The VC Market and its Reactions to Macroeconomic Fluctuations

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Abstract

In our paper, we seek to investigate how VC investor behavior has correlated with typical investor behavior and in what ways VC professionals may differ when evaluating an investment decision compared to that of a traditional investor. In doing this, we first leverage relevant literature on Venture Capital and its elements, before introducing a simple macroeconomic model of making investment decisions that applies to all fields of investment. We solve the model and evaluate its predictions in terms of how investment fluctuates with different exogenous variables like interest rate and tax rate. Following this, we leverage historical data on Venture Capital transactions to understand how the VC market has corresponded with our model assumptions empirically.

In our work, we find that post series A Venture Capital investing seems to strongly follow the predictions of the model, with metrics like average VC deal size and monthly number of VC deals falling with higher interest rates, higher corporate tax rates, and recessionary periods. Pre series A investing does not show any empirical correlation with elements like deal size and number of deals showing strong robustness to model parameters like interest rates and recessionary periods. It does however show strong negative correlation with higher corporate tax rate, where it is equally sensitive to interest rate increases as late-stage investments. We believe the results found in the paper speak to the general risk averseness found in early-stage VC, where deal sizes are small relative to an investor's portfolio, little leverage is used, and investor decisions are made more on qualitative judgements rather than quantitative ones, making the decisions more robust to tightening macroeconomic parameters.

All source code used to produce the below graphs and regressions can be found at `https://github.com/madsgroholdt/ES94-Final_Project`.

1 Introduction

Alternative investments, including venture capital, have evolved from a fringe group into a structured market driving the growth of numerous startups over the latest decades. As alternative financing methods have gained prominence it has become crucial to understand how VC markets differ from traditional investor markets and how they react to various exogenous shifts in the macroeconomic environment they find themselves in. While there are obvious benefits to the growth of the venture capital market, there is a need to model the effect of various exogenous shifts. With the increasing frequency of large macroeconomic shocks in the latest years, combined with the rising presence of venture capital, it has become more important to understand how the VC market corresponds to various macro changes. Because of this, we seek to understand how the venture capital investment behavior compares to a traditional model of investment.

Prior to our analysis, it is critical to understand the goal and investment process of traditional venture capital. Venture capitalists typically invest in the early to middle stages of a company's innovation cycle, helping to commercialize innovations and build a strong foundation for future profitability. In How Venture Capital Works, Bob Zider explains that "more than 80% of the money invested by venture capitalists goes into building the infrastructure required to grow business"(1). Furthermore, he emphasizes that, "venture money is not long-term money. The idea is to invest in a company's balance sheet and infrastructure until it reaches a sufficient size and credibility so that it can be sold to a corporation or so that the institutional public-equity markets can step in and provide liquidity". These insights may hint at VC investors being less sensitive to macro factors, as they take a more active role in their investments through operational improvements and management assistance. Because they act less as pure financial engineers, they may see a lower downside to tighter macroeconomic environments because aspects like human capital make up more of their investment decision.

Venture capitalists invest in promising industries rather than individual companies. Their

high level of control in daily operations and industry focus suggest their would be differences when responding to economic shifts compared to traditional investors. Tyebjee and Bruno outline five sequential steps in the venture capital investment process: deal origination, screening, evaluation, deal structuring, and post-investment activities. This can essentially be narrowed down to potential investments first being identified, and then considered. Next, these prospects are narrowed down to a few promising opportunities for further analysis. Then investors assess risk and return of each opportunity and make the investment decision. Once the decision is made, they negotiate terms, such as the deal price and covenants (which limit investor risk). After the investment is made, venture capitalists support the company in areas like strategic planning and locating expansion financing. This process has more steps than one of, for example, a public equities investor, where post-investment activity likely will be close to 0.

VC focuses on the middle part of the industry S-curve, avoiding both the early stages, where market needs are unknown, and the later stages, when competitors arise and growth rates are substantially slowed (2). If the VC is able to exit the company before it peaks, they can reap extraordinary returns with very little risk. However, despite the benefits, the track record and reputation of a firm is what leads institutions to invest in a fund. These institutions are typically composed of pension funds, financial firms, insurance companies, and/or university endowments. As the VC market matures, it has expanded to cover a broader spectrum of investment stages and deal sizes, diversifying beyond early-stage ventures.

For the following paper, we intend to discuss the literature surrounding VC investment and what factors said literature has shown to be likely to alter VC investment behavior. We will then present a model of traditional investment behavior that we will use to predict how investment activity changes to various macro factors, before evaluating the model's predictions empirically through a large dataset of historical VC deals. In our empirical analysis, we seek to contrast early VC investor behavior with later stage venture capitalists (who are investing in an already existing infrastructure). To test behavioral differences, we

compare investor behavior and its relation to changes in interest rate or tax rate.

2 Literature Review

In our paper, we seek to understand how recessions, high tax rates, and high interest rates affect investment behavior. More specifically, we aim to compare general investment behavior with VC behavior to hopefully shed light on any particular deviations between the two.

Current literature surrounding the VC market financing in times of financial crisis finds a decrease in the amount of funds raised (3). However, there are conflicting findings when considering which funding rounds were more impacted. While some literature indicates that there were larger impacts in later funding rounds, it seems more intuitive (and more empirically supported) that the decrease generally is stronger for the first funding round than later funding rounds (4). Nonetheless, there is an overall decrease in the number of funding rounds with the amount raised per funding round decreasing (4). Furthermore, when considering the 2008 financial crisis, literature finds that VCs allocate more funds to core startups especially in early-stage investments. Essentially, VCs are concentrating on their core sectors during liquidity supply shocks, taking advantage of their sector-specific expertise and experience. Empirical findings show that experienced VCs concentrate investment in their core sectors during times of crisis.(5) Additionally, these startups (core sector) tend to outperform all other startups, particularly at the early stage where the screening and monitoring skills of experienced VCs are most useful. (5).

Considering the performance implications, startups in the core sectors of experienced VCs have higher chances of successful exits than non-core startups or startups funded by less-experienced VCs. (5) While the vast majority of VCs are tightening their scope to core sectors, not all VCs are able to benefit from the reduced pipeline, with more experienced VCs possessing larger endowments of capital, which enables them to use this narrowed scope to dedicate more resources to core startups that are likely to thrive from the increased focus.(5)

However, less-experienced VCs lack the expertise to derive the same benefits from focusing on core sectors. As a result they are more likely to hold a diversified portfolio, similar to a less-informed individual investor in the stock market (5). All in all, during times of crisis, experienced VCs become more conservative with their investment allocation and spend more time focusing on companies within their field of expertise. While this makes sense intuitively, the analysis was conducted in 2008 and there is a need to investigate how behaviors have changed as the VC market has matured.

Moreover, general investment during the financial crisis behaved as expected. There was a drop in real private investment of 21.1% over the period covering the Great Recession(6). While the other two private investment categories rebounded, residential investment did not recover. The changes to private investment were not surprising, and literature surrounding individual investor behavior indicate that there are substantial swings in trading and risk taking behavior during the crisis that are driven by changes in investor perceptions. These perceptions fluctuate throughout the various stages of the recession. Towards the end of the crisis, return expectations, risk tolerance, and risk perceptions recover (7). However, one notable finding is that individual investors continue their trading habits and do not derisk their investment portfolios during the crisis (7). Essentially, these investors do not try to reduce risk by shifting from risky investments to cash. Instead, they use the depressed prices as a chance to enter the stock market (7). Contrasting with VC, general investment does not follow the same tightening and de risking behavior that VCs implement during times of crisis.

In order to effectively analyze the effect that various exogenous shifts have on VC investment behavior, we delved into literature surrounding the effect of capital gains taxes on general and VC investment behavior. Regarding general investment behavior, current literature informs us that capital gains taxes reduce an investor's flexibility in taking advantage of security price fluctuations and switching to alternative investments. Despite this finding, the impact of capital gains taxes on investment decisions have been exaggerated in the minds

of many investors. (8). While the effect on general investment behavior is not as notable, literature on the VC effects posit that there are potential benefits to an increasing tax rate. In "The Capital Gains Tax: A Curse but Also a Blessing for Venture Capital Investment", the authors found that "higher capital gains tax rates lead to a reduction in the number of companies receiving their first investment and to a lower probability of receiving follow-up investment." (9).

Due to the reduction in the overall company number, the higher tax rates are correlated with more successful ventures. Essentially, higher capital gains tax rates are associated with a lower number of successful companies but increase the success probability of finance companies. This increase in success probability is likely to yield reputational benefits to the VC, which is a major determinant in the future success of the VC firm. Despite these potential benefits, in "Venture Capital and Capital Gains Taxation", author James Poterba investigates the presence of a significant link between taxation and venture capital activity. His findings suggest that organized venture capital industry growth in the last decade is not primarily driven by reduced taxes (10). While there were some relationships between capital gains tax rates and venture financing, the results were fuzzy and confounded by a number of other factors. However, the paper was published in 1989, which were the early stages of the VC market. Given the maturity of the VC market today, there is a need to extend his analysis to present time using more robust analysis tools which can provide more concrete evidence about the relationship.

Following our investigation into the effect of capital gains tax rates, the next logical step was to understand the current literature on VC and general investment reactions to changes in interest rates. Literature indicates that people in low interest rate conditions invest significantly more in risky assets than people in high interest rate conditions (11). Authors Lian, Ma, and Wang suggest that "when interest rates fall below the reference level, people experience discomfort, and become more willing to invest in risky assets to seek higher returns. The reference point can be shaped by what people have become used to over

past experiences" (11) The VC market differs from general investment behavior, especially in high interest rate environments. While there is little evidence directly relating interest rates to VC investment behavior, the effect of interest rates can be seen through the IPO's (which are the main exit mechanism for VCs).

In "The Determinant of Venture Capital Funding: Evidence across countries", Jeng emphasizes that the most attractive option to liquidate a fund is through an IPO (12). He goes further and attributes IPOs as the main force behind cyclical swings in venture capital. While there is clear evidence connecting IPOs and venture capital investment fluctuations, literature suggests that later stage venture capital investments respond strongly to different levels of IPOs across counties, but early-stage investments are unaffected (12). This reinforces the notion that the distinct stages of venture capital are fundamentally different.

Given the links between VC and IPOs, the relationship between IPOs and interest rates offers us insight into the potential connection between VC investment behavior and interest rates. Literature suggests that the rise in interest rates is expected to impact the IPO market significantly, as it could dampen investor appetite for equity, resulting in fewer IPOs (13). Therefore, there is expected to be an inverse relationship between VC investment and rising interest rates empirically. While the VC firm overall would suffer in high interest rate environments, there is a need for further research focusing on early stage venture capital investments. The lack of sufficient literature investigating the effects between the distinct stages of venture capital positions us to fill the gap in current VC literature.

3 Model of Investor Behavior

In formulating a model of investment behavior, we seek to make it as general as possible. Because our intention is to understand how VC investor behavior correlates with typical investment behavior this model is not intended to represent VC investment decisions, but rather allow for an understanding of the fundamental trade-offs involved in making an in-

vestment decision for any company or individual. The model draws on well-established macroeconomic theory about investment behavior and should mostly be familiar to those with experience from intermediate macroeconomics courses.

A similar model is often used to explain firm investment decisions regarding inventory, equipment, and human capital, but the idea of the model translates well over to an investor seeking to allocate proportions of a portfolio in an optimal way. Because our main objective not is to understand how investors (VC or not) evaluate the different investment vehicles they are presented with, but rather how their allocations to a given investment opportunity changes with macroeconomic context, our model can be made quite intuitive and much simpler than if we were to have a broad offering of investment opportunities at any given time.

3.1 Model Parameters and Variables

The model has the following exogenous variables

- $r \in [0, \infty]$: 1-period return on benchmark asset. Can be thought of as interest rate on fixed rate deposit. Assumed to be constant across the asset holding period of the model for mathematical simplicity in solving the model.

- $\tau_t \in [0, 1]$: Corporate tax rate in period t.

- $\delta_t \in [0, 1]$: One-period dilution rate of capital in period t. Represents dilution in the periods where the company brings in outside capital, but will be 0 in many periods empirically.

- $p_t^K > 0$: Price of purchasing an additional unit of capital for investment in period t. Can be thought of as share price in period t.

- $F(K_t)$: F is a function of the capital allocated to the company and represents the one-period profit on capital invested in the company. Assumed to be increasing ($F' > 0$)

and concave ($F'' < 0$).

Additionally to the above exogenous variables, the model has endogenous variables

- K_t: Total level of capital the investor has in the company in period t.
- I_t: Amount of new capital the investor commits to the company in period t.

Because our model represents a simplified version of a complicated process, we make a number of assumptions in designing it. These are as follows

- There are only two possible allocations for the investor. They can allocate capital to a company that generates F_K in profit from an additional unit of K, where K can be thought of as a single share in the company, making F_K the per-period profit per share. Alternatively, they can allocate capital to a benchmark asset generating 1 + r in return in a period.
- The investor has available capital to allocate to the two different assets, and has no source of income aside from the capital inflows from his investment allocations.
- The company returns all profits back to investors, meaning that K_{t-1} invested in period t - 1 will return $F(K_{t-1})$ in period t.
- The investor is risk neutral, and therefore has the objective of maximizing personal profits in any given period, with single-period profit defined as

$$\pi_t = F(K_{t-1}) - p_t^K I_t$$

  meaning that the investor maximizes the returns from capital already allocated to the company in previous periods minus additional capital invested in the current period.

- The investor's capital allocation in the company is subject to the following constraint

$$K_t = (1 - \delta_t)K_{t-1} + I_t$$

Where $(1-\delta)K_{t-1}$ is the investors diluted ownership from period $t-1$, and I_t represents new capital commitments made in period t.

With the above definitions and assumptions in mind, we can define the investors complete maximization problem as follows

$$\max_{K_t, I_t} \left\{ \sum_{s=t}^{t+T} \left(\frac{1}{1+r} \right)^{s-t} \left((1-\tau_s) F\left(K_{s-1}\right) - p_s^K I_s \right) \right\} \quad \text{s.t.} \quad K_t = (1-\delta_t) K_{t-1} + I_t \tag{1}$$

which means that an investor interested in allocating capital to a company over a total holding period of T years would maximize the sum of single-period profits, with their total period t capital stock in the company constrained to be equal to diluted previously committed capital as well as freshly committed capital.

3.2 Solving the Model

To solve the above-described model of investment behavior we can begin by setting up the investor's Lagrangian as follows

$$L(\{K, I\}_{s=t}^{t+T}) = \sum_{s=t}^{t+T} \left(\frac{1}{1+r} \right)^{s-t} \left((1-\tau) F\left(K_{s-1}\right) - p_s^K I_s - \lambda_s \left((1-\delta_s) K_{s-1} + I_s - K_s \right) \right) \tag{2}$$

which stems directly from the maximization problem defined in equation 1. Now we can proceed to take the FOCs of the above with respect to K_t and I_t. This yields

$$\frac{\partial L}{\partial K_t} : \frac{(1-\tau_t) F_K(K_t)}{1+r} + \frac{1}{1+r} \lambda_{t+1} (1-\delta_{t+1}) = \lambda_t \quad \text{and} \quad \frac{\partial L}{\partial I_t} : p_t^K = \lambda_t \tag{3}$$

Now, we can divide the two partials by one another to obtain

$$\frac{(1-\tau_t) F_K(K_t)}{1+r} + \frac{1}{1+r} p_{t+1}^K (1-\delta_{t+1}) = p_t^K$$

which we finally can rewrite to obtain the investor's intertemporal Euler equation of investment as

$$\frac{(1-\tau_t)F_K(K_t) + p^K_{t+1}(1-\delta_{t+1})}{p^K_t} = 1 + r \tag{4}$$

This shows that the trade-off an investor faces in any given period is that of investing money in the company at price p^K_t, to yield $(1-\tau)F_K$ from the company's profits, as well as have additional diluted capital in the company at price p^K_{t+1}, or they can place capital into the bank and earn an interest rate of r on the money.

3.3 Model Predictions

As can be seen from solving out the model in section 3.2, the culmination of the model is a intertemporal trade-off between allocating capital to the company as an investment or allocating money to a bank account returning the fixed interest rate r. In understanding how the allocation decisions vary with the various exogenous parameters in the model, we can move to taking comparative statics of equation 4.

Firstly, we can see how the trade-off between saving and allocating money to the company changes with the interest rate, r. As can be seen from equation 4, if r increases the right side increases in value. Since the only endogenous variable on the left-hand side is K_t, we have that the model predicts a higher interest rate will decrease the amount of capital the investor allocates to the company. This corresponds to empirical results regarding general investment behavior, where a strong inverse relationship has been seen between interest rate/benchmark asset return and investments into other assets.

Next, we can move to investigating how the results change with varying tax rates. This is difficult to see without knowing the form of F, so to understand the relationship we can make the assumption that $F(K) = K^\alpha$, with $\alpha \in [0, 1)$ to ensure decreasing marginal returns

which is typical for any production function. This would yield the following Euler equation

$$\frac{(1-\tau)\alpha K_t^{\alpha-1} + p_{t+1}^K(1-\delta)}{p_t^K} = 1 + r$$

Rewriting the above, we get to the expression

$$K_t = \left(\frac{\alpha(1-\tau)}{(1+r)p_t^K - p_{t+1}^K(1-\delta)}\right)^{\frac{1}{1-\alpha}} \tag{5}$$

Now we can clearly see that a higher tax rate, τ, would lead to lower levels of capital allocated to the company, as it only appears in the numerator of the expression with a negative sign. We can show this more clearly by taking the partial derivative of the above expression with respect to τ, which yields

$$\frac{\partial K_t}{\partial \tau} = \frac{1}{1-\alpha}\left(\frac{\alpha(1-\tau)}{(1+r)p_t^K - p_{t+1}^K(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}} \frac{-\alpha}{(1+r)p_t^K - p_{t+1}^K(1-\delta)} < 0$$

This clearly has to be negative since we know that $(1+r)p_t^K - p_{t+1}^K(1-\delta) > 0$ to ensure a non-negative capital allocation in equation 5, making the only negative element the $-\alpha$ in the third fraction, which will make the entire expression negative. This makes intuitive sense when one thinks about profits being taxed, since it creates a devalued upside to allocating capital to the company compared to the no-tax scenario. Additionally to making intuitive sense, this has been shown to be true empirically for general investments, with higher tax rates diverting investment away from the corporate sector.

4 Empirical Results

Now that we have established model predictions for investor behavior, we can move to our investigation of whether or not the Venture Capital market has followed these predictions in the past. The following section will first describe the various data sources we have used in

our analysis, before presenting results related to empirical interest and tax rate sensitivity of VC deals in the past. The analysis will look at the VC market as a whole, as well as adress early- and late-stage VC deals and how their sensitivities have differed in the past.

4.1 Data

Our main dataset has been retrieved from Prequin, a database of Private Equity and VC deals available to Harvard students. Prequin allows for world-wide searches of historical venture capital deals, which we took advantage of to export a dataset of N = 318,591 historical VC deals from a variety of countries dating from 1980-2023. The deals encompass all sectors imaginable, and have information about the portfolio company, investor(s), deal size, deal stage, and more.

After obtaining the data set, we went through various data cleaning efforts to ensure that our analysis data would not have adequate intraperiod sample sizes and be well-fit for empirical work. These efforts included

- Removed all deals pre-1995, as the earlier time periods showed small sample sizes and provided little additional value.
- Removed all deals with a deal size above $\$10,000,000,000$, as these represented substantial outliers in the data and are not very representative of typical VC-deals.
- Removed all deals with inadequate information like missing deal size and investor name.

After the above was completed, we were left with a dataset of N = 220,141 VC deals as our main analysis set.

Following the retrieval of VC deals, we obtained historical data on corporate tax rates by year for a variety of countries. This was stitched with the VC-deal data by investor country and year to accurately represent the corporate tax the investing firms faced on their profits.

Lastly, we obtained a data set of nominal interest rates by country and year and stitched it with the VC-deal data. This allowed us to have a proxy for the benchmark return investors

faced when making investment decisions, making it a representation of r in the model described in section 3.

4.2 Results

In attempting to identify whether or not historical VC investment behavior has coincided with the general investment model's predictions we employed a variety of analysis techniques. The following section will first address our analysis of interest rate sensitivity, before moving to tax rate sensitivity. In each section, we first describe the regressions we have run and their intended meaning before we present the outcomes.

4.2.1 Venture Capital Investments and Tax Rate

In investigating the historical relationship between the VC-investment market and corporate tax rate, we began by running regressions for various dependent variables, both with and without fixed effects, that can be defined as follows

$$Y_{i,t} = \beta_0 + \beta_1 \text{Tax Rate}_{i,t} + \delta_t + \alpha_i + \epsilon_i \tag{6}$$

where δ_t represents time fixed effects, α_i represents a vector of individual fixed effects, and ϵ_i represents the error term of the regression. Time fixed effects are considered very crucial, as all the dependent variables explored have varied strongly over time, particularly in a positive manner. An example of this is VC deal size, which quarterly average has been plotted as a time series below. As can be seen, it would be difficult to identify trends in the data if one did not take time fixed effects into account, considering the dependent variable's drastic development throughout history.

Additionally to time fixed effects, a crucial individual fixed effect is deal size, as deal metrics naturally vary a lot with the size of the deal. Another fixed effect adressed was portfolio company industry, as there may be variations in deal metrics depending on the

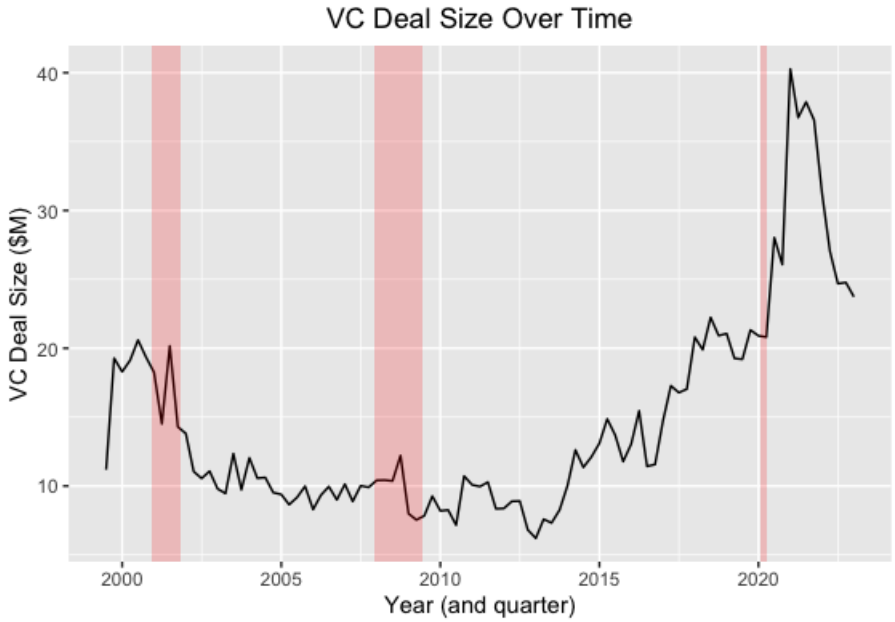

Figure 1: Average quarterly VC Deal size since 1995 with recessionary periods in red.

industry of the company seeking funding. It is important to stress that the below results are not intended to be causal, but rather are intended to explore whether the models predictions seems to have empirical merit in the VC-industry by identifying correlations within deal stages, industries, and time periods.

The first dependent variable we addressed was the VC deal size, for which we obtained strong results. As can be seen in the below table, VC deal sizes are decreasing with a higher tax rate with strong significance, as was predicted by the model. Although the results show that the decrease in deal size is smaller for early-stage deals, this difference is mainly a result from the larger absolute deal sizes that come in later deals. We can look at the relative change in deal size for both categories by dividing by the mean deal size, which gives us

$$\Delta\text{Large VC} = \frac{-0.67}{40.5} = -0.017 \quad \text{and} \quad \Delta\text{Small VC} = \frac{-0.19}{8.9} = -0.021$$

So we can see that the relative sensitivity is similar for both late and early stage deal. A notable aspect of the below table, however, is the consistently lower R^2 in early-stage deals compared to the late-stage deals. This could perhaps suggest that tax rate is a more

substantive part of the investment decision in late-stage deals compared to early-stage deals. This may be because late-stage investor profits often become more marginal, meaning that a higher tax rate could be more detrimental when evaluating the investment opportunity. Early-stage investors seem to pay attention to tax rate, but it explains less of the deal-size, which could arise from them evaluating investment options from a more qualitative standpoint, thinking that their upside is so large if things go well that the tax rate becomes a non-determining factor in whether or not the investment is profitable.

Table 1: Dependent Variable: VC deal size (in $M)

	Late VC Deals			Early VC Deals		
	All FE	Time + Stage FE	Time FE	All FE	Time + Stage FE	Time FE
Tax Rate	-0.67^{**}	-0.67^{**}	-0.74^{**}	-0.19^{***}	-0.19^{***}	-0.14^{**}
	(0.21)	(0.21)	(0.26)	(0.04)	(0.05)	(0.05)
Num. obs.	9362	9362	9362	39778	39778	39778
Num. groups: Deal Year	24	24	24	24	24	24
Num. groups: Deal Stage	17	17	–	5	5	–
Num. groups: Industry	11	–	–	11	–	–
R^2 (full model)	0.07	0.04	0.01	0.02	0.01	0.01
Adj. R^2 (full model)	0.06	0.04	0.01	0.02	0.01	0.01

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Aside from the dollar figure of deals, the number of deals being closed can also be explored to get an understanding for how VC activity changes with the tax rate. In the below table, we grouped the deals by country, year, and deal stage to find the yearly number of deals completed for each of the partitions available. Before running the regression, we trimmed away all categories with fewer than 10 closed deals to avoid small-samples confounding the results.

As can be seen by the results in the below table, VC deal counts also seem to be negatively

correlated with a higher tax rate. Interestingly, however, we can see that this relationship holds at much stronger significance for late stage deals. This is particularly interesting considering that the counts for the late stage deals are no larger than the counts for the early stage deals, meaning that the change is both more significant and more prominent in size in the late stage deals. This is perhaps eluding to the idea that early-stage investments are fueled more by qualitative rather than quantitative judgments, indicating that a higher tax rate is weighted less in the decision-making process of the investor than in the late-stage case.

Table 2: Dependent Variable: Yearly Number of VC Deals by Deal Stage and Country

	Late VC Deals		Early VC Deals	
	Time + Stage FE	Time FE	Time + Stage FE	Time FE
Tax Rate	-4.27^{***}	-2.41^{***}	0.84	0.93^{*}
	(0.98)	(0.53)	(0.49)	(0.41)
Num. obs.	151	151	637	637
Num. groups: Deal Year	18	18	24	24
Num. groups: Deal Stage	9	–	5	–
R^2 (full model)	0.27	0.07	0.11	0.04
Adj. R^2 (full model)	0.12	0.05	0.07	0.03

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

4.2.2 Venture Capital and Interest Rates

In investigating the historical relationship between the VC-investment market and nominal interest rates, we began by running regressions for various dependent variables, both with and without fixed effects, that can be defined as follows

$$Y_{i,t} = \beta_0 + \beta_1 \text{Interest Rate}_{i,t} + \delta_t + \alpha_i + \epsilon_i \tag{7}$$

where δ_t represents time fixed effects, α_i represents a vector of individual fixed effects, and ϵ_i represents the error term of the regression.

Looking at the below table's results, we can see that also interest rate has a strongly significant negative impact on VC deal size, both for early and late stage deals. Once again we can investigate the relative magnitude of the change by comparing it to the mean as

$$\Delta\text{Large VC} = \frac{-2.37}{40.5} = -0.06 \quad \text{and} \quad \Delta\text{Small VC} = \frac{-0.70}{8.9} = -0.08$$

So once again we can see that the relative magnitude of the changes in the two variables are quite similar. Once again, we can also see that the R^2 is lower for early-stage deals compared to the late-stage deals. This may, similarly to tax rate be due to early-stage deals typically being unlevered, making the investment decision less directly dependent on interest rate levels, since it now only exemplifies the opportunity cost of investment, while for late-stage investors it also increases the cost of capital. As an example, early-stage deal size may decline because higher interest rates are correlated with slowing economic activity in general, bringing early-stage investors with them, while late-stage investors may have more of a causal relationship with interest rate due to credit markets.

Table 3: Dependent Variable: VC Deal Size (in $M)

	Late VC Deals			Early VC Deals		
	All FE	Time + Stage FE	Time FE	All FE	Time + Stage FE	Time FE
Interest Rate	-2.37^{***}	-2.49^{***}	-2.99^{***}	-0.70^{***}	-0.71^{***}	-0.58^{**}
	(0.50)	(0.53)	(0.58)	(0.18)	(0.18)	(0.18)
Num. obs.	64041	64041	64041	156100	156100	156100
Num. groups: Deal Year	25	25	25	25	25	25
Num. groups: Deal Stage	18	18	–	5	5	–
Num. groups: Industry	11	–	–	11	–	–
R^2 (full model)	0.07	0.07	0.03	0.02	0.01	0.01
Adj. R^2 (full model)	0.07	0.07	0.03	0.02	0.01	0.01

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

This relationship can be visualized with a binned scatter plot as below, showing the strong negative trend in VC deal size with higher interest rates. This plot naturally does not employ any of the fixed effects included in the above regressions, but shows the general relationship between the two.

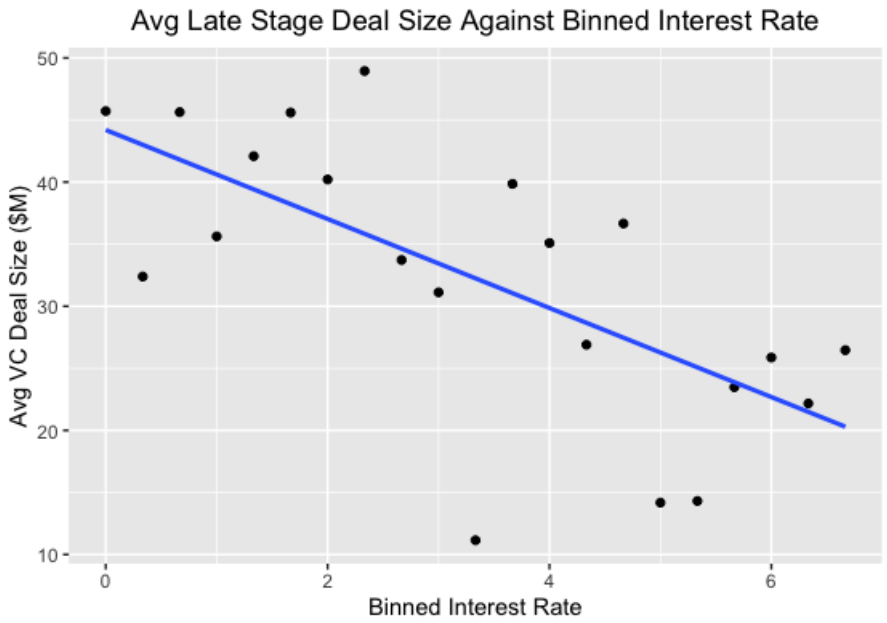

Figure 2: Average late-stage VC deal size and binned interest rate (0.25 interval).

Lastly, we can turn toward investigating the impact of interest rates on the quantity of VC deals. Using the same aggregation as for tax rate, grouping by country, year, and deal stage, we can regress the number of deals completed yearly on the interest rate to get a sense of their correlation.

As can be seen from the below table, a higher interest rate does not seem to show a significant correlation with the number of VC deals completed when controlling for deal stage, both for late and early stage deals. However, it may make sense to not include deal stage fixed effects, since a funding round may move from one deal stage to a different one because of a different interest rate. This could potentially explain the significance ound in the regressions only including time fixed effects.

Table 4: Dependent Variable: Quarterly Number of VC Deals

	Late VC Deals		Early VC Deals	
	Time + Stage FE	Time FE	Time + Stage FE	Time FE
Interest Rate	−2.66	−5.74*	−7.63	−6.95*
	(10.06)	(2.74)	(8.90)	(3.20)
Num. obs.	691	691	1355	1355
Num. groups: Deal Year	25	25	25	25
Num. groups: Deal Stage	13	–	5	–
R^2 (full model)	0.08	0.02	0.01	0.02
Adj. R^2 (full model)	0.03	0.02	0.01	0.02

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Although the fixed effects regression does not show significance for the relationship, another way to gauge the relationship between the two variables is through a scatter plot. It can make sense to evaluate number of VC deals without taking into account the deal stage, as deals may move from one deal stage to another depending on a variable like interest rate. In the below binned scatter plot, a negative relationship can be observed between number of VC deals completed and the average interest rate in a quarter. This plot includes both early- and late-stage deals, but the relationship holds when plotting the two categories separately as well.

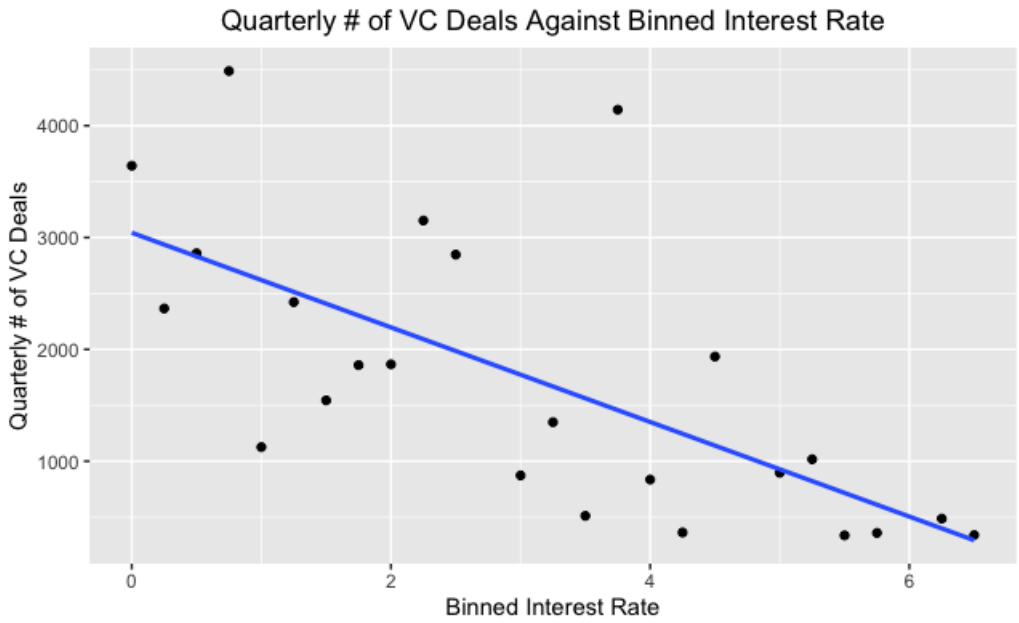

Figure 3: Quarterly VC deals completed and binned interest rate (0.25 interval).

4.2.3 Venture Capital and Recessionary Periods

Although not explicitly encapsulated in our model, the decision on whether or not to invest in an asset often involves the riskiness of the asset. As mentioned in the literature review, recessionary periods have typically been the clearest indicators of markets having higher risks, as more companies are subject to severe financial problems and thereby bankruptcy. Using our dataset on historical VC deals, we have looked into how VC market behavior has changed historically in periods of recession, where we have used the 3 main recessions in the 21st century as recession indicators. The dates used to indicate whether or not a recession was taking place are **Recession Dates:**

- **Dot-Com:** March 2001 - November 2001.
- **The Great Recession:** December 2007 - June 2009.
- **Covid-19:** March 2020 - May 2020.

To investigate the relationship between these recessionary periods and VC market metrics, we created a binary variable as

$$\mathbb{1}\left(\text{Recession}\right) = \begin{cases} 1 & \text{if date} \in \text{Recession dates} \\ 0 & \text{if date} \notin \text{Recession dates} \end{cases}$$

Following the definition of this binary variable, we ran regressions set up the same way as in equation 7, but this time with the binary recession variable as the main independent variable.

As can be seen from the below table, we have that VC deal size will decrease with approximately \$6-7 million on average in a recessionary period for late stage deals (significant at 10% level for all FE), while early stage deals will decrease with \$1.6 million in a recession. The stronger level of significance in the early-stage deals could partially be explained by the larger early-stage sample sizes available, but might also have to do with the higher riskiness associated with early-stage investments, leading investors with higher risk averseness to want to invest less in each round because of recessions being more of an imminent threat to early-stage companies with more vulnerable finances.

Running a similar regression for number of quarterly VC deals, we did not find a significant relationship. However, the below does suggest that VC markets see a slowdown in overall activity in recessionary periods, particularly in the high-risk early stage market.

Table 5: Dependent Variable: VC Deal Size (in $M)

	Late VC Deals			Early VC Deals		
	All FE	Time + Stage FE	Time FE	All FE	Time + Stage FE	Time FE
Recession Indicator	−6.48	−6.13	−7.58*	−1.61***	−1.59***	−1.54***
	(3.64)	(3.62)	(3.40)	(0.26)	(0.19)	(0.12)
Num. obs.	64041	64041	64041	156100	156100	156100
Num. groups: Deal Year	25	25	25	25	25	25
Num. groups: Deal Stage	18	18	–	5	5	–
Num. groups: Industy	11	–	–	11	–	–
R^2 (full model)	0.07	0.07	0.03	0.02	0.02	0.01
Adj. R^2 (full model)	0.07	0.07	0.03	0.02	0.02	0.01

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

5 Conclusion

In our paper, we first found that previous literature about the VC market and its reactions to macroeconomic changes has come to conflicting conclusions. This sparked motivation to explore the relationship further, with freshly updated data, in an attempt to get a better understanding of the relationship. We first presented a model of investment behavior, which applies broadly to both VC and general investments, that predicted decreased investment activity in environments with a higher interest rate or higher tax rate. This model became the foundation of our ensuing empirical analysis of 21st century VC deals, which was motivated by both evaluating the model's predictions as well as get a clearer understanding of the VC market and how its reactions to macro may differ to that of traditional investors.

In our empirical analysis we first investigated the VC market's relationship with tax rate, for which we found that there is a strongly significant relationship between a higher tax rate and lower average VC deal size. This showed to hold for both late and early stage deals,

with similar relative magnitude for both categories. We also found that there is a significant relationship between a higher tax rate and decreased number of quarterly VC deals closed. This showed to be substantially more significant for late-stage deals, which may speak to the more institutional and quantitative approach of late-stage investing, where margins are thinner and a higher tax rate may prove to be the difference between a net profitable and net unprofitable project.

Following the tax rate analysis, we moved to investigate the relationship between the VC market and interest rates. We found that there once again is a significant decrease in average deal size in environments with higher interest rates. This decrease also proved to be of similar magnitude for both late and early stage deals, with both categories showing extremely strong significance. For quarterly VC deals completed, we found that there was less of a significant relationship. Overall deals completed (regardless of stage) decreased with a higher interest rate.

Lastly, we looked into how investor mentality may change in periods of extreme financial distress, by utilizing a recession indicator as the main regressor to see how it has correlated with average deal size. This showed a strongly significant relationship with early stage deals, and a weaker and only partially significant relationship for late stage deals. As mentioned, this difference may speak to the inherent risk of the different investments, where late-stage investments naturally have less bankruptcy risk than early-stage ones and therefore may prove more attractive in periods of recession. However, we consider this an area that would benefit from additional analysis.

In conclusion, we found that Venture Capital Investment behavior seems to be strongly correlated with general investment behavior as observed empirically and predicted by our proposed model. We believe that an interesting future extension of our research can include finding comparable metrics across different investment markets. Additionally, comparing their relative changes with fluctuating macroeconomic conditions would be the next natural extension, but this would be a topic for a later paper.

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