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Dynamics of Venture Capital Investment during periods of Market Boom and Bust

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Abstract

By the end of the 1990's a large amount of venture capital was invested in the telecommunications and internet industries which became over-funded. During the first years of the new millennium, venture capital investment in these industries collapsed. The purpose of this study is to explore the causes underlying the rise and decline in venture capital and the role of time delays on VC industry performance. A model of venture capital investing is built using the system dynamics simulation approach. The model produces behaviors characteristic of the boom-and-bust. Alternative scenarios, with different model parameters, permit to examine the effects of investment speed on industry performance. The results of the simulations suggest that faster is not always better. Aggressive investment strategies may lead to poor performance for the industry as a whole.

Keywords: Venture capital, private equity investment, boom-and-bust, decision-making, strategy

1 Introduction

Venture capital is a major source of funding for innovation. In the first quarter of 2000, venture capital disbursements equaled fully one-third of all money spent on the national R&D in the US (Mandel, 2000). Drawing large pools of institutional investors' capital, venture capital is targeted at stimulating the growth of highly innovative startup companies, which has a tremendous impact on economic growth.

Figure 1 shows the boom and bust in the US venture capital industry between 1998 and 2003. VC investment activity experienced significant growth, which reached record levels in 2000 when more than $106 billion were invested (over 200% increase from its historical values).

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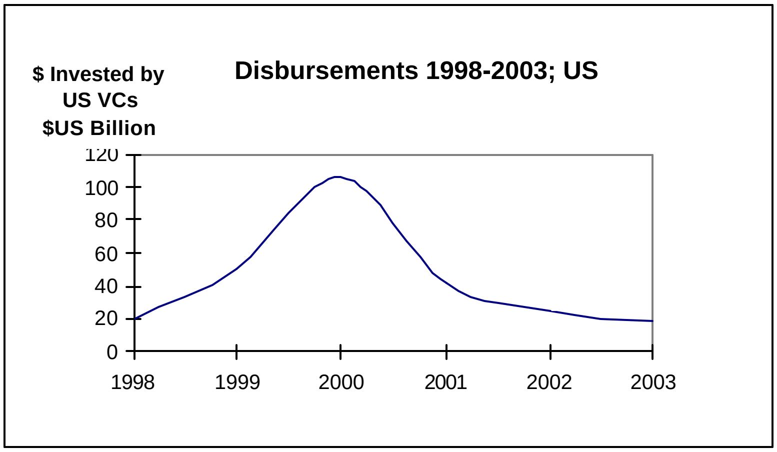

Source: VentureEconomics/PriceWaterHouseCoopers/MoneyTree

Figure 1. US Venture Capital Disbursements (1993-2003)

The boom years of the telecommunications and internet industries in the late 1990s were accompanied by intense investment activity and competition among venture capitalists, drawing large pools of institutional investors' capital, and driving to the rapid expansion of startup companies, which greatly stimulated economic growth. When the bubble burst during the early years of the new millennium, private equity markets contracted. Venture capitalists realized that the excess of investment in many startups would be very difficult to recover, which forced startups to slow down and to operate with lower and lower amounts of capital. Furthermore, customers were buying less, and bankruptcies followed suit. This chain of events would bring unemployment and economic stagnation for entire regions[3].

Historically, VC has been subject to dramatic swings of boom-and-bust behavior. The boom-and-bust phenomenon is defined as the upswing and decline of investment in capital markets (Kindleberger, 1978). Sahlman (1998) argues that the VC industry has a cyclical behavior characterized by periods of aggressive investment activity, combined with periods of little activity or stagnation. This is not an uncommon phenomenon in financial markets where investors tend to over-react to market signals (Shleifer, 2000; Shefrin, 2000; Getmansky et al., 2002). As long as the causes of the sharp swings in VC investment are not understood or adequately managed, too much value will continue to be lost.

The objective of this study is to develop an exploratory model of VC investment decision-making. The model relates market participants' decisions with overall VC industry performance. The model suggests how the boom-and-bust phenomenon may be generated by market participants' intendedly rational decisions within a competitive market that leads to unintended poor performance for the industry as a whole.

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[3] This study was originally set to explore the venture capital bubble in Ottawa, Canada. Ottawa is a technology cluster for telecommunications. In this city, more than $3.5 billion were invested in over 200 telecom startups, few of which survive to this date.

Market participants are the economic agents in a venture capital market. They include venture capitalists (VCs), institutional investors, entrepreneurs and public investors. The model developed in this study suggests that market participants fail to account for the impact of critical delays and feedback processes (i.e., interactions) in their decision-making, which leads to high levels of investment activity in the short-term and lower returns performance in the long-term.

To the authors' knowledge, the present study is the first to: i) identify key feedbacks, time delays, and behavioral motivations within the venture capital investment process, ii) to implement them in a system dynamics model of investment decision-making, and, iii) to design scenarios of VC investment speed that help us to better understand the sources of the problem behavior within the system.

The paper is organized as follows. Section 2 presents a rationale with the main strands of literature that guide this study. Section 3 develops the dynamic hypothesis and discusses the model structure. Section 4 presents and discusses the simulation results of four scenarios based on investment speed. Section 5 comments on the boundary of the model. Section 6 describes the tests made on the model. Section 7 presents the conclusions. Section 8 discusses the directions for further research.

2 Rationale

Gompers and Lerner (2001, p. 146) define venture capital as "independent, professionally managed, dedicated pools of capital that focus on equity or equity-linked investments in privately held, high growth companies". In general terms, venture capitalists (VCs) invest in high-technology firms where growth and returns are expected to be significantly higher than other industries.

2.1 Venture Capitalist Decision-Making

Many studies examine the decision processes of venture capitalists. Tyebjee and Bruno (1984) found that VCs investment decisions can be predicted from the their perceptions of risk and return, where return is assessed by new venture profitability and risk is assessed in terms of new venture failure. Shepherd et al. (2000) examine the relationship of strategy variables into VC decision-making domain. Shepherd (1999a) finds that the policies to assess new ventures used by VCs are consistent with those of the competitive strategy literature. Additionally, VCs have been found to have limited introspection into the policies they "use" to assess likely profitability. VCs have the tendency to overstate the least important criteria and understate the most important criteria compared to their "in-use" decision policies (Shepherd, 1999b, c). Along these lines, Zacharakis and Meyer (1998) suggest that, due to cognitive capabilities, VCs may not have strong insight, especially when confronted with information-rich situations such as the ones they face in making an investment decision.

Several qualitative and quantitative research approaches have been used to study the decision process of VCs: participant direct report (Tyebjee and Bruno, 1984; MacMillan et. al., 1985, 1987), verbal protocols (Sandberg et al., 1988; Hall & Hofer, 1993; Zacharakis and Meyer, 1995), conjoint analysis (Muzyka et. al., 1996; Zacharakis and Meyer, 1998; Shepherd, 1999; Shepherd and Zacharakis, 2002), and bootstrapping models (Sheperd and Zacharakis, 2002; Kemmerer et al., 2003).

Despite the amount of research on VC decision-making, very little is known about the dynamic decision processes that VCs execute in the real world. The importance of dynamic decision processes lies in recognizing that investment decisions in venture capital take place in complex, rapidly changing, and highly competitive technology markets. The fact that a new venture passes the evaluation of a VC group does not mean that the VC group can make the deal. There are mutual interactions between the decision process and the resource environment of the VC firm that have direct impact on the VC firm performance. For example, there may be funding restrictions that restrict the VC firm to finance a venture, no matter how profitable the deal promises to be. Another example is the effect of other VCs bidding for the same deal, which would have direct implications on the price or the structure of the deal itself, therefore affecting future returns.

2.2 Boom-and-Bust phenomena

The causes of the sudden upswing and demise of industries, markets, and even economies are far from certain. Kindleberger (1978) narrates the histories of famous price bubbles. He gives a behavioral explanation of how such bubbles emerge. Bubbles start from initial good news about a substantial profit opportunity that constitute a ‘displacement’ event which changes the perceived expectations and profit opportunities in the market. This event is followed by sudden demand, which in turn leads to a shortfall in supply. An increase in prices follows suit, which increases profits. The bubble is born as market participants speculate with higher demand forming a positive feedback loop. Eventually, at some stage, there is a rush for liquidity that leads to sudden collapse.

One plausible explanation of price bubbles is when supply outruns demand (Galbraith, 1972). Along these lines, Sahlman and Stevenson (1986) study venture capital involvement in the disk drive industry bubble of the 70’s and 80’s. They explain that, taken in isolation, each individual decision seemed to make sense, but when taken together, those decisions led to collective disaster. Sahlman (1998) reinforces this argument arguing that in VC markets the supply of capital has a tendency towards exceeding the supply of opportunities in a cyclical fashion. Lerner (2002) suggests that short-run rigidities in the supply response of capital create a tendency for this supply to react in an excessively dramatic manner “overshooting” the desired levels of investment resulting in disappointing returns for those funds.

Researchers have analyzed the apparent deviation from rationality of venture capitalists during the Internet Bubble. Wheale and Amin (2003) structure their analysis around behavioral finance arguments based on heuristic-driven bias, frame dependence, and inefficient prices. Their findings show that prior to the market correction, returns were correlated to a few basic measures of market performance, while after the market correction, returns were correlated to all the measures of market performance. The findings are consistent with deviations from the rational model, and reinforce the behavioral explanation of investor over-optimism that is driven by the great prospects of a new technology sector. Valliere and Peterson (2004) develop a qualitative model of investment decision-making grounded on the cognitive behaviors of 57 venture capital investors. They suggest that the generally accepted venture capital decision-making practices were bypassed by the emergence of artificial self-reinforcing loops of increasing investment that contributed to create the bubble. They attribute these artificial loops to new unfamiliar sectors with unknown success criteria. They suggest that the perceived difference and advantage of the unfamiliar Internet sector acted to suppress normal risk assessment controls that might otherwise avoided the bubble.

Overshoot-and-collapse can also result from aggressive growth strategies. Oliva, Sterman et al. (2003) develop a dynamic model of competition among online and click-and-mortar companies in retail e-commerce. They show how companies during the boom years of the late 1990’s used “get big fast” (GBF) strategies that sharply increased their demand for capital. They suggest that the rise and fall of the firms in the e-commerce sector is endogenous. It can be a consequence of the imbalance of positive feedbacks favoring aggressive firms with increasing returns and negative feedbacks that emerge to limit their growth (e.g., service quality erosion).

In summary, the literature on boom and bust suggests that price bubbles can be generated due to positive feedback trading strategies. Positive feedback trading results in trend chasing behavior due to short-run expectations combined with a belief in a long run return to fundamentals (Schleifer, 2000). In particular, investor over-reaction in VC is difficult to reconcile with a fully rational model (Sahlman and Stevenson, 1986; Sahlman, 1998; Lerner, 2002). In such cases, alternative explanations of the psychology of investors (Wheale and Amin, 2003; Valliere and Peterson, 2004; Oliva et al., 2003) may shed more light on what happens and why.

2.3 Venture Capital Boom-and-Bust

Previous research suggests that the boom-and-bust phenomenon in VC is supply and demand driven. Lerner (2002) and Sahlman (1998) agree that the reasons behind the over- and under- investment behavior in VC lie in the perceived performance of the VC market. When return expectations are high there is more investment activity and, conversely, lower returns expectations lead to poor investment activity. Black and

Gilson (1998) suggest that there is a strong link between the health of the public equity markets and VC fundraising. In a similar vein, Jeng and Wells (1997) found that the strength of the market for Initial Public Offerings (IPOs) is an important factor in determining commitments to VC funds. In general, these studies agree that the health of the VC market depends on the existence of a vibrant public market.

Previous literature also investigates the decision of firms to go public (Lerner, 1994; Gompers and Lerner 1999). This literature suggests that IPOs may be subject to fads, providing evidence that VCs take firms public at market peaks. However, this behavior has often been a bad omen for VC markets. According to Gompers and Lerner (1999, p. 211):

> "Many institutions, primarily public and private pension funds, have increased their allocation to venture capital and private equity in the belief that the returns of these funds are largely uncorrelated with the public markets…to ignore the true correlation is fraught with potential dangers."

There is also the belief that there are "hot" markets for IPOs. Many studies (Helwege and Liang, 2001; Stoughton et al., 1999; Benveniste et al., 2002) argue that "hot" IPO markets occur in industry clusters with abundant technological innovations and high growth prospects. "Hot" markets may drive a "herding effect" that pushes forward high levels of entrepreneurship and investment activities. Stein (2001) observes the herding phenomenon observed in the VC industry:

> "…[VCs] may exhibit an excessive tendency to "herd" in their investment decisions, with any given manager [VC] ignoring his own private information about payoffs, and blindly copying the decisions of previous [other] movers."

Scharfstein and Stein (1990) show how the herding incentive can arise in a reputation-based model. They suggest that the relative performance of a group of agents may generate an incentive for other agents to mimic each other, regardless of their actual signals. Along these lines, Gompers (1996) finds that young venture capital firms have incentives to "grandstand". That is, they build reputation by bringing firms public earlier than older venture capital firms in an effort to demonstrate track record of high rates of return (ROR) to attract investors and raise new funds shortly after IPOs. Along these lines, Forrester (1992) observes on the behavior of VCs:

> "…often venture capital groups finance new enterprises in which policies, products, and markets are chosen in such a way that they predetermine failure."

This study attempts to explore how venture capital investment develops over time and the interaction between the decision and resource environments of venture capitalists (VCs). The decision environment refers to the decision variables used by investors when searching for profitable opportunities. The resource environment refers to the available resources that firms look at, make use of, or dispose of, when investing. All this phenomena develops in the context of the industry. The linkages between the decision and resource environments are crucial to explain the dynamics of growth and change in the venture capital industry. Understanding these linkages and creating a structure through which to examine them is the research focus of this study, presented in the next section.

3 A system dynamics model of VC investment

System Dynamics (SD) provides a framework for understanding the role of feedback in complex systems. The behavior of a system is caused by the interrelationships among the components in the structure of the system. System dynamics is the chosen methodology for this research because it suits nicely the analysis of problems that are continuously changing over time. An understanding of the components and relationships in the system leads to insights about the causes of system behavior. The components of a system may be regarded as endogenous or exogenous depending on the particular phenomena being studied. In the venture capital domain, venture capitalists are only one set of agents in a more complex system that comprises the venture capital industry. The effects that entrepreneurs have on investors, and the feedback that VCs receive from institutional and public investors, are all determinants of venture capital investing. This feedback will alter the quantity and quality of the VC investments, and its subsequent effects on VC performance.

Previous research has explored the generation of the boom-and-bust behavior in dynamic markets (Paich and Sterman, 1993). Along these lines, in a previous paper, one of us (Yepez, 2004a) developed a simple model of VC investment for a new product in a new market sector. The model used a simple representation for a decision rule driving new investments based on projected expectations of liquidity events. The model was calibrated with numerical data on investments and IPOs in the disk-drive industry available from Sahlman (1986). The simple model replicated closely the historical behavior of VC investment both in period and magnitude for the real-case available data (see Appendix 1 for results on real-case and simulated reference modes). This paper expands on this previous work by exploring investment scenarios that provide insight on how the sharp swings of venture capital markets are influenced by VCs themselves.

Figure 2 depicts the links between market participants in the system. The venture capital environment is divided into four basic subsystems, as follows:

1) Limited Partners (LPs), which represents the set of wealthy individuals or institutional investors that provide the money to venture capital funds. LPs pay close attention to the state of the IPO and M&A markets, as well as the returns made by VCs, in order to allocate more or less money into venture capital funds.

2) General Partners (GPs), which represents the set of venture capital firms trading in a specific market sector. The GPs or venture capitalists (VCs) invest their funds in private companies of attractive market sectors with the expectation of eventually cashing out the investment via an IPO or M&A transaction.

3) Buyers, which represents the set of potential acquirers of venture backed companies. In the case of acquisitions, the buyers can be publicly traded technology companies. In the case of IPOs, the Buyers can be investment banks or institutional investors. Together, they drive the demand for liquidity events (e.g., IPO and M&A transactions). The Buyers subsystem provides an information source used for several market participants' decisions.

4) Entrepreneurs, which represents the pool of startup companies that develop new products within the specific market sector.

Drawing on Warren (2002), the system structure is depicted as the flow of interdependent resources among subsystems where decision rules are based on readily available information flows. Such flows are the flow of cash from LPs to GPs to Entrepreneurs. The flow of company ownership from Entrepreneurs to GPs to Buyers. And the flow of payouts from the Buyers to the system shareholders (GPs, LPs, Entrepreneurs) when the companies are acquired.

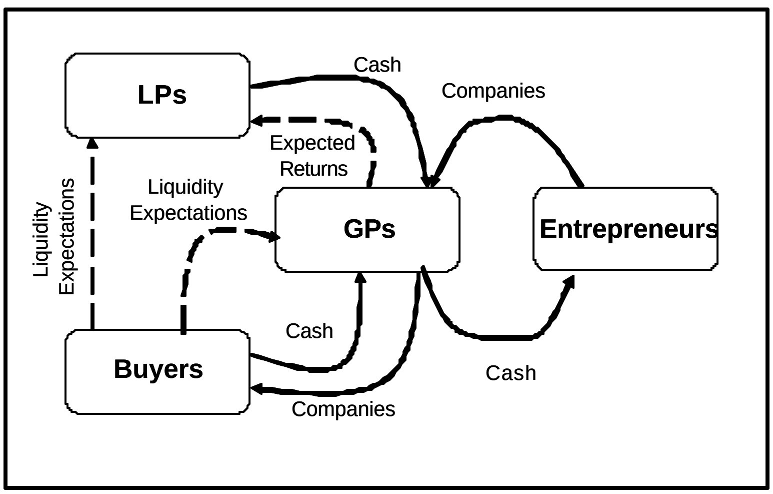

Figure 2. Subsystem diagram of VC industry

3.1 Dynamic hypothesis

The basic feedback structure that explains the boom-and-bust phenomenon in VC is illustrated in Figure 3. The simple causal model represents the VC investment process in a single technology cluster.

The deal inflow (i.e., deal rate) fills the VC pipeline (supply line) with Portfolio Companies . After some time Portfolio Companies mature and become ready for an exit. This exit can potentially be in the form of an M&A transaction by a Buyer interested in the product or technology.

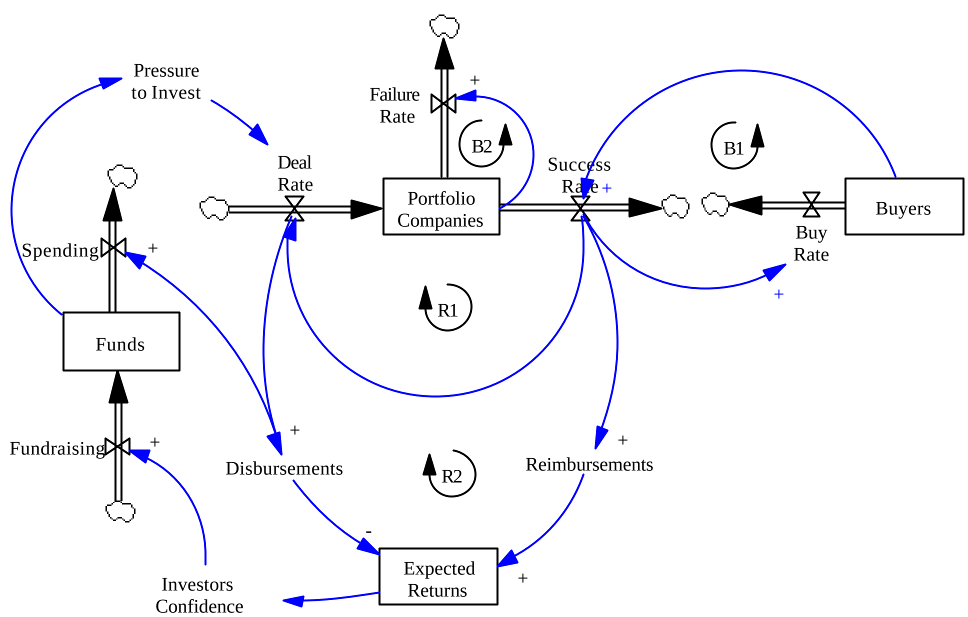

Figure 3. Dynamic Hypothesis

The increase in the number of successful exits gives the signal of a healthy market for M&A transactions, which encourages still more investment activity.

In the supply side, LPs are interested about the returns performance of VC investments. Based on the historical returns performance data, LPs project expectations about VC funds. Therefore, when expected returns are above their desired goal investors become confident in VC and make more commitments expecting still more high returns in a reinforcing loop.

In the demand side, there are two components: First, companies that enter the VC pipeline require financing both at the outset and during their growth period (financing capital may be required until the companies become ready to harvest). Second, when companies are ready to harvest they may be acquired by those Buyers interested in the product or technology.

Since investors (LPs) are profit maximizers, higher returns expectations mean more money is placed into ventures. The more funds are available, the higher the pressure on VCs to put that money to work. VCs relieve that pressure either by increasing the number of deals they make, by increasing the size of their investments, or both. The aggregate effect of all similar investment decisions, also known as "herding effect", explains how the aggregate of all locally rational investment decisions may drive a significant surge of investment in a particular technology cluster. After some time, portfolio companies in the pipeline hit maturity and start being acquired by buyers. As the number of acquired companies increases, the number of Buyers decreases in negative feedback loop.

Finally, as the number of buyers decrease, the liquidity activity is reduced accordingly thereby closing the exit window. The diminishing liquidity activity lowers investors' confidence, who commit less money for VC funds. Since no buyers means no more successful exits, returns performance starts to decrease. Eventually, portfolio companies run out of cash and are discarded as failures in a negative loop.

3.2 Feedback structure of the VC investment process

The model is based on three behavioral assumptions (Yepez, 2004b): First, that investment behavior is led by maximization of shareholder value, that is, LPs allocate money into VC funds when expected returns are higher than desired returns. Second, that market participants are boundedly rational (Simon, 1979). That is, LPs and GPs decisions are led by simple, readily available signals of increasing return expectations and a healthy market for IPO or M&A transactions. Third, market participants have "misperceptions of feedback" (Sterman, 1989). That is, market participants (e.g., LPs and GPs) fail to account for time lags between the seed and harvest periods in the VC pipeline.
We now proceed to examine in detail each feedback loop of the model, starting with the loops depicted in Figure 4.

1. <u>Loops R1 and B1: The Deal-Making Loops.</u> The assumption for the investment decision heuristic is that VCs use two (2) cues germane to the deal-making activity. First, VCs are interested to invest in new, big and rapidly growing markets. When looking for new venture opportunities they assess the attractiveness of the market sector. If they identify an unexploited sector with great potential, they will place their bets. Second, VCs are interested to invest in new ventures with prospects of a successful exit (e.g., IPO or M&A). That is, they have the expectation that any venture they invest in will be, eventually, cashed out successfully.

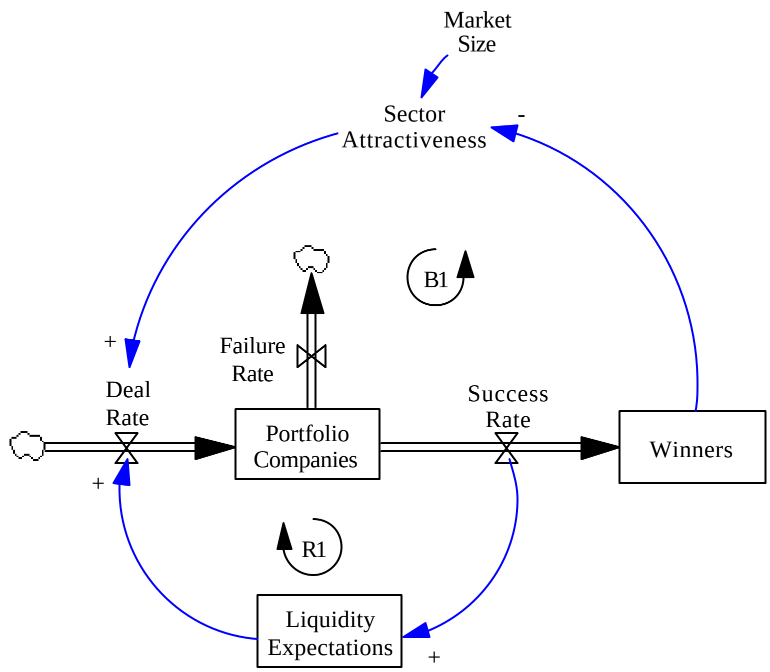

Figure 4. Feedbacks driving Deal-Making activity (R1 and B1)

As Portfolio Companies mature, some of them will exit as successes while others will exit as failures. The increasing number of successful exits gives signals of increasing liquidity activity (e.g., increasing IPO or M&A transactions), which encourages still further investment activity in a reinforcing loop (R1).

Furthermore, the accumulation of companies in the stock of Winners reduces the Sector Attractiveness which further reduces venture capital investment activity in a balancing loop (B1).

2. <u>Loop B2: The Market Saturation Loop.</u> The loop in Figure 5 depicts how the demand for Portfolio Companies eventually saturates the market sector. Here, the main assumption is that acquirers modify their buying based on the perceived attractiveness of the sector. When Sector Attractiveness is high, Buyers acquire Portfolio Companies. When Sector Attractiveness is low, they stop buying.

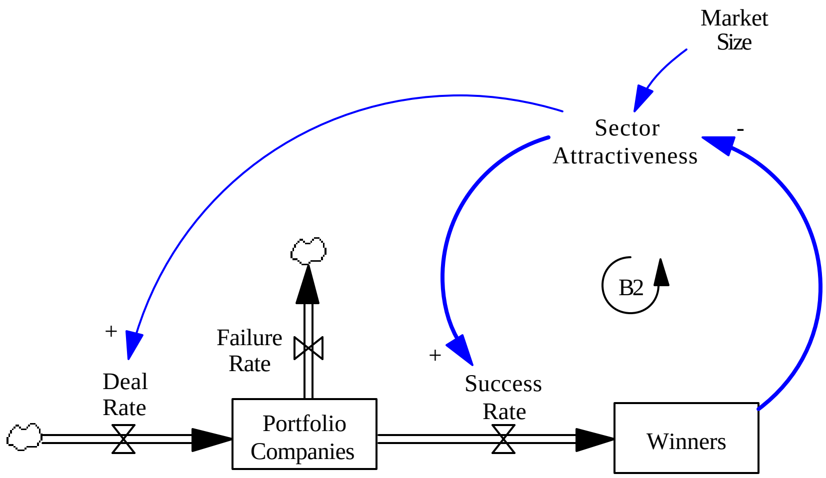

Figure 5. Feedback generating Market Saturation (B2)

The increasing number of companies in the stock of Winners reaches limits to its own growth due to the finite size of the market. The Market Size determines the total number Winners that can compete profitably in the sector. The more the number of Winners competing in the market sector, the less the sector is attractive to public investors. In other words, the IPO or M&A window begins to close in a balancing loop (B2). After the window closes, no more Portfolio Companies reach a successful exit.

3. <u>Loop R2: The Fundraising Loop.</u> The loop in Figure 6 describes the decision process to raise funds. Fundraising depends on the confidence of investors in venture capital. Investors Confidence is based on the assumption that LPs are profit maximizers. Therefore, LPs constantly assess the returns performance of venture capital funds. When the historical returns expectations from venture capital exceed their desired returns goal (e.g., 25% ROR), LPs allocate money into venture capital funds.

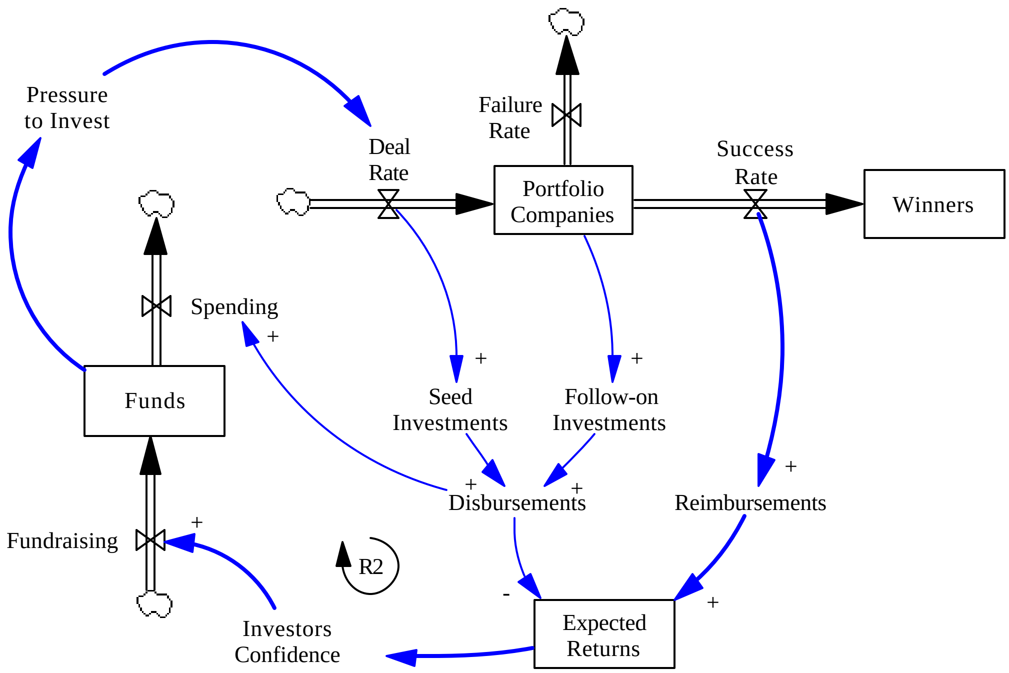

Figure 6. Feedbacks generating Fundraising activity

The initial successes of companies that exit via IPO or M&A increases the returns expectations for venture capital funds. Investors, encouraged by the prospects of good returns and a healthy IPO or M&A market, allocate more money into venture capital funds. The availability of money creates pressure on VCs to further invest in more companies in a reinforcing loop (R2).

4. <u>Loop B3: The Competition Loop.</u> The loop in Figure 7 suggests how competition among venture capital firms would influence the price change in deal valuations. Here, the main assumption is that the competition for deals among VCs drives prices up (i.e., both seed and follow-on valuations). Therefore, deal valuations are influenced by the number of VCs looking for a deal in the market sector.

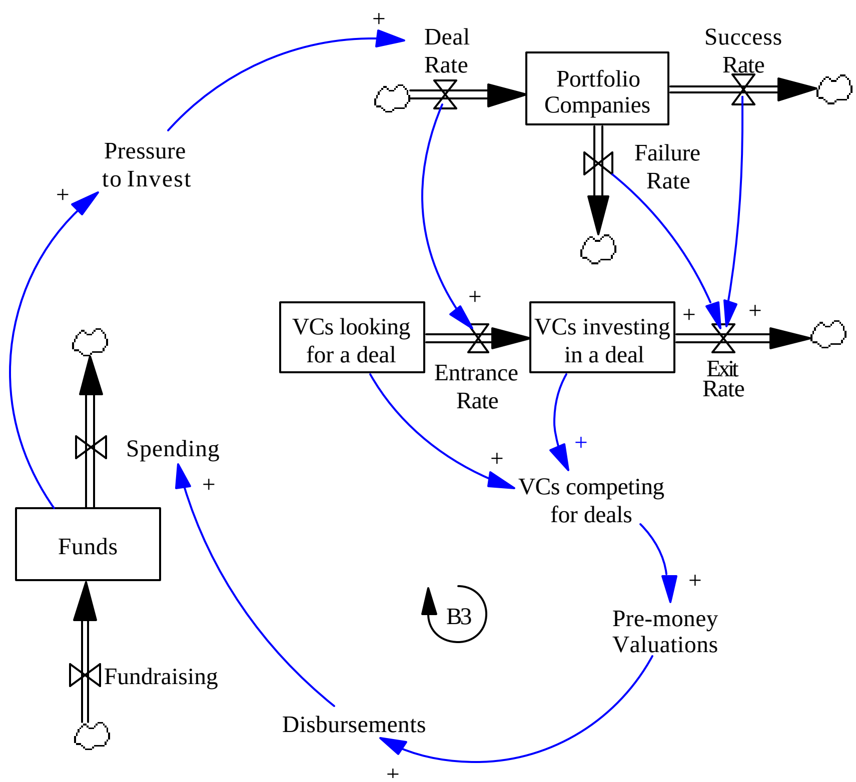

Figure 7. Feedback generating Competition (B3)

The increasing number of venture capital firms competing in the market, drives the prices of deal valuations up. Investments at higher deal valuations decrease the stock of Funds, which further diminishes the pressure of VCs to invest in Portfolio Companies. The less the investments, the less the competition among VCs, which completes the balancing loop (B3).

5. Loop B4: The Demand Loop. The loop in Figure 8 suggests how price changes in exit valuations would be influenced by Buyers demand for Portfolio Companies. Here, the assumption is that each successful exit transaction requires one buyer. After each buyer makes a transaction it exits the market by depleting the stock of buyers by one unit each. The current number of buyers competing for acquisitions of Portfolio Companies drives the prices up. Therefore, exit valuations are influenced by the competition for Portfolio Companies among buyers.

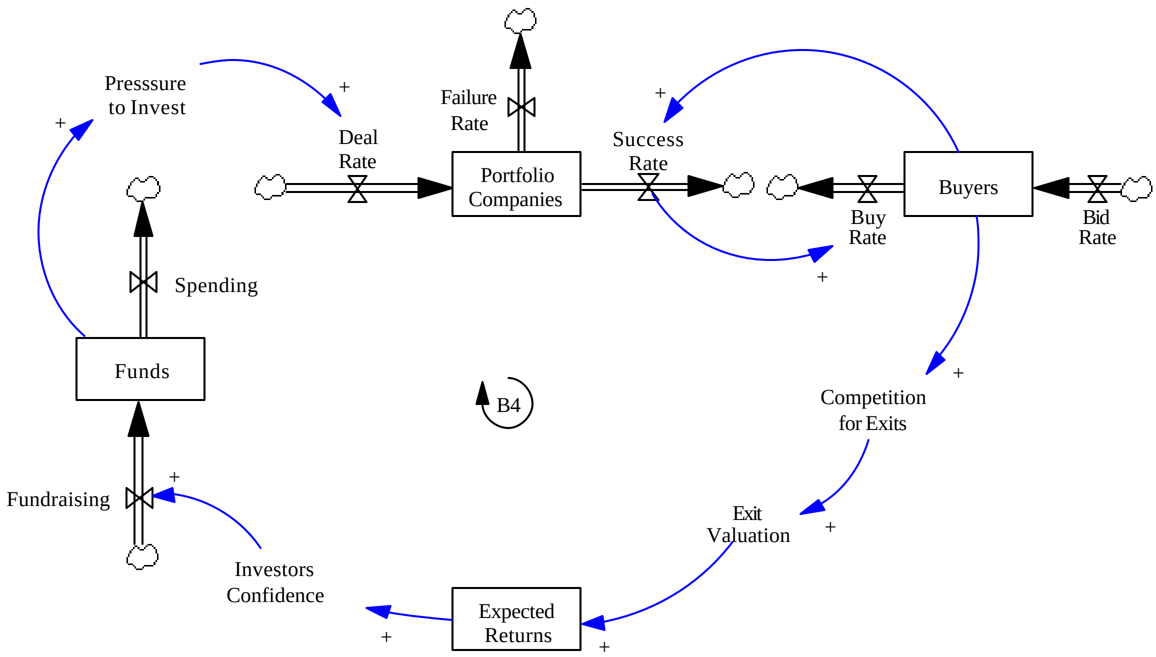

Figure 8. Feedback generating Demand (B4)

Early buyers of Portfolio Companies in the new sector attract more buyers into the market. As the number of Buyers bidding for Portfolio Companies increases, the prices that those Buyers are willing to pay also increases. Higher exit valuations increase the return expectations for new investments in the sector, which helps to attract more venture capital firms into the sector. This in turn increases the number of startup companies that get financed. However, the more exits, the less Buyers. The diminishing number of Buyers, decreases prices of Exit Valuations, which reduces returns expectations in a balancing loop (B4).

4 Model Simulation and Scenario Analysis

This section presents and discusses the simulation results of running the model. The first sub-section describes the rationale for the base run of the model, which is used as a "benchmark" to compare the results of subsequent simulations in the second sub-section. Next follows the scenario analysis sub-section which includes two parts. i) the design and simulation of four investment scenarios based on investment speed. ii) the simulation of a stock market crash scenario to evaluate the impact on the system behavior. The scenarios are compared to the "benchmark" on the basis of several performance variables commonly used in the venture capital industry. Finally, I discuss the results obtained from the simulations of the model.

4.1 Base Run[4]

The base model is calibrated with average industry values and best estimates for several key parameters (e.g., key delays). Other parameters such as average valuation, agents' populations, and so on are fictitious and were chosen with the sole purpose of providing a "benchmark" model of a virtual venture capital industry that would be used to compare against other scenarios in the next sub-section.

4.1.1 Key parameters

A summary of the key parameter values of the model are shown in Table 1.

Parameter	**Value**	***Units***
Average due diligence delay	6	*Months*
Average liquidity delay	60	*Months*
Discard delay	24	*Months*
Redemption delay	60	*Months*
Buyer population	10	*Firms*
Initial VC Population	10	*Firms*
Buyer Population	10	*Firms*
Average Pre-money valuation	1	*Dollars*
Average Exit valuation	10	*Dollars*

Table 1. Parameter values for the model

4.1.2 Performance measures

In order to measure the performance of the virtual venture capital industry the following metrics are used to analyze the model behavior:

1) Portfolio Companies: Number of companies financed by VCs
2) Success rate: Amount of successful exits ("winners") per time period (i.e., month)
3) Exit distribution: Outcome distribution of the cumulative number of companies that end up as "winners", "losers", and "survivors"
4) Valuations: The trend in the price of valuations over time
5) Commitments: Cumulative amount of money invested into Portfolio Companies
6) Proceeds: Cumulative amount of money obtained from exiting Portfolio Companies
7) Returns: Cumulative returns for the venture capital fund deployed. This variable is calculated from total cumulative commitments and total cumulative proceeds.

[4] The full model is available in a Vensim PLE formal (*.mdl file). The model file can be obtained from the corresponding author by contacting him at: cyepez@sce.carleton.ca

4.1.3 Base run performance

A summary of the simulation results for the base run is shown in Figure 9 (refer to Appendix 1. Simulation results). The base run is calibrated with the parameters specified in Table 1 and is used as a "benchmark". The performance of the "benchmark" scenario is the following:

- Investment and liquidation activities peak between years 6 and 7.
- Returns reach an attractive peak of 100% by year five. Long-term returns remain at 30%, within the industry standard for venture capital.
- Exit distribution for this virtual venture capital industry is: 20% winners, 50% losers, and 30% survivors.

4.2 Scenario Analysis

This section presents the design and simulation of four investment scenarios based on investment decision speed. Four investor types are proposed based on the speed they have to make deals and exit portfolio companies. Drawing on Valliere and Peterson (2004), this study matches the four investor types matched with the cognitive behaviors of bubble investors identified by these researchers. The analysis of the performance of each investor type sheds light on the importance of investment speed in venture capital decision making.

4.2.1 Investment Speed Scenarios

The simulation runs were designed to analyze model behavior as a result of the variation of key delay variables under influence of VCs, namely: due diligence and liquidity delay.

1) Due Diligence delay. This variable represents the average time that VCs take to assess a prospect startup for venture capital financing. VCs define their own pacing requirements when evaluating a deal. The average value of due diligence is set to 6 months. This value was varied 50% for upper and lower bounds in order to observe its impact on venture capital industry performance.
2) Liquidity delay. This variable represents the average time that a Portfolio Company resides in the supply line before it is ready for an exit. The average value for liquidity delay is set to 3 years (36 months). VCs can influence the timing to take a company through a liquidity event. The liquidity delay value was varied 50% for upper and lower bounds in order to observe its impact on venture capital industry performance.

The upper and lower bounds of the key delay variables were used to evaluate the effect of investment decision speed on venture capital industry performance relative to the "benchmark", or base run. Thus four investment speed scenarios are illustrated in Table 2.

VC speed variable		Due Diligence	
		Low	**High**
Liquidity Delay	**Low**	Sector Speculators	Company Creators
	High	Diversified Investors	Focused Investors

Table 2. Scenarios based on Investment Speed

The rationale for the VC investor-speed type according to the four scenarios draws on the findings on bubble investor behavior identified in previous research (Valliere and Peterson, 2004).

1) Focused Investors are a passive type of VC. They take time identify new companies based on individual merits. However this investors are not very involved in the working and particular management of a company, suggesting that, on average, it may take their companies longer to cash-out.
2) Sector Speculators are the most aggressive type of VC. They are the quickest to make deals and can execute or exit companies the fastest. These VCs are really a momentum-type of investor. They are trend chasers who invest in hot markets and exit their investments as soon as they can with the sole purpose of getting the highest profits.
3) Company Creators are "smart money" investors. They are picky and take their time to choose specific individual companies rather than relying in the prospects of an entire sector. Once they invest, they work closely with a particular management team to get the company to grow to critical mass sooner rather than later.
4) Diversified Investors are another passive type of VC. They are eager to invest in companies in specific sector. However, they are not operationally involved with investee companies, which affects the likelihood of getting those companies out in a timely fashion. Young and inexperienced VCs would fit in this category since they are excited about their new job and want to gain reputation by betting on hot market sectors.

4.2.2 Comparison of VC investment speed scenarios with base run

Figures 12 to 20 show the simulation results for the four investment scenarios compared with the base run. Table 3 presents a summary of the observed behaviors with respect to two factors. i) the time to reach the maximum of the variable under measure (*the peak time*). ii) the *peak value*, which determines the maximum value of the variable under measure.

A few important patterns are observed in the data which are discussed next. The comments of each scenario are made with particular interest on the trends for the short-term (first 5 years) and long-term (10 years).

1) Focused Investors – Outcome: Slow but steady.
   - No system collapse. Deal-making and liquidation activity remain at its lowest levels.
   - Competition is never high enough meaning low pre-money valuations.
   - High and sustained exit valuations due to an increasing number of buyers waiting for companies to be ready for harvest.
   - Break even by year 4, two years after the benchmark.
   - Successful exits reach 50% of optimum
   - High long-term returns (90%) for the industry as a whole
2) Sector Speculators – Outcome: Faster is not always better.
   - System collapse. The sharpest and fastest rise and decline in investment and liquidation activity. It creates the highest investment peak (as measured by number of portfolio companies), exceeding more than twice the base run.
   - Short and sharp rise and decline for both pre-money and exit valuations
   - Quickest break-even by year 1, one year ahead of benchmark.
   - Successful exits reach optimum by year 3.
   - Short-term returns peaking at 80% by year 2, but still lower than benchmark. Low long-term returns (12%) for the industry as a whole.
3) Company Creators – Outcome: Great for a few, terrible for the industry.
   - System collapse. However the peaks of investment and liquidation activity are lower and later than the extreme case scenario (Sector Speculators).
   - Highest peaks in pre-money valuations. Second to shortest rise and decline trend in exit valuations.
   - Quick break even by month 14.
   - Successful exits reach optimum by year 4.
   - Highest peak of short-term returns reaching abnormal returns in excess of 130% by year 3.
   - Poorest long-term returns (0%) for the industry as a whole.
4) Diversified Investors - Outcome: Lucky strike?
   - No system collapse. Deal-making and liquidation activity remain at low levels.
   - Lowest trend in pre-money valuations. High and sustained trend in exit valuations.
   - Break even by year 3, one year after the benchmark.
   - Successful exits reach 60% of optimum
   - Short-term returns slightly superior to the Focused Investors scenario. High long-term returns (90%) similar to the Focused Investors scenario.

The results obtained from the simulations above appear to be counter-intuitive since they suggest the rewards go to the passive-type of investors. Would this be possible? The following section introduces an external market pressure, a sudden crash in the public market, to later pick up the discussion on the effect of an external market shock in the behavior of the system.

	Portfolio	Exit Distribution (%)			Returns (%)		
	Companies	**Winners**	**Losers**	**Survivors**	**Break-even**	**Short-term**	**Long-term**
Base							
Peak Value	9 firms	20%	50%	30%	-	100%	30%
Peak Time (month)	80	72	108	108	24	60	120
Focused Investors							
Peak Value	2 firms	22%	52%	26%	-	-	90%
Peak Time (month)	2	240	240	240	48	-	120
Diversified Investors							
Peak Value	3 firms	24%	48%	28%	-	-	90%
Peak Time (month)	6	240	240	240	36	-	108
Company Creators							
Peak Value	15 firms	20%	55%	25%	-	130%	0%
Peak Time (month)	48	48	108	108	14	36	108
Sector Speculators							
Peak Value	20 firms	20%	52%	28%	-	80%	12%
Peak Time (month)	30	30	72	72	12	24	84

Table 3. Summary results for investment speed scenarios

4.2.3 Market Crash Scenario

The previous investment speed scenarios suggest that VCs, when given all their time, would fare better if using conservative exit strategies. Would this hold if VCs were faced to an unexpected event at some point in time? What should happen to the system if it was impacted by a sudden crash in the public market? The system analyzed in the previous section assumes that buyers have the propensity and ability to buy Portfolio Companies at all times. To study the behavior of the system to a sudden crash in the stock market, I assume that the ability of buyers to acquire companies is affected by their stock price. This is a reasonable assumption based on the data I gathered from interviewing experienced investors. Therefore, when the currency (stock) used for acquiring companies gets affected due to a stock market crash, buyers stop doing acquisitions.

In this experiment, the stock market crash is modeled by applying an external shock to the stock of buyers which depletes it at time 36 or year 3 of the simulation. The impact of a public market crash in the different investment speed scenarios is presented in figures 21 to 27. Table 4 presents a summary of the observed behaviors.

	Portfolio	Exit Distribution (%)			Returns (%)		
	Companies	Winners	Losers	Survivors	Break-even	Short-term	Long-term
Base							
Peak Value	9 firms	20%	50%	30%	-	100%	30%
Peak Time (month)	80	72	108	108	24	60	120
Focused Investors							
Peak Value	2 firms	22%	52%	26%	-	-	90%
Peak Time (month)	2	240	240	240	48	-	120
Diversified Investors							
Peak Value	3 firms	24%	48%	28%	-	-	90%
Peak Time (month)	6	240	240	240	36	-	108
Company Creators							
Peak Value	15 firms	20%	55%	25%	-	130%	0%
Peak Time (month)	48	48	108	108	14	36	108
Sector Speculators							
Peak Value	20 firms	20%	52%	28%	-	80%	12%
Peak Time (month)	30	30	72	72	12	24	84

Table 4. Summary results for investment speed scenarios with market crash

A few important patterns are observed in the data when the system is impacted with the stock market crash.

1) Focused Investors – Outcome: Irrelevant for fast-paced markets.
   - No system collapse. Deal-making and liquidation activity remain at its lowest levels.
   - Competition is never high enough meaning low pre-money valuations.
   - Lowest exit valuations due to lack of buyers.
   - Never breaks even.
   - Successful exits reach 30% of optimum
   - Poorest and negative returns for the industry as a whole
2) Sector Speculators – Outcome: Faster is not always better.

   The simulation results are similar with or without the stock market contingency.
3) Company Creators – Outcome: Great for a few, bad for the industry.

   The simulation results are slightly affected by the stock market contingency in a few key aspects:
   - System collapse. However peak values for investment and activity are marginally lower compared to the previous run.
   - Successful exits do not reach optimum value (but 90%)
   - Long-term returns slightly improve (8%) compared to previous run due to the slightly reduced investment activity.
4) Diversified Investors – Outcome: Back to basics
   - No system collapse. Deal-making and liquidation activity remain at low levels.
   - Lowest trend in pre-money valuations. Low trend in exit valuations.
   - Still breaks even by year 3.
   - Successful exits reach 30% of optimum
   - Short-term returns low but positive (8%). Long-term returns lower but still positive (3%).

The results obtained from the simulation runs considering external market pressures such as the stock market suggest that the slow-type of investors fare the worst. A few remarks are worth noting.

- Aggressive exit scenarios overshoot and collapse and have similar trends in both pre-money and exit valuations with or without the stock market crash.
- Sector Speculators are the only ones able to reach the optimum number of successful exits before the market crashes, all other investment speed scenarios under-perform under this metric.
- Passive or conservative exit scenarios never take-off. The effect of slowing down the process of investing and liquidating firms impacts negatively industry performance. Evidence shows that not only the stock market crash can create external market pressures on investors. A fast-paced competitive environment creates an incentive for faster investment decisions rather than slower. The benchmark scenario provides long-term returns of 20% for the industry as a whole. This result suggests that even if there is no incentive for slow investment decisions, there is not necessarily an incentive for faster

ones either. At the wake of a stock market crash in year 3, the best scenario continues to be the benchmark which maintains the average levels of investment speed.

4.3 Discussion

The overall simulation results suggest that the impact of investment speed is critical in exacerbating or attenuating the boom and bust dynamic in venture capital markets, with or without the stock market crash. The market crash only helps to create an external market pressure on the system. However, not only the stock market can cause a timing pressure. Other time pressures might arise from other investors, incumbents and existing startups already competing in the market sector where VCs are investing.

The most salient findings of the overall simulation runs are the following:

- Aggressive exit scenarios (Sector Speculators and Company Creators) are sufficient to explain how the boom-and-bust phenomenon may be produced endogenously. The reason is found in a strong positive feedback between the rate at which companies are harvested and the rate at which new deals are made. The more exits, the more deals, which brings forth more exits until the system reaches limits to growth set by the finite number of buyers of portfolio companies.
- Faster is not always better. Although aggressive investment strategies continue to reward a few with handsome returns, the long-term industry performance is poor and lower than the benchmark.
- Spending more does not necessarily mean investing smarter. Aggressive exit scenarios spend and receive the most money on absolute values. However returns are poorer than benchmark.
- Valuations, both pre-money and exit, peak and decline sharply due to the high competition produced by aggressive exit scenarios.
- With market crash, aggressive exit strategies have higher returns than benchmark on the short run, while lower on the long run.
- With market crash, conservative exit strategies under-perform the benchmark at all times.
- Company Creators cause the highest increase and decline in pre-money valuations. This result is counter-intuitive since these investors do not produce the highest peak of investment activity. A closer look into the structure of the model shows that while they take longer to make deal, the accumulation process of VCs looking for a deal is such that it drives valuation prices higher than the other scenarios.
- Conservative exit strategies tend to maintain the system in equilibrium. However, the issue of performance is a different one. Conservative investors would be rewarded in the long-run with exemplar returns if there were no market pressures. With market pressures, these investors become irrelevant to the industry.
- The tried and tested average industry values of the base run show that, even with the market crash, they produce better outcomes for the industry as a whole. This suggests the time that it takes to

conscientiously screen a deal, and the time that it takes to build value in a company and get it ready for harvest should not change with public market swings.

5 Model Boundary

Table 5 presents the boundary chart of the model. The chart summarizes the scope of the model by listing which key variables are included endogenously, which are exogenous, and which are excluded from the model.

Endogenous	Exogenous	Excluded
VCs investing in a deal	Initial VC population	Startup Population
Portfolio Companies	Buyer population	Net income per company
Funds	Initial Funds	Market Share
Winners		Risk premium
Losers		Supply/Demand curves
Survivors		Incumbents
Buyers		Bootstrapped startups
Valuations		Stock Market
Spending		IPO Market
Fundraising		GDP
Proceeds		Growth rates
Returns		

Table 5. Model Boundary Chart

The model is designed to explore the boom-and-bust behavior in venture capital. As such, for the characterization of this phenomenon, certain assumptions and limits were necessary.

1) Assumptions. The model has a few key assumptions including the following:
   - Homogeneity of market participants. Decision rules are the same for all the agents that belong to the same category (LPs, GPs, Entrepreneurs and Buyers)
   - A single fund-of-funds shared by all venture capitalists
   - Buyers enter the acquisition market gradually, following a diffusion of innovations type of pattern
   - Risk-free rate investments
   - Fixed ownership per company
   - Competition is the single cause in the price formation process

- Publicly available information

2) Time Frame. The model simulates a 20-year period. A sufficient period to observe the whole boom-and-bust cycle.

3) Limits. The model is purely qualitative since the availability of quantitative data to test and calibrate the model was very limited. There were three main sources for model conceptualization and formulation, namely: literature review, field interviews, and a case study. Thus, the model relies to a significant extent on variables and assumptions for which no numerical data was available. Therefore, industry averages and best judgment were used to estimate a few key parameters.

4) Level of aggregation. The model represents the aggregate venture capital industry. This level of aggregation was chosen to meet the goals of the model as outlined earlier in this chapter. Therefore, the model does not represent heterogeneity in market participants. Modeling heterogeneity requires additional (quantitative) data and increases the complexity of the model. As discussed earlier, the added complexity makes the modeling process more difficult in terms of time, cost and effort. Weighing these factors, it was concluded that assuming market participant homogeneity is justified for the scope of this model. For similar reasons, details about individual companies' financial metrics for revenues, stock price, and growth projections were not modeled.

It is important to note that the boundaries chosen can affect the reach and extent of the insights that can be derived from the model. Most importantly, the exclusion of the stock and IPO markets, the absence of quantitative data about historical venture capital metrics, and the assumption of agent homogeneity are constraints that make it more difficult for the simulated venture capital industry to reproduce the real historical behavior.

6 Model Testing

An important step of the modeling process is model testing. Tests are designed to discover the flaws in a model and set the stage for improved understanding. Does the model reproduce the problem behavior adequately for its purpose? And more importantly, does it reproduce the problem behavior for the right reasons? The objective of model testing is to resolve inconsistencies between the model and reality.

System Dynamics modelers contend that models should meet the "basic laws of physics". What they mean by this is that violations of physical laws, such as the conservation of energy, arise because the model does not appropriately capture the stock and flow structure of the system. Models should also be robust under extreme conditions. Models must be tested under extreme conditions, even if those conditions may never have been observed in the real world. What should happen to investments in a simulated venture capital industry if funding is suddenly reduced to zero? What should happen in the model if the pre-money values suddenly rise by a billion? What should happen if the stock of portfolio companies is suddenly increased by 1000%? As noted by Sterman (2000, Ch. 3) "Even though these conditions have never and could never be observed, there is no doubt about what the behavior of the system must be". Without money, new investments must fall to zero; with valuations one billion times higher, the demand for companies must fall to zero; with a huge surplus of portfolio companies, funding must soon fall to zero but cannot become negative.

Consistent with best-modeling practice for model testing, the model was tested following Forrester and Senge (1980) principles for structure and robustness tests. The purpose of structural tests is to assess the structure and parameters of the model directly, without examining relationships between structure and behavior.

1) Boundary-adequacy (structure) test. This test asks whether or not model aggregation is appropriate and if the model includes all relevant structure. To meet this test, the model develops a plausible hypothesis of the problem behavior based on evidence found from field research conducted by the corresponding author.
2) Structure-verification test. This test points at comparing the structure of the model directly with the structure of the real system that the model represents. In order to pass this test, the model must not contradict knowledge about the structure of the real system. This test was performed during the review stage of this research with individuals highly knowledgeable about the corresponding parts of the real system. The results for this test were satisfactory.
3) Extreme-conditions test. This test uses extreme combinations of the state variables (stocks) in the system being represented. The model has been tested with a variety of extreme input conditions and appears to be robust. A few examples of tests performed include: When Funds reach zero, new investments are zero and Portfolio Companies go to zero. When Portfolio Companies are increased 1000 times, Funds decrease to zero. When Buyers are decreased to zero, there are no exits and investments decrease to zero. When tested with pre-money valuations that exceed 1000 times the normal value, the model makes it impossible to make those investments as the balancing impact of the available funds outweighs the desire to invest.
4) Dimensional-consistency test. A mundane but basic test, the dimensional-consistency test entails the dimensional analysis of the model's rate (flow) equations. The model includes variables and equations with real-life meaning. The equations were assessed with dimensional analysis software and satisfy this test.

The above tests confirm that the model preserves physical laws such as the conservation of energy and there are no unit inconsistencies. The stock-and-flow structure is assessed conforming to good modeling practice. Appropriate time delays, constraints and bottlenecks are taken into account. More specifically, decision-makers in the model are assumed to act rationally within their cognitive limitations. Decisions are based on measurable data that is readily available to the decision-maker.

7 Conclusions

The results obtained throughout the modeling process and the simulation runs suggest the following conclusions:

1) The boom-and-bust phenomenon in venture capital may be intrinsic to the structure of the system. This dynamic may be explained by three key feedback processes: a positive loop linking deal-making with exits accelerating the growth of investments, a negative feedback linking exits with acquisitions that causes the growth to slow as market limits are approached, and another negative feedback that controls for under-performing deals.
2) The simulation results suggest that "faster is not always better". Investors who pursue aggressive exit strategies exacerbate the boom and bust dynamic resulting in poor industry performance. The reason is found in a strong positive feedback linking liquidity activity (i.e., successful exits) with investment and fundraising actions. There is no incentive for conservative exit strategies either, at least when investors are faced with time pressures. Conservative exit strategies tend to maintain the system in equilibrium but are inefficient to produce the desired returns in a timely fashion.
3) Time delays matter. The simulation results show, qualitatively, how the shortening and lengthening of critical time delays in the investment process (due diligence delay and liquidity delay) have a significant impact on both the boom-and-bust dynamic, and the returns performance of the industry as a whole.
4) Under certain circumstances, such as price bubbles, VCs tend to behave as momentum investors by using positive feedback investment strategies that greatly contribute to the generation of the boom-and-bust dynamic. Institutional investors also have their share during bubbles since they increase commitments into VC funds during market peaks with the expectation of realizing the returns they are observing "right now" (Sahlman, 1998). Evidence drawn from extensive document review, intensive interviews, and a case study suggests that investors ignore critical time delays and feedbacks that generate the problem behavior.
5) This study gives insight on why the over-supply of capital produces poor returns performance. First, increasing inflows of capital create a pressure on VCs to invest in higher number of deals or at higher valuations. Second, on the aggregate, exit valuations are not necessarily correlated with deal valuations. Therefore, the greater the pre-money valuations, the lower the overall returns performance.

8 Future research

Further research efforts can be made towards expanding the model and exploring the dynamics of venture capital investment in different directions.

1) Feedbacks due to deal quality. During academic reviews of the existing model several recommendations were made about the existence of diminishing returns due to deal quality erosion. This effect relates the competitive pressures that lead VCs to increase deal inflows while slowly decreasing the quality of the deals. One possible explanation is that variable delays in the investment process may introduce undesired effects in deal-making quality (e.g., the shorter the due diligence, the lower their quality, ergo the lower the likelihood of a successful exit). Such phenomena should be explored in more detail and would require additional field research to explore how the variability of delays in the VC investment process interacts with deal quality. Therefore, it would be interesting to explore the nature of the feedback loops that link deal inflows with the sources of deal quality erosion and the elastic limits of their interactions.
2) Firm level model of venture capital investment. The present model has been designed to show the aggregate behavior of the VC industry. It does not model the individual firm. Modeling an individual firm is interesting for investors since they are concerned on the performance of the individual firm rather than the industry. This model could be expanded to explore the performance of a single VC firm interacting in the industry. By coupling a firm-level module into the industry model it would be possible to test investment strategies in the individual firm and assess which strategies can give it the best payoffs by outperforming the industry indexes.
3) Investor Heterogeneity. Further research should explore the effect of investor heterogeneity in industry performance. Disaggregating the model to enfold different investor types trading in the venture capital market would be a step towards this endeavor. Capturing different parameters for investors' decision rules would be useful to better understand the system behavior in a more realistic setting where investors have different aggressiveness profiles. Additionally, to model heterogeneity in a system dynamics model it would be necessary to use advanced features of the simulation software (e.g., subscripts) not available on the academic version (freeware) used for this study.
4) Dynamic decision-making experiments. The model presented in this paper could be usefully augmented to develop a "management flight simulator" or a simulated decision environment to engage subjects in experiments where they control decision tasks, such as investment decisions. This could be achieved by developing a flight-simulator of a venture capital market. The objective would be to test the "Misperceptions of Feedback" hypothesis assessing subjects' investment performance with respect to benchmark by controlling for feedback complexity (e.g., time delays). Previous research has investigated dynamic decision-making with a similar control task paradigm (Sterman, 1989; Paich and Sterman, 1993; Bakken 1993; Diehl and Sterman, 1995). In such

studies, feedback complexity has been found to reduce task transparency and degrade subject performance compared to benchmark.

Furthermore, considering the relevance of venture capital to areas such as finance and entrepreneurship, a flight-simulator might result in a very attractive tool to use in MBA courses where students could "learn-by-doing".

1) VC investment cycles. Several practitioners and academics highlighted the importance of a better understanding of the cyclical nature of venture capital markets. As such, the boom and bust behavior of venture capital is part of a larger and more complex phenomenon of VC market cycles. Previous research comments on the apparent cyclic nature of VC markets (Sahlman, 1998; Lerner, 2002). However, still little is known about the sources that generate such undesired fluctuations.

   It is true that the overall economy rises and falls with the business cycle, and these movements may induce some corresponding fluctuation in financial markets. Yet VC markets exhibit cycles with different periods (10-20 years), that are not necessarily entrained to the business cycle. This evidence suggests that a feedback structure endogenous to the VC market may be responsible.

   Previous research in the SD tradition has showed satisfactory results in shedding more light on the question of cyclical markets. For example, in commodity cycles, Meadows (1970) shows that the fluctuations arise from the interaction of time delays in production and capacity acquisition, suggesting that the commodity cycles are endogenously generated. More recently, a study by Liehr et al. (2001) models the cycles in the airline industry resulting from aircraft utilization, new aircraft lead-times, and the delayed recognition of over-capacities.

   From this research opportunity, one interesting question arises which could have important policy implications. What is a sustainable rate of VC investment in a national economy that can avoid VC fluctuations?

As a final note, this research effort has attempted to show with a formal model how locally rational decisions where each agent seeks to maximize his profit, may lead on the aggregate, to a global demise of the complete system. The agents fail to appreciate the dynamics of their decisions in terms of short-term and long-term outcomes. As Sterman puts it: "The invisible hand sometimes shakes" (Sterman, 2000, p. 791)

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Appendix 1. Figures

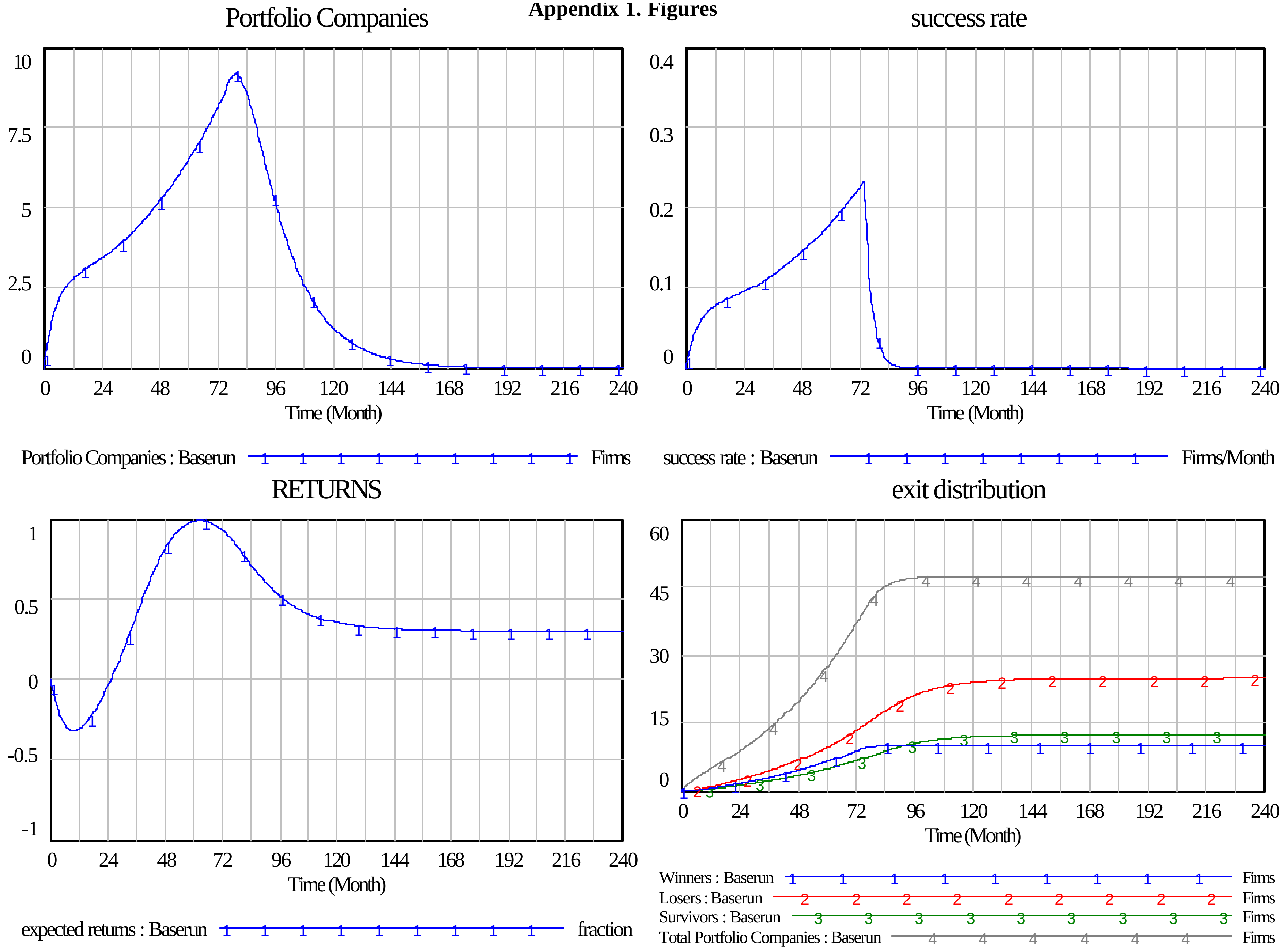

Figure 9. Summary of performance measures for base run

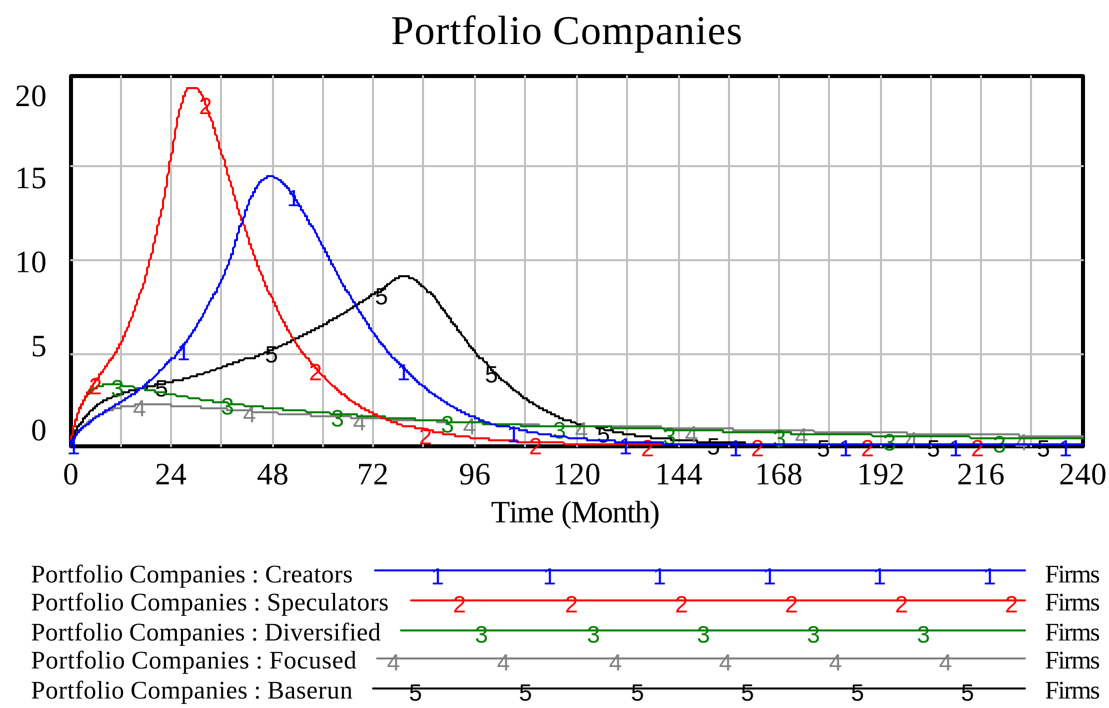

Figure 10. Portfolio Companies

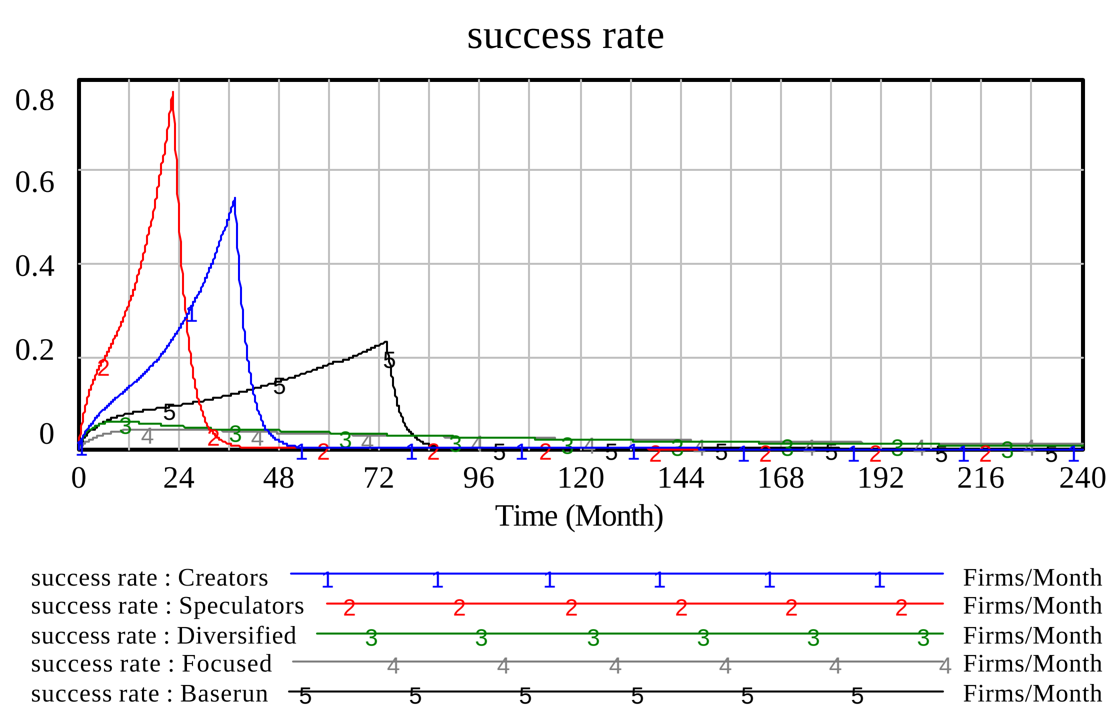

Figure 11. Success Rate

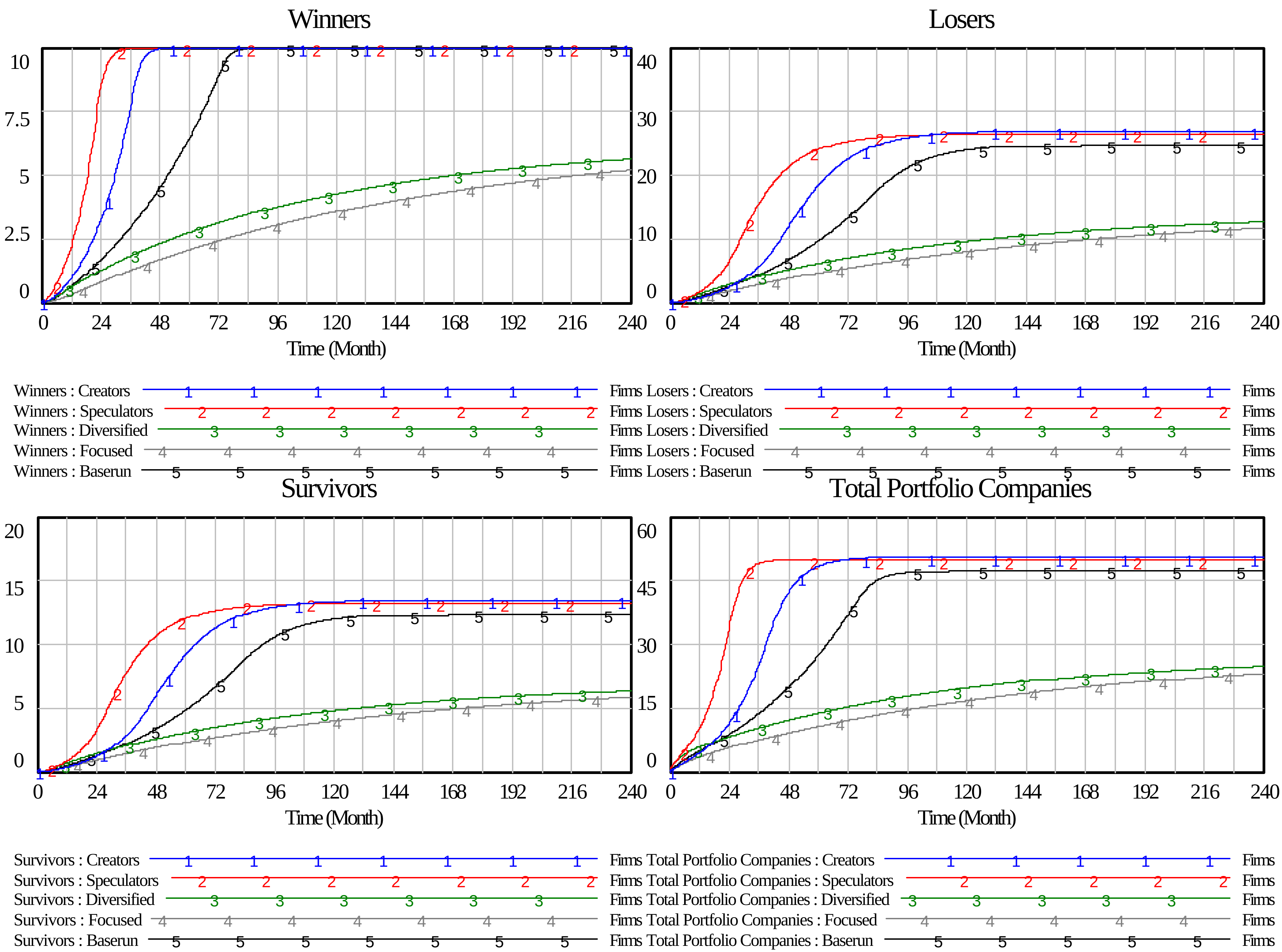

Figure 12. Outcome Distribution

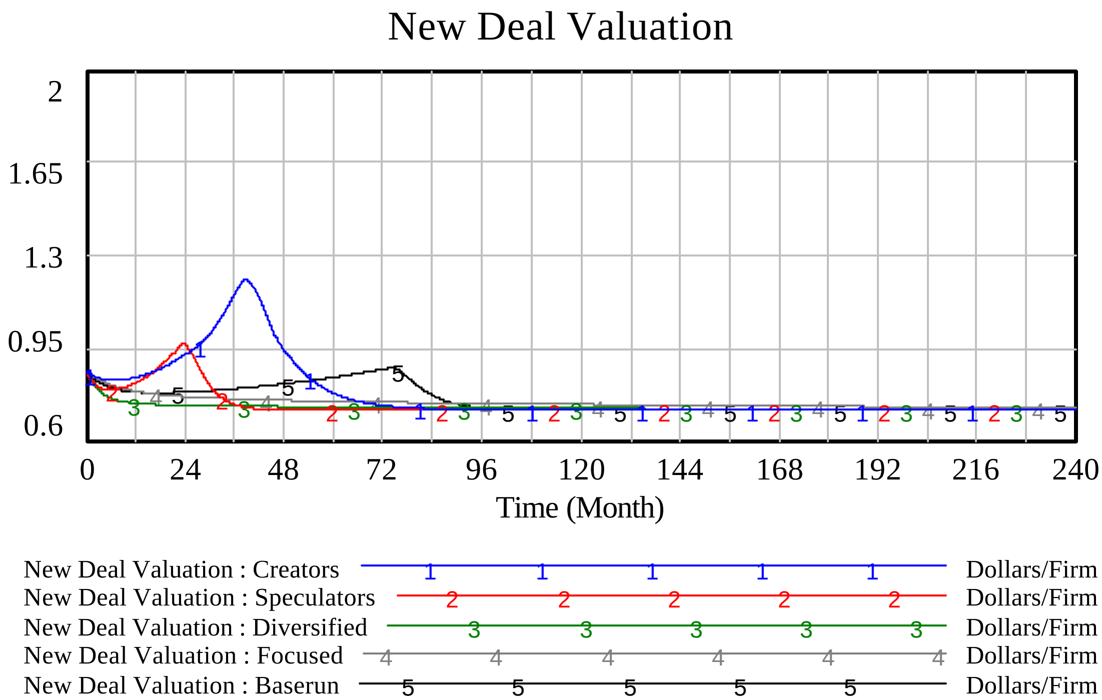

Figure 13. Pre-Money Valuations (New deal)

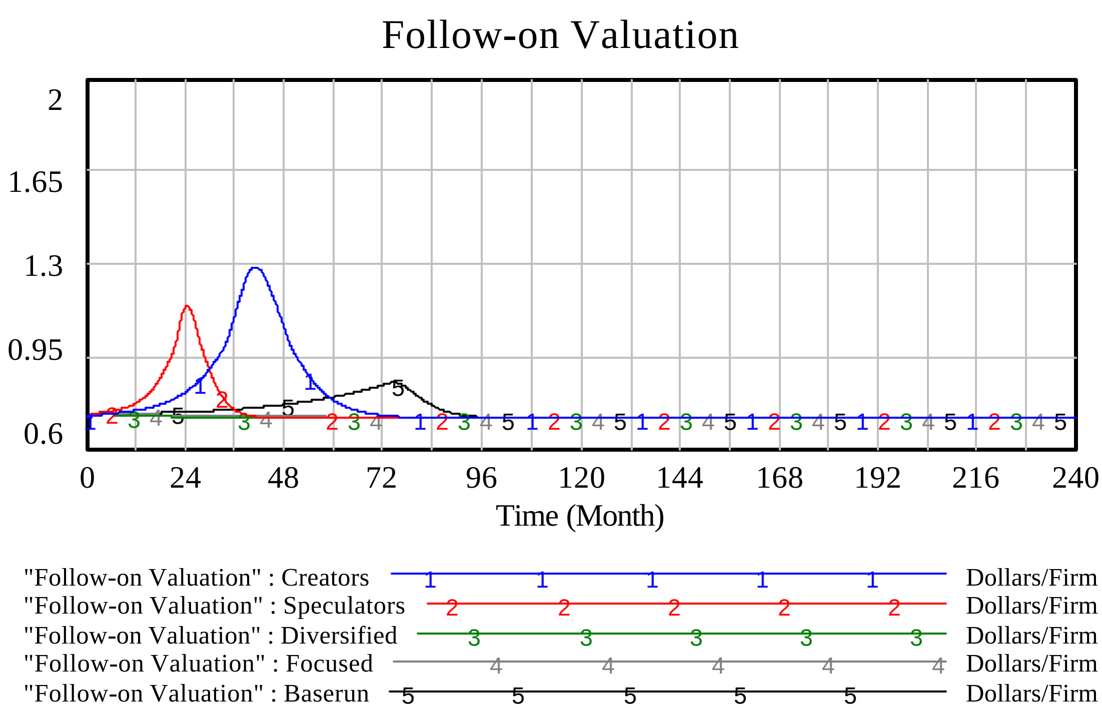

Figure 14. Pre-Money Valuations (Follow-on)

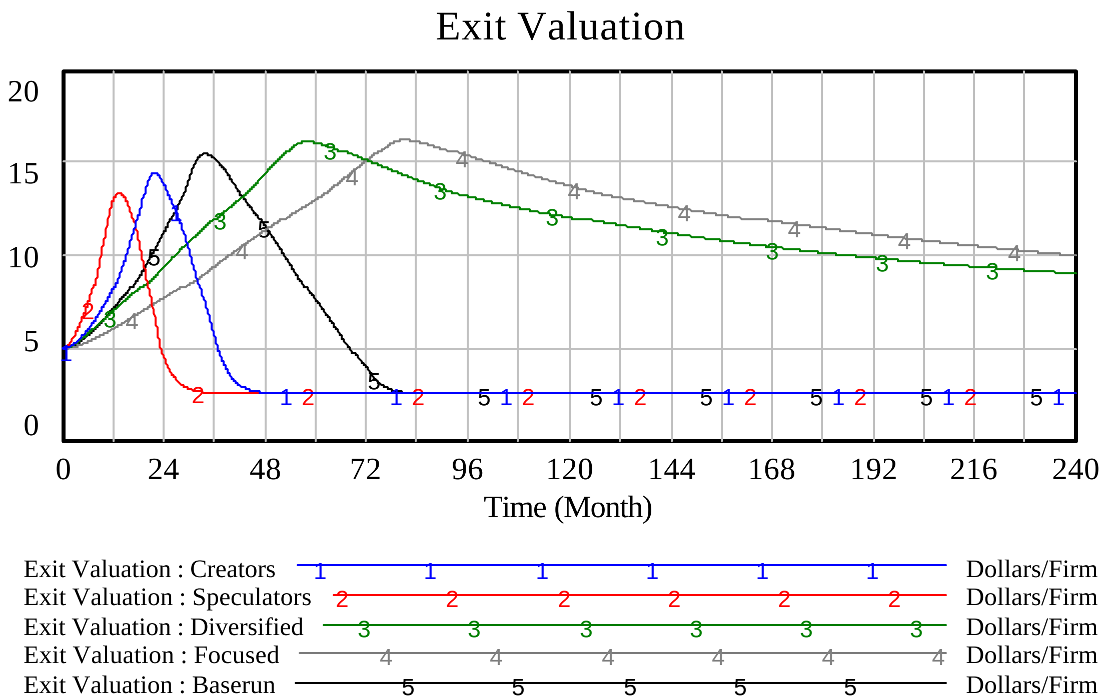

Figure 15. Exit Valuations

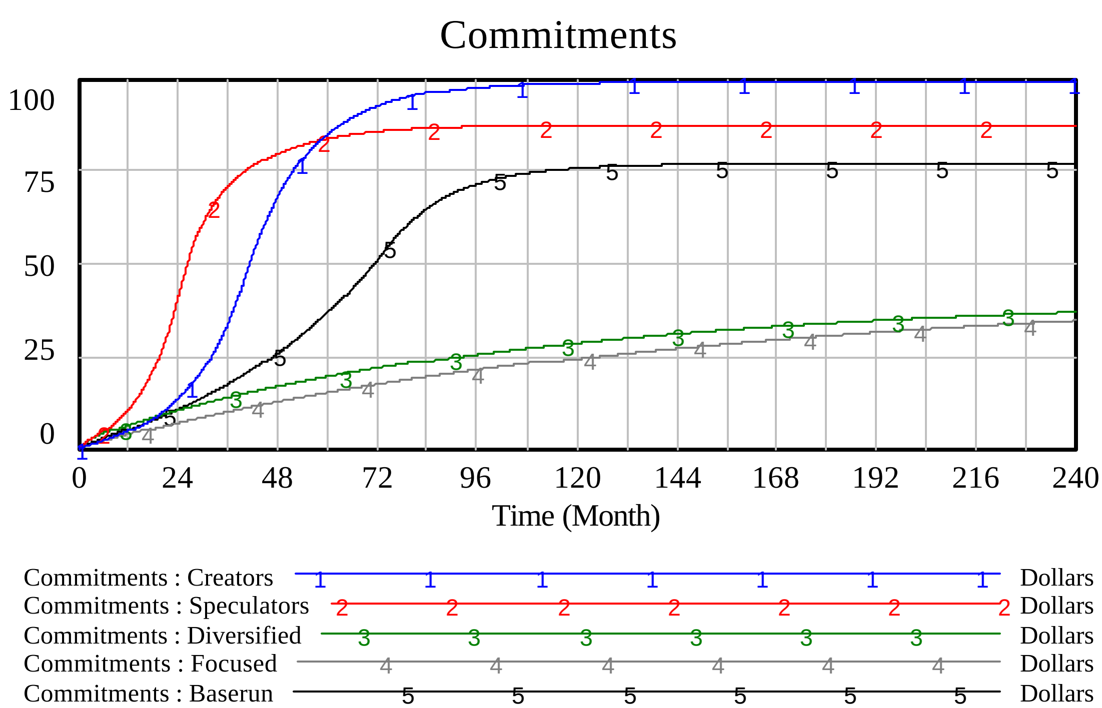

Figure 16. Commitments

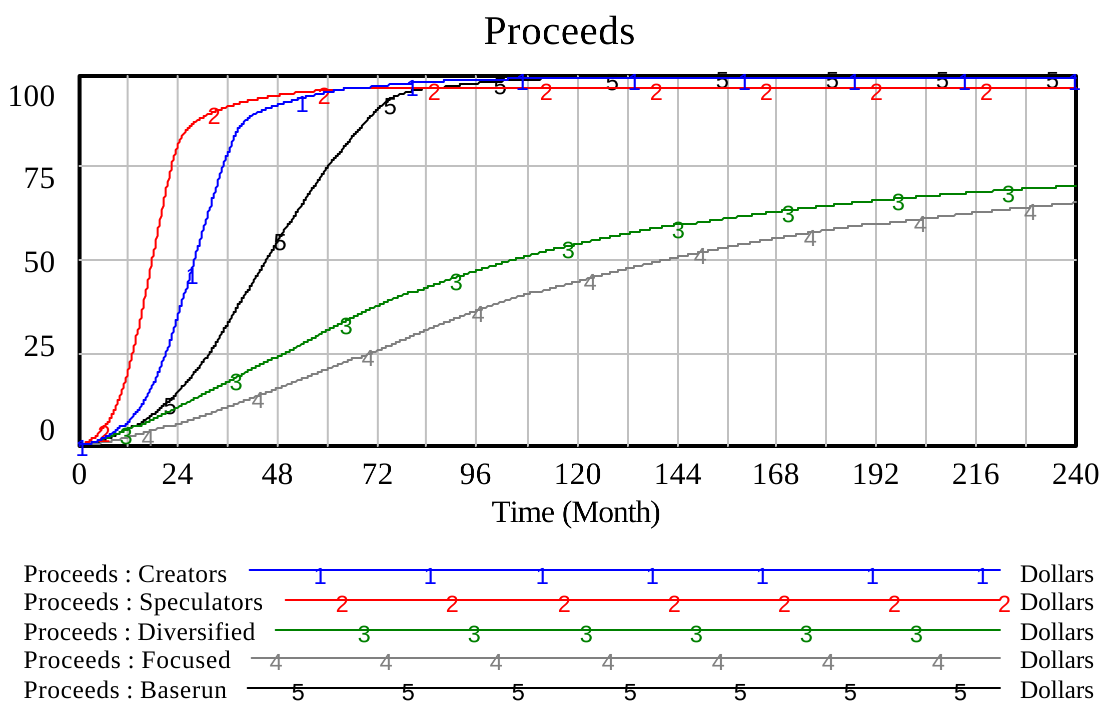

Figure 17. Proceeds

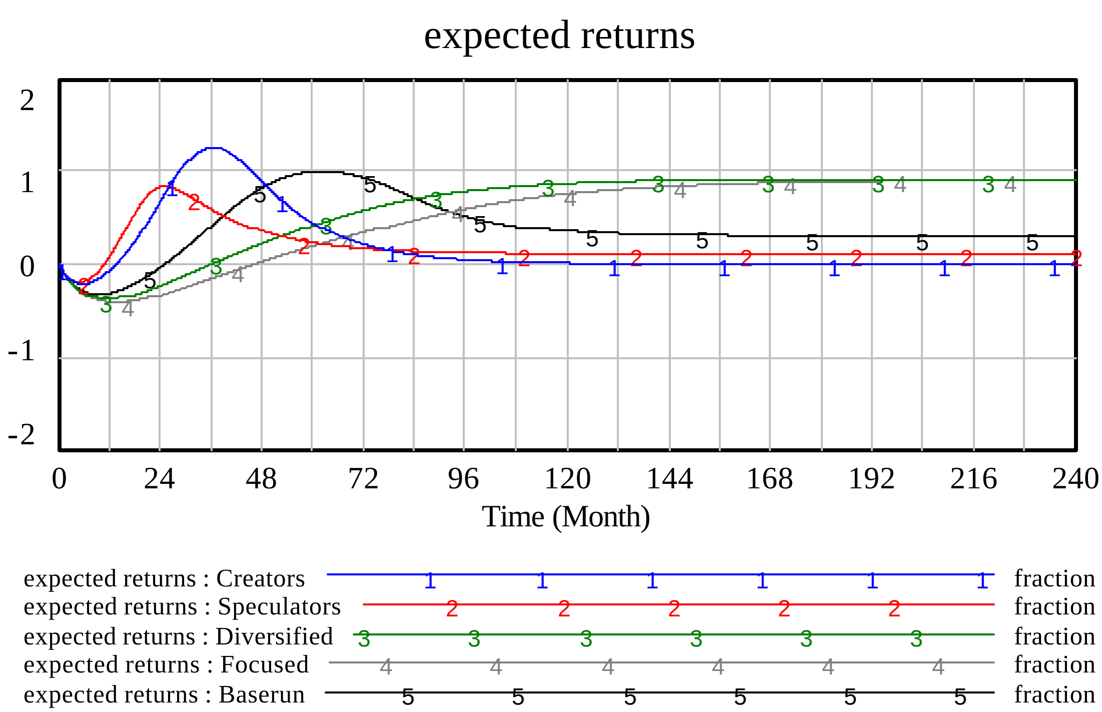

Figure 18. Returns

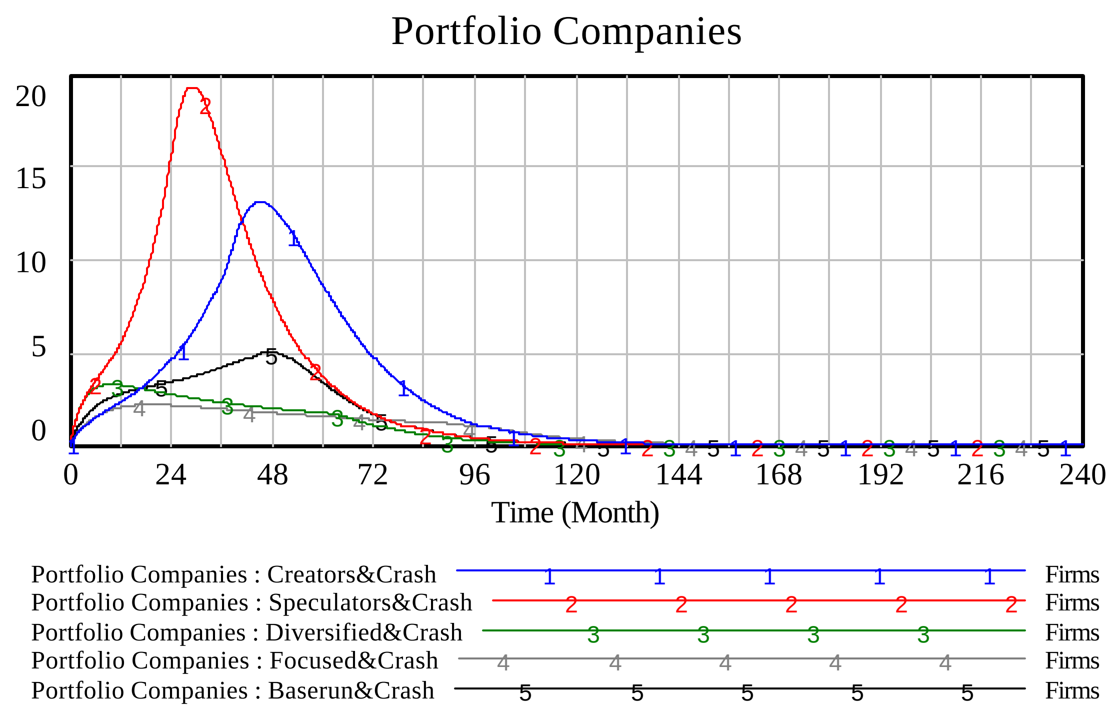

Figure 19. Portfolio companies with stock market crash

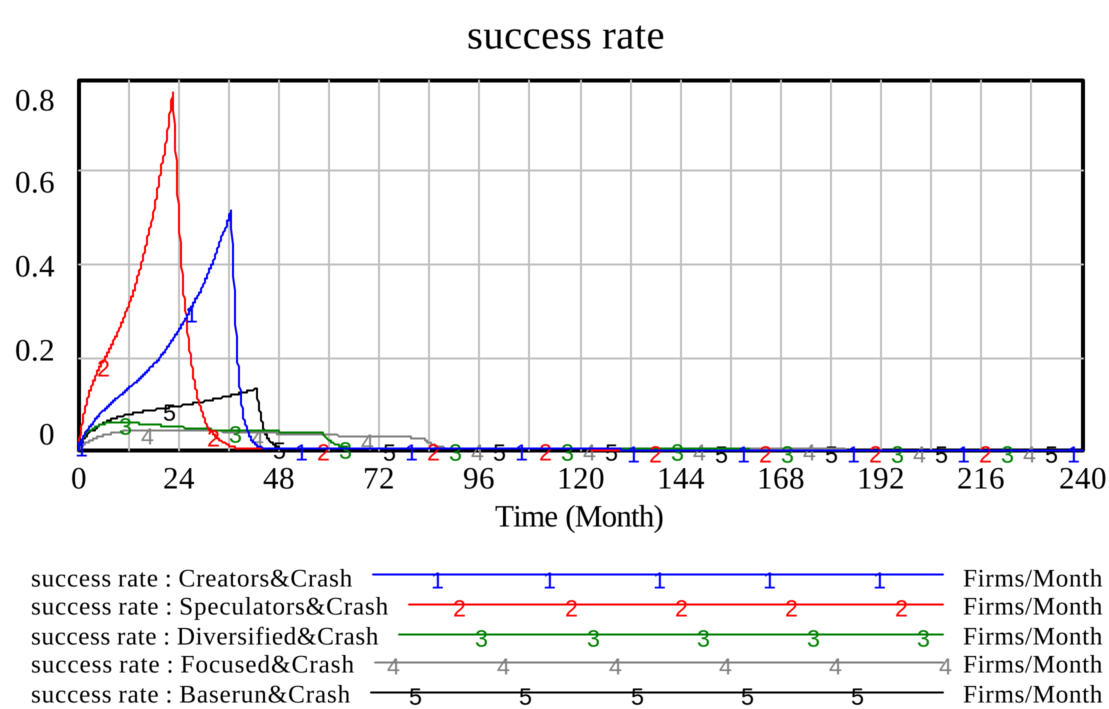

Figure 20. Success rate with stock market crash

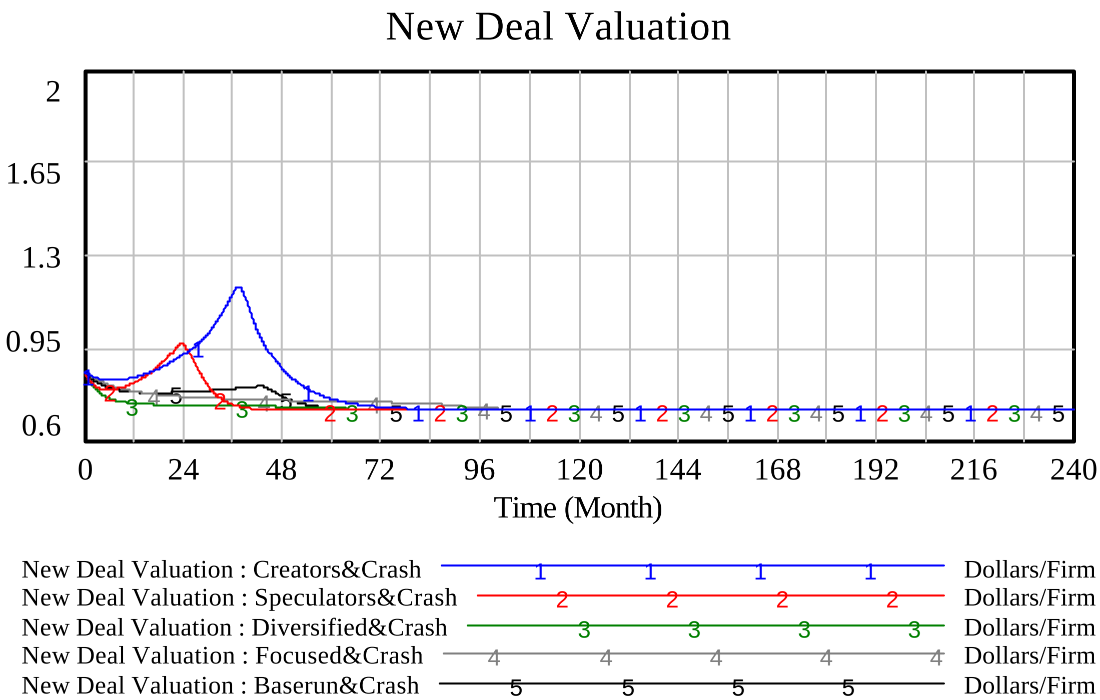

Figure 21. Pre-Money Valuations (New deal) with stock market crash

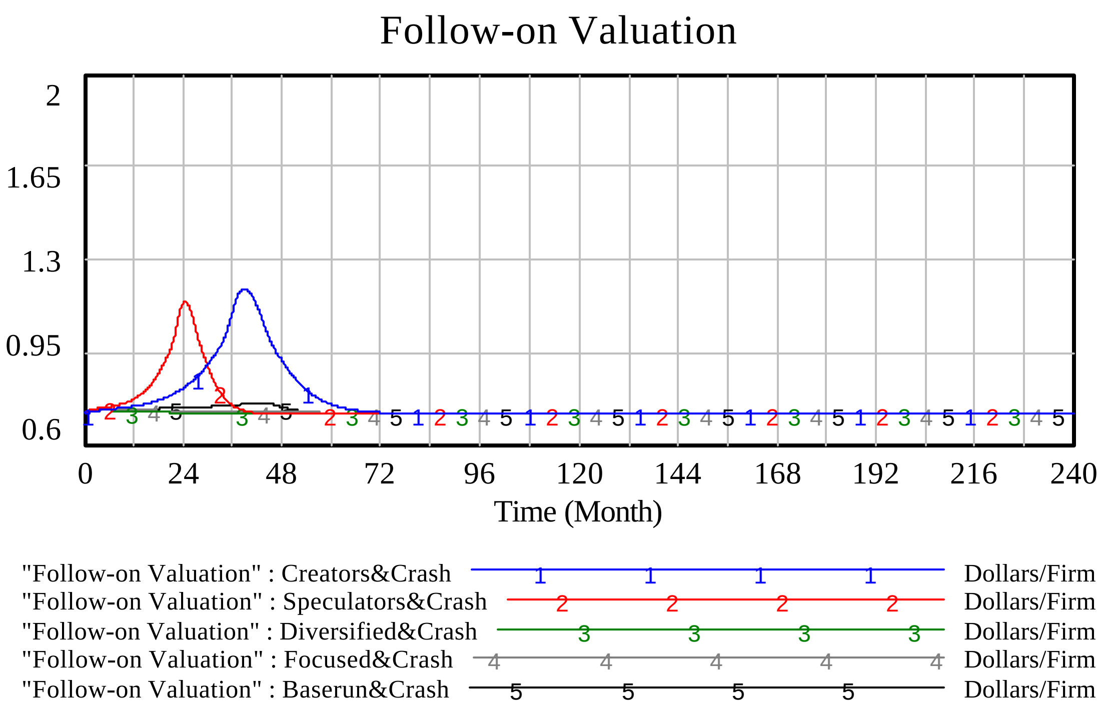

Figure 22. Pre-Money Valuations (Follow-on) with stock market crash

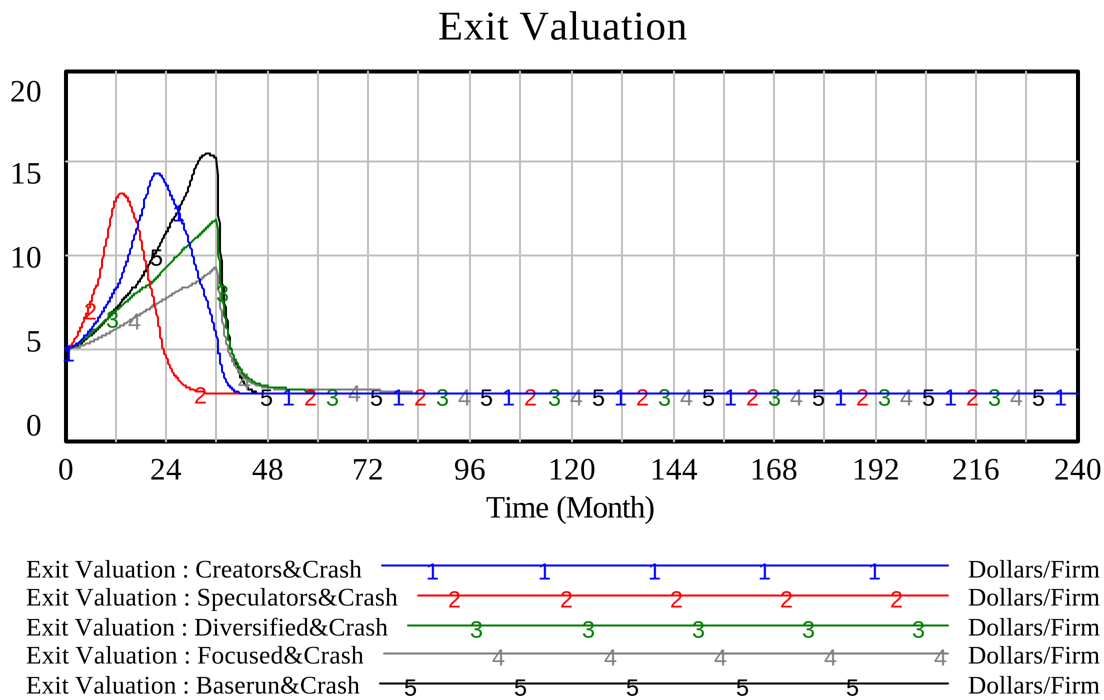

Figure 23. Exit valuations with stock market crash

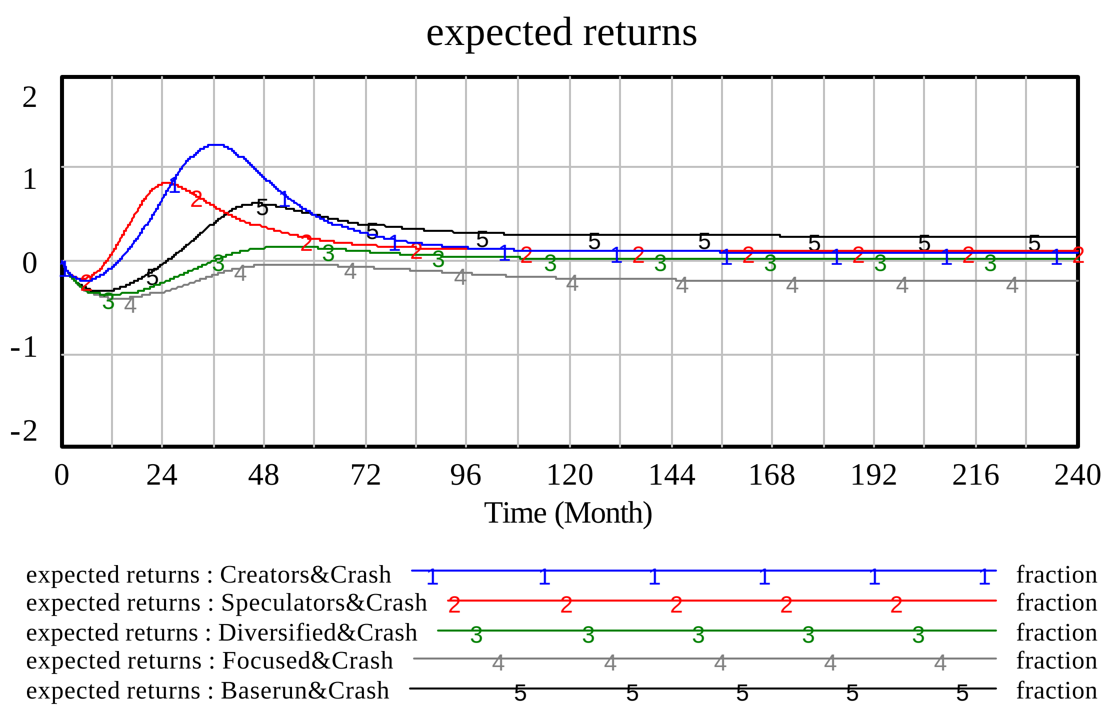

Figure 24. Returns with stock market crash

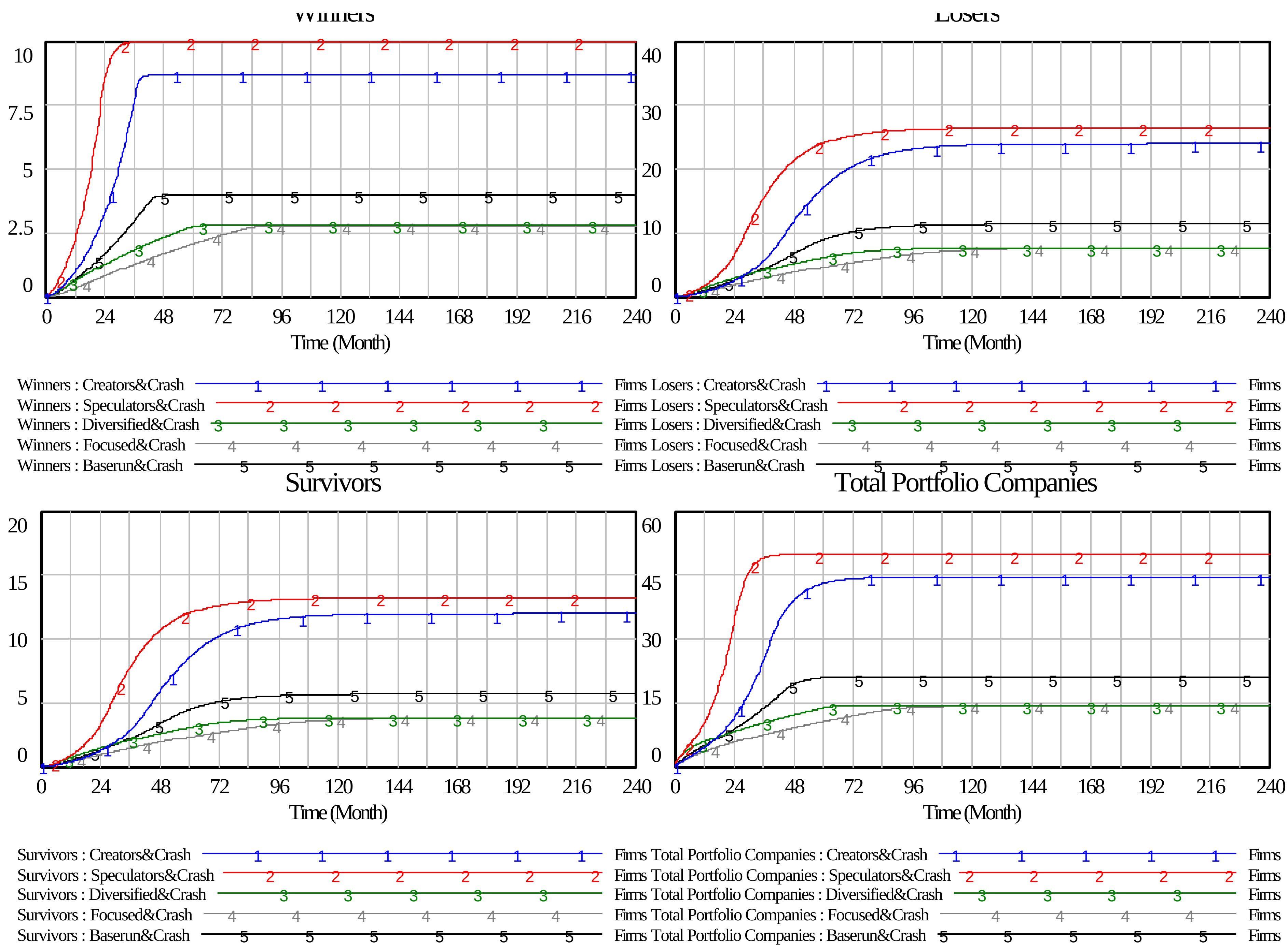

Figure 25. Outcome distribution with stock market crash

Appendix 2. Real and simulated reference modes for the disk-drive industry

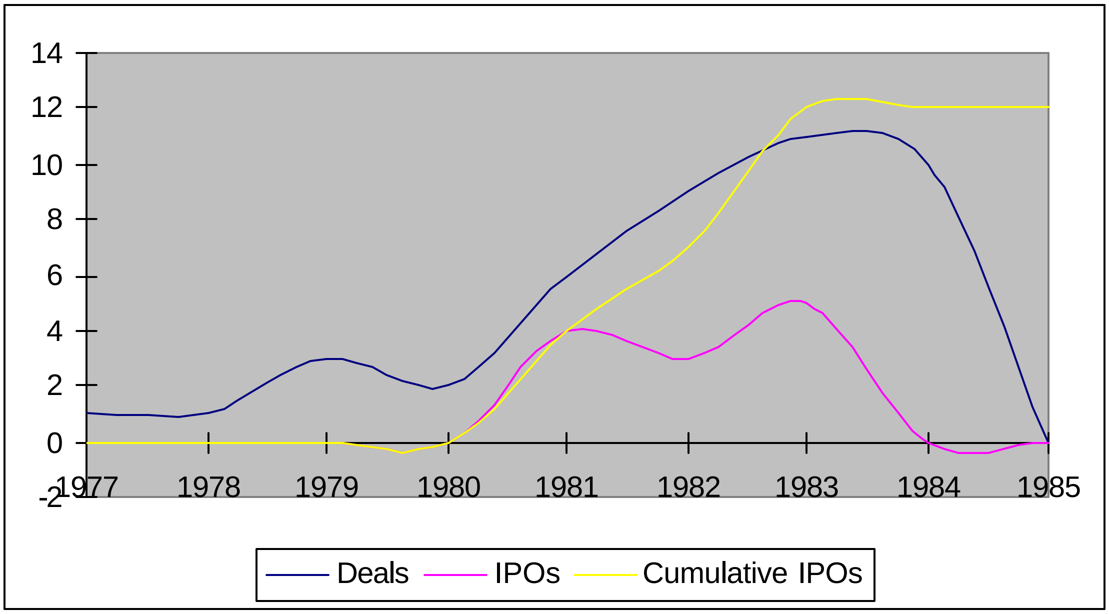

Figure 26. Data from VC investment in disk-drive industry (source Sahlman et al., 1986)

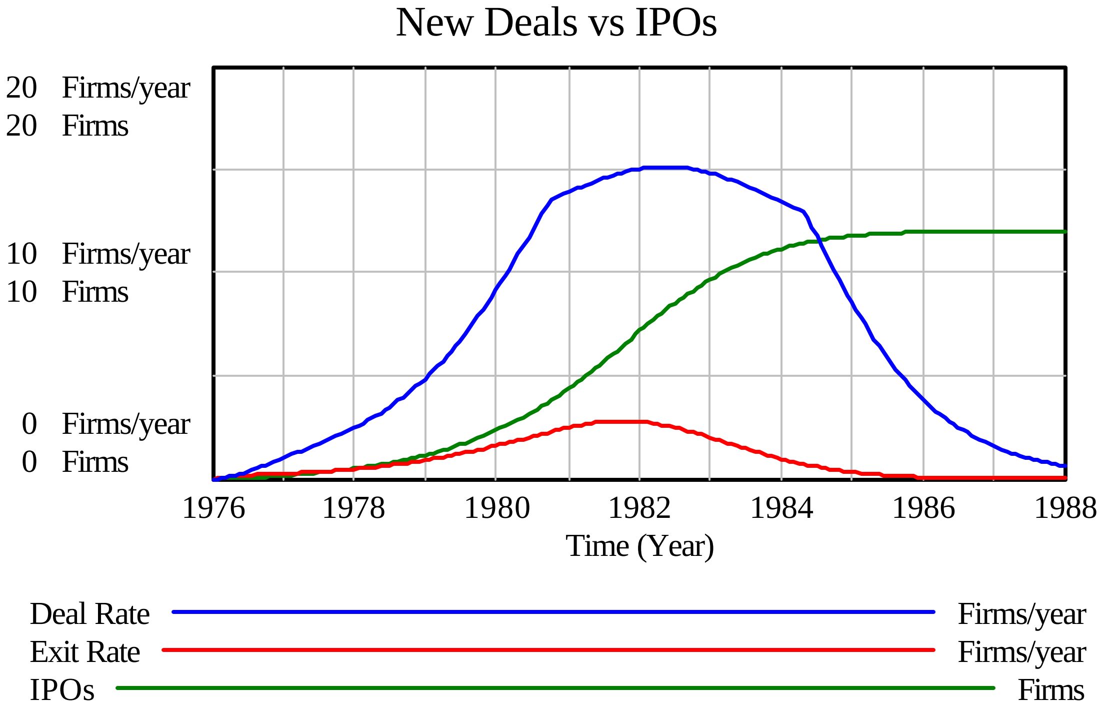

Figure 27. Simulated results from generic model of VC investment (source Yepez, 2004)

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