stage of investment will remained disciplined when it comes to the highest risk seed stage investments. In addition, because of the low valuations and respective investment amounts of seed stage companies, changes in the amount of seed investments made over time are likely more random and impacted by outliers. As shown in the data section of this paper, seed stage investments have a median value of $383.3 million with a standard deviation of 275.8, approximately one fifth the size of the early and late stage investments. For these reasons, it is possible that a number of the results related to seed stage investments are unfounded by any established theory and ultimately a product of spurious correlation.

6.2 Category Variables with Interaction Terms

Table 3 summarizes results of the category variable regression model outlined in Equation 6. The regressions include the same explanatory variables as the previous model, in addition to dummy variables and interaction terms for each stage of investment. The coefficients of the interaction terms delineate the marginal change in slope caused interacted variable at each

stage of investment relative to the seed stage benchmark. Three regressions are included in Table 3, each interacting one variable from the macroeconomic, equity and capital market vectors: GDP, average first day return on IPOs, and investment grade yield spread. One additional regression is used to confirm the results of the Nasdaq Composite Index and its high first rank to GDP. Table 4 contains the coefficients from each stage after the marginal coefficients are added to the seed stage benchmark.

Table 3

Category Variables with Interaction Terms

Interaction Terms	(1) GDP	(2) IPO Return	(3) IGSpread	(4) Nasdaq
Gross Domestic Product	1.426***	3.985***	3.985***	
	(6.07)	(16.41)	(16.71)	
Nasdaq Composite Index				0.578***
				(9.01)
Federal Funds Rate	0.0556**	0.0557*	0.0557*	0.0840***
	(3.24)	(2.46)	(2.51)	(5.29)
Unemployment Rate	-0.0879***	0.0887**	0.0887**	-0.0375
	(-4.05)	(-3.09)	(-3.15)	(-1.80)
Number of IPOs	0.148***	0.150***	0.150***	0.0108
	(5.78)	(4.43)	(4.51)	(0.46)
First Day Return of IPOs	0.387***	0.192	0.379***	-0.013
	(8.54)	(1.81)	(6.47)	(-0.28)
Investment Grade Yield Spread	-0.392***	0.393***	-0.115	-0.356***
	(-9.40)	(-7.15)	(-1.31)	(-9.09)
Early Dummy	-29.47***	1.027***	0.723***	-5.503***
	(-13.22)	-10.29	(4.73)	(-11.79)
Expansion Dummy	-22.95***	1.689***	1.571***	-3.718***
	(-10.29)	(16.93)	(10.29)	(-7.97)
Late Dummy	-39.10***	1.133***	0.572***	-6.932***
	(-17.53)	(11.29)	(3.75)	(-14.85)
Early Interaction Term	3.271***	0.287*	-0.367**	0.928***
	(13.74)	(2.00)	(-3.27)	(14.37)
Expansion Interaction Term	2.646***	0.313*	-0.222*	0.774***
	(11.12)	(2.19)	(-1.97)	(11.98)
Late Interaction Term	4.303***	0.148	0.526***	1.133***
	(18.08)	(1.03)	(-4.68)	(17.54)
Constant	-8.835***	32.72***	32.47***	0.69
	(-3.81)	(-13.22)	(-13.36)	(1.20)
Observations	480	480	480	480
R^2	0.892	0.813	0.819	0.9
Adjusted R^2	0.89	0.808	0.815	0.898
F-Statistics	322.7	168.8	176.6	351.8
Root Mean Squared Error	0.429	0.566	0.556	0.413

t-statistics in parentheses.

* Significant at the 5% confidence level.

** Significant at the 1% confidence level.

*** Significant at the .1% confidence level

VC Investment, GDP, Nasdaq, and # IPOs in natural logarithm.

Table 4

Interaction Term + Benchmark Coefficients

	(1) Seed	(2) Early	(3) Expansion	(4) Late
GDP	1.426***	4.697***	4.072***	5.729***
IPO Return	0.192***	0.479*	0.505*	0.340
IG Yield Spread	-0.115	-0.482**	-0.337*	-0.641***
Nasdaq	0.578***	1.506***	1.352***	1.711***

* Significant at the 5% confidence level.
** Significant at the 1% confidence level.
*** Significant at the .1% confidence level

As expected, there is variance between the magnitudes of each coefficient generated by the interaction terms in the category variable model. The signs and magnitudes of each coefficient relative to each stage have stayed consistent between models. The category variable model was also used to perform analysis on the impact of the Nasdaq on VC investment. As expected, the values of each coefficient vary from its collinear counterpart, but the relative differences between stages of investment remain identical.

6.3 Limitations

The most restrictive aspect to an empirical study on venture capital, and more generally private equity, is the long-term time horizon of such investments. Frequent measurements of fundraising and investment are less significant than long-term trends, however when analyzing the impact of economic time series data, smaller movements remain important. That is the most fundamental limitation of both this study as well as any other study looking to relate macroeconomic and capital market data to a private equity investment.

In addition, venture capital is a relatively new industry. Although this presents an exciting opportunity to make a relevant contribution to a nascent field of study, the amount of available data is limited. One advantage of this study is my dataset, which dates begins ten years prior to and ends five years after the previous literature and data on VC. This doubles the size of the dataset, as the industry, in its modern form, is only approximately 30 years old.

There are also empirical concerns due to collinearity between variables vectors in each the final benchmark model *(5.1.4)*. Because much of the independent data is highly correlated, it is difficult to make independent measures of significance. These independent variables also impact supply and demand concurrently, which presents a simultaneous equations issue where the equilibrium of VC investment is determined simultaneously by each variable, causing econometric problems of correlation between independent variables and disturbances in the regression outcomes. Lastly, it is difficult to establish determinacy in this analysis because of the presence of a number of confounding factors that prevent any individual explanatory variable from truly explaining changes in venture capital investment. The highest degree of certainty is that a relationship exists, however causation is a more elusive conclusion.

7 Conclusion

This thesis was written with the intent of contributing to the literature that studies the determinants of venture capital. It does so through econometric techniques that elucidate the individual impact of particular macroeconomic, equity and credit market conditions have on venture capital investment at each stage of portfolio company development. This study also attempts to show distinction between stages of investment, and determine how particular variables impact stages differently. The second empirical strategy allows for greater power of estimation by increasing the number of observations included in attempt to provide one of the more robust analyses on the determinants of venture capital to date.

One of the most important theoretical considerations of this thesis is the way in which macroeconomic and capital market conditions impact venture capital returns. Some variables, specifically the broader macroeconomic conditions such as GDP and unemployment, are reflective of a greater conditions that, though may be highly correlated with venture investing, are not necessarily direct determinants. For example, both Nasdaq and real GDP are highly positively correlated with all stages of VC investment, however the reason behind these correlations is different. Nasdaq levels are something that a venture investor will look at directly when considering their investment strategy. It's direct role in the liquidation and monetization of investments creates a requirement for strong public equity conditions in order to be confident in a venture investment's ability to generate a suitable return on investment. However, while GDP reflects economic activity and productivity, which may impact venture investments in a number of ways including profitability and value, these are not as directly influential of venture investment. In this way, closely related variables and outcomes of this analysis are open to thoughtful consideration about the true connection they share with venture capital investment.

The most consistent finding in this study is that there are a number of conditions that have strong statistical relationships with venture capital investment. Using these findings to prove causality, in one direction or another is a more complex, potentially impossible endeavor. More generally, each of the conditions studied in this report show that as economic conditions strengthen, venture capital output increases. More telling, the early and late stages of investment have the greatest degree of sensitivity to macroeconomic and capital market conditions. Although these relationships have been shown to statistically exist, there are a number of limitations that prevent the highest degree of certainty or the establishment of causality between such conditions and investment.

References

Black, B. S., & Gilson, R. J. (1998). Venture capital and the structure of capital markets: Banks versus stock markets. *Journal of Financial Economics*, 47, 243–277. doi:10.2139/ssrn.46909

Croce, A., Grilli, L., & Murtinu, S. (2013). Venture capital enters academia: An analysis of university-managed funds. The Journal of Technology Transfer, 39(5), 688–715. doi:10.1007/s10961-013-9317-8

Dobbs, R., Koller, T., Lund, S., Ramaswamy, S., Harris, J., Krishnan, M., & Kauffman, D. (2016). Diminishing Returns: Why Investors May Need To Lower Their Expectations. Mckinsey Global Institute

Durham, J. B. (2013). More on U.S. Treasury Term Premiums: Spot and Expected Measures. *SSRN Electronic Journal*. doi:10.2139/ssrn.2377405

Engen, Eric M., Thomas Laubach, and David Reifschneider (2015). "The Macroeconomic Effects of the Federal Reserve's Unconventional Monetary Policies," Finance and Economics Discussion Series 2015-005. Washington: Board of Governors of the Federal Reserve System, http://dx.doi.org/10.17016/FEDS.2015.005.

Füss, R., & Schweizer, D. (2011). Short and long-term interactions between venture capital returns and the macroeconomy: Evidence for the United States. Review of Quantitative Finance and Accounting, 38(3), 391–410. doi:10.1007/s11156-011-0233-4

Gompers, P., & Lerner, J. (2001). The Venture Capital Revolution. The Journal of Economic Perspectives, 15(2), 145-168.

Gompers, P., Kovner, A., Lerner, J., & Scharfstein, D. (2008). Venture capital investment cycles: The impact of public markets. Journal of Financial Economics, 87(1), 1–23. doi:10.1016/j.jfineco.2006.12.002

Kaplan, S. N., & Strömberg, P. (2004). Characteristics, contracts, and actions: Evidence from venture capitalist analyses. The Journal of Finance, 59(5), 2177–2210. doi:10.1111/j.1540-6261.2004.00696.x

Kortum, S., & Lerner, J. (2000). Assessing the contribution of venture capital to innovation. The RAND Journal of Economics, 31(4), 674. doi:10.2307/2696354

Labonte, M. (2016). Monetary Policy and the Federal Reserve: Current Policy and Conditions. *Congressional Research Service*

Labonte, M., & Makinen, G. E. (2008). Federal Reserve Interest Rate Changes 2001-2008. *Congressional Research Service*

Nahata, R. (2008). Venture capital reputation and investment performance☆. Journal of Financial Economics, 90(2), 127–151. doi:10.1016/j.jfineco.2007.11.008

Ning, Y., Wang, W., & Yu, B. (2014). The driving forces of venture capital investments. Small Business Economics, 44(2), 315–344. doi:10.1007/s11187-014-9591-3

Poterba, J. M. (1989). Venture Capital and Capital Gains Taxation. Tax Policy and the Economy, 3, 47-67. doi:10.1086/tpe.3.20061783

Puri, M., & Zarutskie, R. (2012). On the life cycle dynamics of venture-capital- and non-venture-capital-financed firms. The Journal of Finance, 67(6), 2247–2293. doi:10.1111/j.1540-6261.2012.01786.x

Strebulaev, I. A., & Gornall, W. (2015) How Much Does Venture Capital Drive the U.S. Economy? Insights by Stanford Business

Suliman, Rubi. (2015) Venture Capital *PWC MoneyTree* Retrieved from *http://www.pwc.com/il/en/venture-capital-israel/moneytree-report-definitions.html*

Tang, D. Y., & Yan, H. (2010). Market conditions, default risk and credit spreads. *Journal of Banking & Finance*, *34*(4), 743–753. doi:10.1016/j.jbankfin.2009.05.018

Zider, B. (1998). How Venture Capital Works. Harvard Business Review

Appendix A

Macroeconomic Individual Vector Regression

	(1)	(2)	(3)	(4)	(5)
	Total VC Investment				
Gross Domestic Product	3.162*** (15.68)				
Federal Funds Rate		-0.163*** (-6.31)			
Unemployment Rate			-0.190*** (-3.49)		
Industrial Production Index				4.030*** (21.01)	
Corporate Profits					1.398*** (9.67)
Constant	-21.17*** (-11.19)	9.104*** (75.4)	9.650*** (28.3)	4.200*** (-11.00)	7.176*** (-1.42)
Observations	126	126	126	126	126
R^2	0.665	0.243	0.089	0.781	0.430
Adjusted R^2	0.662	0.237	0.082	0.779	0.425
F-statistic	246.0	39.83	12.17	441.5	93.57
Root Mean Squared Error	0.541	0.812	0.891	0.437	0.705

t-statistics in parentheses. VC investment, GDP, IP and CP in natural logarithm.

* Significant at the 5% confidence level.

** Significant at the 1% confidence level.

*** Significant at the .1% confidence level

Appendix B

Equity Market Individual Vector Regression

	(1)	(2)	(3)
	Total VC Investment		
Nasdaq Composite Index	1.007***		
	(23.61)		
Number of IPOs		-0.113	
		(-1.44)	
Return on IPOs			0.816***
			(5.5)
Constant	1.201***	8.854***	8.045***
	(3.9)	(29.5)	(77.7)
Observations	126	120	120
R^2	0.818	0.017	0.205
Adjusted R^2	0.817	0.009	0.198
F-statistic	557.3	2.083	30.37
Root Mean Squared Error	0.398	0.915	0.823

t-statistics in parentheses. VC investment, Nasdaq and # IPOs in natural logarithm

* Significant at the 5% confidence level.

** Significant at the 1% confidence level.

*** Significant at the .1% confidence level

Appendix C

Equity Market Individual Vector Regression

	(1)	(2)
	Total VC Investment	
10-Year Treasury Yield	-0.290***	
	(-11.07)	
Investment Grade Yield Spread		-0.576***
		(-4.70)
Constant	10.04***	7.796***
	(66.1)	(46.7)
Observations	126	126
R^2	0.497	0.151
Adjusted R^2	0.493	0.145
F-statistic	122.5	22.12
Root Mean Square Error	0.662	0.86

t-statistics in parentheses. VC investment in natural logarithm..

* Significant at the 5% confidence level.

** Significant at the 1% confidence level.

*** Significant at the .1% confidence level

Appendix D

Independent Variable Correlation Matrix

	GDP	FF	UER	IP	CP	Nasdaq	# IPO	RIPO	10YT	Spread
GDP	1.00									
FedFunds	**(0.81)**	1.00								
Unemployment	0.07	(0.46)	1.00							
IndProduction	**0.96**	**(0.70)**	(0.12)	1.00						
CorpProfit	**0.92**	**(0.72)**	0.15	**0.85**	1.00					
Nasdaq	**0.87**	**(0.64)**	(0.12)	**0.86**	**0.79**	1.00				
# IPO	(0.40)	0.33	(0.29)	(0.32)	(0.35)	(0.16)	1.00			
Return IPO	0.05	0.11	(0.34)	0.24	(0.05)	0.43	0.29	1.00		
10Y Treasury	**(0.94)**	**0.90**	(0.21)	**(0.88)**	**(0.85)**	**(0.80)**	0.33	(0.08)	1.00	
IGSpread	(0.42)	0.41	(0.30)	(0.35)	(0.21)	(0.29)	0.42	0.00	0.44	1.00

Highest correlations are in bold. Industrial Production, Corporate Profit, Nasdaq and 10Y Treasury Yield removed from Model 1 – Final Benchmark Regression due to collinearity.