**VENTURE CAPITAL INVESTMENT DYNAMICS:
MODELING THE OTTAWA BOOM-AND-BUST**

by

Carlos Yepez

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of
Master of Engineering in Telecommunications Technology Management

Department of Systems and Computer Engineering
Carleton University
Ottawa, Canada, K1S 5B6

© Copyright 2004, Carlos Yepez

Library and
Archives Canada

Bibliothèque et
Archives Canada

Published Heritage
Branch

Direction du
Patrimoine de l'édition

395 Wellington Street
Ottawa ON K1A 0N4
Canada

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence

ISBN: 0-612-97468-5

Our file Notre référence

ISBN: 0-612-97468-5

The author has granted a non-exclusive license allowing the Library and Archives Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

Canada

PAGINATION ERROR.

TEXT COMPLETE.

ERREUR DE PAGINATION.

LE TEXTE EST COMPLET.

ABSTRACT

By the end of the 1990s a large amount of venture capital was invested in the telecommunications and internet industries in North America. However, during the first years of the new millennium, venture capital investment in these industries collapsed. The purpose of this study is to examine this boom-and-bust phenomenon in venture capital investment and to explain why it happens. Specific issues addressed were: the causes underlying the rise and decline in venture capital investment, the key variables and relationships of the venture capital investment process, the key feedback processes driving venture capital investment activity, the behavior of market participants and its impact on the venture capital system, and the role of time delays on venture capital industry performance. The study uses data from 10 practitioner interviews and the case of the venture capital boom-and-bust that occurred in Ottawa between 1998 and 2003. An exploratory 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 relationship of investment speed with venture capital industry performance. The results of this research suggest that the boom-and-bust has an endogenous component, which is found in the interaction of positive feedbacks that drive growth and negative feedbacks that lead to decline. Finally, simulations of the model demonstrate that speed impacts both short and long-term performance of the VC industry as a whole.

Acknowledgements

Researching and writing this thesis taught me much. I am particularly grateful to my supervisor John Callahan, whose open mind led us to try a new way of doing things. I am also grateful to Tony Bailetti for reminding me of my call to duty, and Samuel Ajila for his advice and encouragement. From all of them I learned the most during the past two years.

Pioneering to apply the tools of the system dynamics method in my program resulted in a very rewarding experience. However without the guidance, support, and advice of numerous people I would be unfinished. Arif Mehmood provided a helping hand at the right moment. Eliot Rich significantly influenced my work, even though we met only a few but key times. Paulo Goncalves gave me a head start into the System Dynamics community. I also met many other great people during this journey, a fleeting experience with the System Dynamics Group at MIT – Hazhir, Gokhan, Jeroen and Mila- was fascinating, and the supporting environment with the National Capital System Dynamics Group – Joel, Gordon, Lanhai and Bob- was always helpful.

I am indebted to my family -Eliana and Kamran, Maria Alejandra and Denis, Juan Pablo and Sandra - who were fundamental for giving me sustenance throughout this journey, and my friends –Alison, Piedad, Abdul, Jairo and Nivia- who kept me in good spirits.

Finally, I dedicate this thesis to my Parents and my Tia in Colombia, whose love and faith in me are invaluable.

Chapter Headings

1	INTRODUCTION	10
2	LITERATURE REVIEW	18
3	RESEARCH METHOD.....	36
4	A CASE STUDY ON VENTURE CAPITAL INVESTMENT DYNAMICS	49
5	ELEMENTS OF A DYNAMIC CAUSAL MODEL	73
6	A SYSTEMS MODEL OF VENTURE CAPITAL INVESTMENT DYNAMICS	83
7	MODEL REVIEW	89
8	MODEL TESTING.....	102
9	MODEL SIMULATION AND SCENARIO ANALYSIS	109
10	CONCLUSIONS, LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH.....	123
	References	140
	Glossary	152
	Appendix 1. Simulation results	153
	Appendix 2. Model review booklet.....	164

Table of Contents

1	INTRODUCTION	10
1.1	Relevance	10
1.2	Objective	11
1.3	Rationale	11
1.4	Background	13
1.5	Research Questions	14
1.6	Audience	15
1.7	Contributions	15
1.8	Organization.....	16
2	LITERATURE REVIEW	18
2.1	Venture Capital	18
2.1.1	Venture capital investments.....	18
2.1.2	The venture capital cycle	20
2.1.3	The venture capital investment process	21
2.1.4	Organizational structure of a venture capital firm.....	22
2.1.5	Types of private equity financing	23
2.1.6	Venture capital decision processes	25
2.2	Competitive Strategy	26
2.3	Behavioral Decision Theory	28
2.3.1	Bounded Rationality	28
2.3.2	Misperceptions of Feedback	29
2.3.3	Behavioral Finance	30
2.4	Boom-and-Bust phenomenon	32
2.5	Lessons Learned.....	34
3	RESEARCH METHOD.....	36
3.1	Rationale for using System Dynamics	38
3.2	Research approach.....	39
3.3	Implementation	42
3.3.1	Problem definition	43
3.3.2	Initial System Conceptualization.....	44
3.3.3	Model formulation	45
3.3.4	Review of formal model and scenario analysis	46
3.4	Summary.....	48
4	A CASE STUDY ON VENTURE CAPITAL INVESTMENT DYNAMICS	49
4.1	VC and geographical clusters	49
4.2	Preconditions	55
4.2.1	The Internet.....	55
4.2.2	Telecom Deregulation.....	55
4.2.3	Telecom Wars: Cisco, Nortel, Alcatel and Lucent	55
4.2.4	Public market	57
4.3	VC Boom-And-Bust in Ottawa.....	59
4.3.1	Beginning.....	59
4.3.2	Cambrian.....	62

4.3.3	Momentum.....	63
4.3.4	Inertia.....	66
4.3.5	Meltdown.....	68
4.3.6	Aftermath.....	70
4.4	Discussion.....	70
5	ELEMENTS OF A DYNAMIC CAUSAL MODEL	73
5.1	Background	73
5.2	Fieldwork on the dynamics of venture capital investment	74
5.2.1	Fundraising.....	76
5.2.2	Investment.....	77
5.2.3	Exiting.....	79
5.3	Key delays.....	80
5.3.1	Fundraising.....	80
5.3.2	Due diligence	81
5.3.3	Liquidity.....	82
6	A SYSTEMS MODEL OF VENTURE CAPITAL INVESTMENT DYNAMICS	83
6.1	Subsystems in a dynamic causal model.....	83
6.2	Resource structure of the venture capital system.....	85
6.3	Behavioral foundations of the causal model.....	86
6.4	Dynamic Hypothesis	87
7	MODEL REVIEW	89
7.1	Approach to Model Review	89
7.2	Interview Protocol.....	90
7.3	Interview Administration.....	92
7.4	Expert reaction to model structure	93
7.5	Indicated changes to the model.....	100
8	MODEL TESTING.....	102
8.1	Model Goals.....	102
8.2	Model Boundary	103
8.3	Model Testing	106
8.4	Further Testing.....	108
9	MODEL SIMULATION AND SCENARIO ANALYSIS	109
9.1	Base Run	109
9.1.1	Key parameters	109
9.1.2	Model Behavior Metrics	110
9.1.3	Base run Behavior	111
9.2	Scenario Analysis.....	111
9.2.1	Investment Speed Scenarios	111
9.2.2	Comparison of VC investment speed scenarios with base run	113
9.2.3	Market Crash Scenario.....	117
9.3	Discussion.....	120
10	CONCLUSIONS, LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH.....	123
10.1	Key findings	123
10.1.1	Review of the literature.....	123
10.1.2	Intensive interviews and historical document review	124

10.1.3	Modeling	126
10.1.4	System dynamics simulations	127
10.2	Answers to Research Questions	129
10.3	Conclusions	132
10.4	Contributions	133
10.5	Limitations	134
10.6	Future research.....	136
	References	140
	Glossary	152
	Appendix 1. Simulation results	153
	Appendix 2. Model review booklet.....	164

List of Tables

Table 1.	Research objectives and approaches	37
Table 2.	Research Timetable.....	43
Table 3.	VC Investment Activity in the Ottawa Region.....	51
Table 4.	Ottawa region companies among the Top 10 VC deals made in Canada (by size), 1998-2001	53
Table 5.	Ottawa region companies among the Top 10 VC deals made in Canada (by size), 2002-2003	54
Table 6.	Main private equity investment groups active in Ottawa prior to 1998	61
Table 7.	Deal Making Loop Indicator Reactions	94
Table 8.	Fundraising Loop Indicator Reactions.....	95
Table 9.	Market Saturation Loop Indicator Reactions	96
Table 10.	Competition Loop Indicator Reactions	97
Table 11.	Demand Loop Indicator Reactions	99
Table 12.	Causal Loop Explanation Reactions	100
Table 13.	VENTURE1 Model Boundary Chart.....	104
Table 14.	Parameter values for the VENTURE1 model.....	110
Table 15.	Scenarios based on Investment Speed	112
Table 16.	Summary results for investment speed scenarios	116
Table 17.	Summary results for investment speed scenarios with market crash.....	118

List of Figures

Figure 1. New venture financing lifecycle.....	19
Figure 2. Organizational structure of a limited partnership fund.....	23
Figure 3. Venture capital industry structure	27
Figure 4. Overview of the System Dynamics approach	39
Figure 5. NASDAQ composite	58
Figure 6. Stock performance of Cisco, Nortel, Lucent, and Alcatel (10 year)	58
Figure 7. VC Investment activity in Canada during 1998-2003	74
Figure 8. Subsystem diagram of the venture capital market.....	84
Figure 9. Dynamic resource view of the venture capital industry	85
Figure 10. Feedback structure of VC Investment	88
Figure 11. Summary of base run behaviors.....	154
Figure 12. Portfolio Companies.....	155
Figure 13. Success Rate	155
Figure 14. Outcome Distribution.....	156
Figure 15. Pre-Money Valuations (New deal)	157
Figure 16. Pre-Money Valuations (Follow-on)	157
Figure 17. Exit Valuations	158
Figure 18. Commitments	158
Figure 19. Proceeds.....	159
Figure 20. Returns.....	159
Figure 21. Portfolio companies with public market crash.....	160
Figure 22. Success rate with public market crash.....	160
Figure 23. Pre-Money Valuations (New deal) with public market crash	161
Figure 24. Pre-Money Valuations (Follow-on) with public market crash.....	161
Figure 25. Exit valuations with public market crash	162
Figure 26. Returns with public market crash.....	162
Figure 27. Outcome distribution n with stock market crash.....	163

1 INTRODUCTION

1.1 Relevance

Venture capital (VC) is a major source of funding for innovation. In the first quarter of 2000, VC disbursements equaled fully one-third of all money spent on the national R&D in the U.S. (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.

In North America, 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. However, during the early years of the new millennium, private equity markets contracted significantly. 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.

Historically, VC has been subject to dramatic swings of boom-and-bust behavior. The boom-and-bust phenomenon is defined as a sudden and significant rise 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 and Papastaikoudi, 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.

1.2 Objective

The persisting problem of the sharp swings in venture investment calls for a better understanding of the underlying drivers and implications of VC investment during periods of boom-and-bust.

The objective of this thesis is to develop and simulate a model of VC investment decision-making grounded on the system dynamics approach. The model relates market participants' decisions with overall VC industry performance, which is measured by the returns made from VC funds already deployed. The model suggests that the boom-and-bust phenomenon has an endogenous component, which is captured in the aggregate effect of market participants' intendedly rational decisions and their interactions leading to the unintended poor performance for the VC industry as a whole.

Market participants are the economic agents in a venture capital market. They include venture capitalists (VCs), institutional investors, entrepreneurs and buyers (e.g., public companies). 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.

This study attempts to enhance our understanding of the dynamics of VC investment by developing a qualitative model that describes how feedback processes among institutional investors, venture capitalists, entrepreneurs, and public investors may contribute to the generation of the boom-and-bust behavior observed in the VC industry.

1.3 Rationale

Researchers (Sahlman and Stevenson, 1986; Sahlman, 1998; Lerner, 2002) suggest that the boom-and-bust phenomenon in VC is driven by imbalances in supply and demand. ,

these studies 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 return 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. Along these lines, VC fundraising does influence investment decisions. Researchers have found (Gompers and Lerner, 2000) that there is a strong relation between the valuation of VC investments and the supply of capital 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 by 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' which pushes forward high levels of entrepreneurship and investment activities. Stein (2001) describes 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.

Drawing on the previous findings as a starting point, this study seeks to link extant theory and field interviews with domain experts to develop a system dynamics model to enhance our understanding of the dynamics of VC investment. This study develops a qualitative model that captures key feedback processes among market participants that helps us to better understand the generating components of the boom-and-bust in VC investment.

To the author’s knowledge, the present study is the first: i) to identify key feedbacks, time delays, and behavioral motivations of market participants in the VC market, ii) to implement them in a computer simulation model that captures the dynamic complexity of the VC system, and, iii) to design scenarios of investment speed that help us to better understand the sources of the problem behavior in the VC system.

1.4 Background

By the end of the 90s and the beginning of the new millennium, the VC industry went through a dramatic cycle of boom-and-bust. In the U.S., this cycle was mainly driven by the so-called ‘Internet bubble’ (Perkins and Perkins, 2001). During the Internet bubble, high-tech investments reached such unequalled valuations, that soon after they were followed by an unrivaled destruction of companies’ value. In the Canadian venture capital industry, a similar phenomenon took place. However the rise and fall of venture capital in Canada was not only a byproduct of the Internet bubble. Very little is known about the particular context that led to the boom-and-bust phenomenon in the Canadian VC industry.

To study the VC industry in Canada, this research explores VC activity in the telecom cluster in the Ottawa-region. Given the close relationship between venture capital and entrepreneurial activity, it is reasonable to surmise that VC investments are geographically localized around technology-based industrial clusters (Saxenian, 1994; Stuart and Sorenson, 2003). These finding suggests that VC investment activity concentrates in relatively small and usually well dispersed geographic areas that form regional clusters of firms. Therefore, studying the context of investment activity in a technology cluster is relevant to better understand the set of circumstances and conditions that explain particular modes of VC investment behavior.

In the Canadian context, the Ottawa-region cluster went from almost negligible investment activity in 1998, to more than 25% of the total VC investments made in Canada during the year 2000. The Ottawa region is characterized by high levels of entrepreneurial activity in the telecom industry; particularly in the photonics, semiconductors, and networking sectors. The study of the boom-and-bust phenomenon in the Ottawa-region cluster is useful for this research for three reasons: i) little research has explored the boom-and-bust phenomena in the Canadian VC industry; a meaningful study of this problem should be anchored around a regional technology cluster that drew a significant portion of investment capital; ii) a large share of Canadian VC investments were made in the Ottawa-region, over \$3.5 billion (Canadian dollars) were invested in more than 200 Ottawa-startups during 1998-2003; and iii) developing a case study is important to link theory to what happens in the real world. The study of the boom-and-bust in the Ottawa region is useful to link the qualitative data collected from field research to what happened in the real world.

1.5 Research Questions

Based in part on the above premises, in this thesis I pose the following research questions:

- 1) What were the reasons for the rise and decline of VC investment in Ottawa during 1998-2003?
- 2) What role do market participants play during cycles of boom-and-bust?
- 3) How do market conditions affect market participants' judgment?
- 4) What are the key variables and feedbacks in the VC investment process that generate the boom-and-bust?
- 5) What is the impact of investment speed in VC industry performance?

In pursuing answers, I explore different streams of literature encompassing behavioral decision theory, strategy, psychology, economics and finance. I capture information-rich mental-model data from field interviews with domain experts in venture capital. I develop a qualitative model of venture capital investment decision-making based on the system dynamics approach. Finally, I design investment scenarios and run computer simulations to find insights into the dynamics of venture capital investment.

1.6 Audience

Institutional investors, venture capitalists (VCs), and academics with interest in venture capital may draw important lessons from understanding the underlying feedbacks that lead to the boom-and-bust in VC investment. Based on case data and field research I develop a simple system dynamics model of VC investment, which captures the key variables of the investment process which are essential to explain the generation of the boom-and-bust endogenously. By running computer simulations of several VC investment scenarios, insights are gained that help both institutional investors and VCs to better understand how the boom-and-bust is influenced by their own intendedly rational decisions.

1.7 Contributions

This thesis offers at least four contributions to the academic literature and management practice. First, it provides a case study of the Canadian VC industry boom-and-bust from

the perspective of a single technology cluster, namely the Ottawa-region cluster. I argue that to better understand the macro behavior in the VC industry is first necessary to focus on the regional context and the a priori conditions that contribute to the overall boom-and-bust in the Canadian VC industry.

Second, I identify the key variables and causal relationships among market participants in the VC market. The key variables refer to the key resources controlled by decision-makers (e.g., capital, equity), which build and deplete over time, the decision rules used to manage the accumulation and depletion of those resources, and the time delays between action and outcome. The premise of this study is that complex system behaviors usually arise from the interactions (i.e., feedbacks) among the components of the system, not from the complexity of the components themselves (Sterman, 2000).

Third, this thesis is the first to develop a system dynamics model depicting the key feedback processes involved in the whole venture capital cycle. I find strong evidence for the existence of positive feedbacks that reinforce investment activity, which are coupled with negative feedbacks that limit its growth.

Fourth, I run computer simulations on the model in order to explore the impact of investment speed on VC industry performance. The results of the simulations give two key insights. i) the boom-and-bust dynamic is influenced by investment speed, slower decisions attenuate the problem behavior while faster ones accentuate it; and, ii) faster investment decisions create a tradeoff between short and long-term VC industry performance.

1.8 Organization

The next chapters of this thesis develop the basis for the research project and the model. Chapter 2 presents a review that links different strands of the literature that frame the goals of this research. Chapter 3 discusses the research approach, describing the method for collection and analysis of qualitative data for system dynamics models drawing from

intensive interviews with domain experts. Chapter 4 studies the case of the Ottawa VC boom-and-bust, which uses historical document review on the Canadian VC industry. This chapter helps to relate the components and feedback processes identified in this research to a real case situation. Chapter 5 combines the findings of the two previous chapters with field interviews to develop a causal model of VC investment dynamics. Chapter 6 discusses the model. Chapter 7 presents the results of the review of the model with domain experts in the venture capital industry. Chapter 8 discusses the model boundary and model testing. Chapter 9 presents the simulation results of running the model under four hypothetical scenarios based on investment speed. Chapter 10 concludes the thesis with a discussion of findings and directions for further research. The attached Appendixes include elements of the simulation runs and research protocols.

2 LITERATURE REVIEW

This chapter presents a literature review comprising five parts. First, I provide an overview of venture capital with a focus on the investment and decision processes. Second, I examine the competitive strategy literature and relate it to venture capital industry evolution. Third, I examine the behavioral aspects of human decision-making. Fourth, I examine the literature on boom-and-bust phenomena which identifies positive feedbacks in capital markets. Finally, I discuss the lessons learned from literature.

2.1 Venture Capital

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.

2.1.1 Venture capital investments

As illustrated in Figure 1, venture capital investments in new ventures can be classified in different stages of funding (Ruhnka and Young, 1987). Those stages determine the financing lifecycle of the venture and may have different shareholders.

Financing Lifecycle

Figure 1. New venture financing lifecycle

The stages are:

- 1) Seed financing. At this stage there is only an idea or product concept. Typically, at this stage the sources of financing are limited to the entrepreneurs themselves and friends and family. Seed financing is the earliest stage of a new venture.
- 2) Early stage (or startup) financing. At this stage it is common to have a proof-of-concept or a working prototype that constitute a formal technical development of the product. The entrepreneur may start to develop a business plan and marketing analysis that can help him look for outside capital. Typical sources of financing at this stage are “Angel” investors. Angels are high net-worth individuals who like to make technology investments. In many cases they have been entrepreneurs themselves and are quite familiar with technology. In some cases venture capitalists invest at this stage.

- 3) Series A financing. At this stage a product has been developed, there is a potential market for the product that needs to be seized, and the full management team is in place. Venture capitalists are common investors at this stage.
- 4) Series B financing. At this stage there is expansion and growth of the venture reflected on sales and market share. The venture is expected to complete its development and position itself for a subsequent public offering or a merger & acquisition (M&A). Venture capitalists are common investors at this stage.
- 5) Series C (or mezzanine/late stage) financing. At this stage investors actively look for an exit mechanism. The venture has typically reached break-even and is profitable. Banks and other financial institutions are typical investors at this stage providing debt capital to the firm. Venture capitalists may also invest at this late stage.

A new venture reaches liquidity when it is acquired by another company (public or private) or when it issues shares during an initial public offering (IPO) in the public markets. These liquidity events are the most desired by investors since they provide the biggest payoffs. Typical investors in an IPO stage are investment banks who serve as underwriters (i.e., establishing the market value of the shares and issuing the shares) during the IPO process of the company.

2.1.2 The venture capital cycle

In their book, *The Venture Capital Cycle*, Gompers and Lerner (1999) present an excellent review of VC activity from an economic perspective. The investment cycle involves three main stages summarized as follows:

- 1) How funds are raised. VC firms usually get their funding from limited partnerships with private and institutional investors for periods of about 10 years after which they have to be renewed or returned to the investors.
- 2) How investments are made. After the VC firm has raised a pool of capital it then becomes ready to invest in high growth companies; generally VC firms prefer a diversified investment portfolio of companies over which they have constant control and monitoring. VC investments are usually made by staging their

disbursements, with the objective of exerting tight control on firm performance. To protect their downside risk, VC firms also use syndication. This term means that VC firms engage in co-investment opportunities with other VC firms thereby spreading the risk of investments.

- 3) How investments are exited. VCs have very high expectations on the return of their investments. The most expected measure of success (i.e. the most profitable) is the liquidity event where the portfolio company exits by means of going public or by being acquired by another, often larger, company.

2.1.3 The venture capital investment process

The VC investment process deserves special attention since it represents the core of VC activity. This stage usually starts with every new venture business plan handed to the VC. Only a very small number of new ventures capture VC attention. After a deal is made, venture capitalists engage in several post-investment management activities that ideally would result in cashing out the investment in a successful liquidity event (acquisition or IPO).

The VC investment process is briefly summarized drawing from Tyebjee and Bruno (1984) as a sequence of five key stages:

- 1) Deal origination. Prospect ventures are enter VC firms by means of technology scans, referrals by personal contacts or entrepreneur's direct approach.
- 2) Screening. Deals are screened based on salient factors such as stage of development, industry, and investment size.
- 3) Evaluation. If the deal reaches this point, extensive due diligence is performed on the company.
- 4) Structuring. When the decision to invest has been done, entrepreneur and VC agree on the terms and conditions of the deal.
- 5) Post Investment Activities. At this point, VCs are involved in the management of the firm, usually playing roles in the board of directors.

2.1.4 Organizational structure of a venture capital firm

Figure 2 depicts the structure of a typical limited partnership venture capital fund. The stakeholders in the fund are the General Partners (GPs) and the Limited Partners (LPs).

- 1) GPs are the venture capitalists (VCs). They manage the venture capital fund and invest the money in private companies (i.e., portfolio companies) on behalf of the LPs. They are highly involved in the management of the Portfolio Companies in their fund until they cash them out via an IPO or M&A transaction. GPs main activities in the management of portfolio companies include (Smith and Smith, 2000, p.500):
 - Board Service
 - Recruitment of management team
 - Assistance with external relationships (e.g., customers, suppliers)
 - Arrangement of additional financing
- 2) LPs are institutional investors or rich individuals that provide the money to open a venture capital fund. LPs place their money for a fixed amount of time (e.g., a 10 year lifetime of the fund) after which the expected appreciated capital is returned to them. They are not involved in the management of the fund.

Organizational Structure of a Venture Capital Fund

Source: Smith and Smith (2002)

Figure 2. Organizational structure of a limited partnership fund

2.1.5 Types of private equity financing

Venture capitalists are not the only source of private equity financing for startup companies. To give an example of the different types of private equity investors I list those relevant to the Canadian context:

- 1) Angel Investors. Wealthy individuals who have likely been former entrepreneurs who cashed out a successful startup, or former senior managers from high technology companies. They are an important source of financing for companies in seed or early stages. Angels invest their own money in ranges between \$100K to \$500K.

- 2) Private Venture Capitalists. Traditionally constitute a limited partnership fund. Some Private VC groups prefer to invest at early stages (e.g., Series A) while others prefer later stages (e.g., Series C or Mezzanine). VCs usually invest between \$500K and above. Interestingly, Private VC groups are not that common in Canada as they are in the US. These groups account to less than 50% of the total private equity funds raised in Canada¹.
- 3) Labour Sponsored Venture Capital Corporation Funds (LSVCCs). Traditionally LSVCCs have constituted a large share of the total private equity funds raised in Canada (i.e., about 50%)². An LSVCC raises funds from ordinary or retail investors. The federal and provincial government offer tax credits to Canadians investing in these funds. Like private VC funds, they invest in early and late stage companies. LSVCCs raise funds annually with the RRSP season. They are regulated by government statute which has direct implications on the size of their investments (e.g., up to \$2 M per company), and poses certain pacing requirements on the deployment of the funds (i.e., 100% a fund has to be deployed in a 2-year period)³.
- 4) Corporate Venture Capital Funds (Corporate VCs). Traditionally the private equity arms of corporations. Bell Canada, Telus and Nortel have such funds. In their case, the funds are usually specialized in telecom-related investments. Corporate VCs may offer an incubator-type of environment to the companies they fund. They tend to invest in later stages and their investee companies are likely to be bought by the corporation where the fund is affiliated to.
- 5) Government Investment Funds. Organizations such as the Business Development Bank (BDC) of Canada, has a national BDC Venture Capital fund. BDC has a history of private equity investment dating back to the 70's⁴. BDC features an 'evergreen' fund which allows them greater flexibility to deploy funds. BDC

¹ Sources: The venture capital industry in 2003: An overview. CVCA website, http://www.cvca.ca/statistical_review/index.html; MacDonald&Associates Ltd.

² Ibid.

³ Personal interview with a local LSVC manager.

⁴ BDC Venture Capital website.

http://www.bdc.ca/en/business_solutions/venture_capital/about_us/default.htm

investments are made at any stage of development in the company. Investments are within the \$500K - \$3M range.

2.1.6 Venture capital decision processes

Many studies examine the decision processes of venture capitalists. Tyebjee and Bruno (1984) found that VCs investment decisions can be predicted from 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 (Shepherd and Zacharakis, 2002; Kemmerer et al., 2003).

Despite the abundant 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 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 can be funding restrictions that restrict the VC to finance the venture, no matter how profitable the deal promises to be. Another example is the effect of other VC bidding for the same deal, which would have direct implications on the price or the structure of the deal itself, therefore affecting future returns.

To the author's knowledge, there are no such studies that link both the decision and resource environments in a dynamic framework. This thesis adds to the literature a dynamic model the venture capital investment process. This model is unique because it captures the feedbacks and time delays inherent throughout the complete venture capital cycle.

2.2 Competitive Strategy

Figure 3 draws on Porter's five forces model to illustrate the competitive forces affecting the VC industry as observed during the late 1990s. Higher expected returns and low barriers to entry make the threat of substitutes (i.e., Angels and corporate VCs) and the threat of new entrants (i.e., new VC firms and foreign VC firms) more likely to occur. Entrepreneurs have the ability to pick the best bidder for their companies and acquirers have a bigger pool of candidates to buy the best-in-breed company. Higher competition leads to higher valuations, which impacts negatively the returns performance of the industry.

Determinants of Venture Capital Industry Profitability

Source: Adapted from Porter, Sahlman and Stevenson

Figure 3. Venture capital industry structure

The drawback of Porter's model is that it only captures a snapshot of competitive forces of the industry in what is, in reality, a dynamic world.

Along these lines, Warren (2002) dynamic resource system view (DRSV) offers a framework to gain insight on how competition evolves over time. The DRSV contends that to capture the industry architecture, is necessary to model it as a flow of interdependent resources and firms' policies that interact to generate the mutual evolution of resources on the demand and the supply sides. Drawing on Warren (2002), this study develops an industry model that links the flows of resources (e.g., capital, company ownership, etc.) and decisions (e.g., investment and liquidity decisions) that permit the assessment of the time path of VC industry performance, as well as an exploration of how endogenous policies may contribute to improve long-term industry profitability.

2.3 Behavioral Decision Theory

Behavioral decision theory (BDT) models what decision-makers actually think and do, not what they should do and think. BDT is cautious about the assumption of an ideal world full of perfectly rational individuals making optimal decisions.

This sub-section discusses the behavioral foundations of human decision making that guide this research.

2.3.1 Bounded Rationality

The “principle of bounded rationality” argues for the powerful notion that there are several limitations on the information processing and computing abilities of human decision makers. In his seminal work on rationality and decision-making, Herbert Simon (1957, p. 158) defines bounded rationality as:

“The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problem whose solution is required for objectively rational behavior in the real world or even for a reasonable approximation to such objective rationality.”

This theory has wide support in the behavior modeling of decision-making. According to this view, the behavior of complex organization can be understood only by taking into account the psychological and cognitive limitations of the decision-maker. Along these lines, Miller (1956) has shown that the cognitive capabilities of humans are very limited, suggesting that decision-makers need to simplify their environment by using between “ 7 ± 2 ” information cues at a time.

Cyert and March (1963) further develop the ideas of bounded rationality in the organizational decision-making domain. They argue that decision-making in organizations is indeed much simpler than one would anticipate based on classical models that assume rationality (i.e., perfect knowledge and optimal decision-making). Organizational decisions depend on goals, expectations and choice. Goals are usually aspirations related to past goals and past performance. Expectations refer to drawing

inferences from available information. Choice is the response to a problem by using standard operating procedures or heuristics, which in the short-run do not change, representing the accumulated knowledge embodied in the organization.

Along these lines, Morecroft (1983) explores the linkages between system dynamics and bounded rationality at the most fundamental level of information flow and processing. He identifies a number of empirical features of organizational decision-making that can be interpreted as consequences of the principle of bounded rationality. These features are:

- 1) Factored decision-making. Decision-problems in a business firm are divided among sub-units of the firm (e.g., R&D and marketing). These sub-units are interdependent and have sub-goals that contribute to the larger goal of the firm.
- 2) Partial and certain information. Decisions are made on the basis of relatively few sources of information that are readily available and low in uncertainty.
- 3) Rules of thumb. The firm uses standard operating procedures or rules of thumb to make and implement decisions. Rules of thumb process information in a straightforward manner, recognizing the computational limits of normal human decision makers under pressure of time.

Morecroft (1983) argues that bounded rationality is embodied in the feedback structure of system dynamics models and illustrates these aspects in Forrester's Market Growth model (Forrester, 1968) to show how intendedly rational policies made at each sub-unit, can conflict and generate market collapse in a sufficiently complex organizational setting.

2.3.2 Misperceptions of Feedback

Sterman (1989) tests the deficiency of decision-makers in ignoring feedbacks and interdependency. He reports an experiment in which people managed a simple system dynamics model of a simulated economy; the vast majority of the subjects generated oscillations much like the behavior of the model of the economic long wave (Sterman, 1985). The various and distinct sources of poor subject performance were identified and termed by the Sterman as "misperceptions of feedback" (MoF). The MoF hypothesis conveys the failure on the part of the decision-maker to correctly assess the nature and

significance of the causal structure of a system, particularly the linkages between their decisions and the environment.

In another experimental study, Paich and Sterman (1993) test the decision-making task by simulating the dynamics of a new product market model that tested how subjects reacted to the variation in the strength of feedback processes. The study showed that subjects' performance relative to potential severely degraded when feedback complexity was high. This finding was consistent with the MoF hypothesis, the stronger the feedback processes in the environment the worse people do relative to the benchmark.

Thus, in addition to being boundedly rational (Simon, 1957; Cyert and March, 1963), decision makers tend not to account for crucial feedbacks and time delays in the structure of complex systems (Sterman, 1989). This research gives insight on how, under certain conditions, intendedly rational decisions may lead to dysfunctional dynamics for the VC system as a whole.

2.3.3 Behavioral Finance

The Efficient Markets Hypothesis (EMH) is considered as the central premise of finance. As defined by Fama (1970), an efficient financial market is one where security prices always fully reflect available information, so that securities prices always must equal fundamental values. The EMH rests on three arguments:

- 1) Investors are assumed to be fully rational and assess each security for its fundamental value.
- 2) Some investors are not rational, but in the aggregate, their trades are random and therefore cancel each other out without affecting prices
- 3) Arbitrage eliminates any pricing abnormalities.

In contrast to EMH, behavioral finance contends that market inefficiencies exist and are due to highly pervasive and systematic deviations of investors from the maxims of economic rationality better explained by psychological phenomena (Schleifer, 2000, Shefrin, 2000). As Wheale and Amin (2003, p.121) state:

“Behavioral finance can be defined as the study of how humans interpret and act on information to make informed investment decisions, and its findings suggest that investors do not always behave in a rational, predictable and an unbiased manner as indicated by traditional finance models.”

Along these lines, Shleifer (2000) groups three broad, yet fundamental, areas in which decision-makers deviate from the standard decision-making model: attitudes towards risk, non-Bayesian expectation formation, and sensitivity of decision making to the framing of problems.

- 1) Individuals do not often look at the levels of final wealth they can attain but at gains and losses relative to some reference point, which vary from situation to situation, and display loss aversion as described by ‘Prospect Theory’ (Kahneman and Tversky, 1979). One conspicuous example is investors’ reluctance to realize their losses. Investors have the tendency to sell winner stocks too early and stick to loser stocks too long (Odeon, 1998).
- 2) Individuals systematically violate Bayes’ rule and other maxims of probability theory in their predictions of uncertain outcomes (Kahneman and Tversky, 1973). For example, investors may take recent history of rapid earnings growth of some companies as representative and extrapolate expectations far into the future. They may overprice these companies without recognition of reasonable companies’ valuations. It may often happen that past history is generated by chance rather than constituting a trend. Such overreaction lowers future returns as past growth rates fail to repeat themselves and prices adjust to more reasonable valuations.
- 3) Investors’ preferences and beliefs based on heuristics that conform to psychological evidence rather than Bayesian rationality are known as ‘investor sentiment’ (Schleifer, 2000, Ch. 5). Investors sharing these beliefs are called ‘unsophisticated’ investors. Furthermore, there is evidence that ‘unsophisticated’ investors deviate from rationality in the same way and not randomly. For example, ‘investors may behave socially and follow each others’ mistakes by listening to rumors or imitating others (Schiller, 1984). ‘Investor sentiment’

reflects the common judgment errors made by a large number of investors, rather than uncorrelated random mistakes.

Market abnormalities are not only a result of trading by unsophisticated investors. Shleifer (2000) contends that further distortions into the financial market can be introduced by professional money managers, such as pension funds and mutual funds. By investing on behalf of other individuals and corporations using 'other people's money' they may cause costly investment distortions. For example, professional managers may herd and select stocks that other managers select to avoid falling behind and looking bad (Scharfstein and Stein, 1990), or they may artificially add to their portfolios stocks that have recently done well, and sell stocks that have recently done poorly to look good to their managers. There appears to be some evidence of such window dressing in pension funds (Lakonishock et al., 1991).

Finally, behavioral finance contends that real-world arbitrage is risky and limited. The efficacy of arbitrage depends crucially on the availability of close substitutes for stocks whose price is potentially affected by unsophisticated investors. There is evidence that in many cases securities do not have obvious substitutes and therefore arbitrage becomes risky (Shleifer, 2000).

In summary, the argument of behavioral finance is that behavioral explanations anchored around psychological knowledge are germane for a better understanding the, so-called, abnormalities in 'efficient' financial markets.

2.4 Boom-and-Bust phenomenon

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 VC boom-and-bust in the disk drive industry during the 70s and 80s. 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.

The boom-and-bust can also result from aggressive growth strategies. Oliva 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, Ch.6). In particular, investor over-reaction in VC is difficult to reconcile with a fully rational model (Sahlman and Stevenson, 1986; Sahlman, 1998; Lerner, 2002; Wheale and Amin, 2003).

2.5 Lessons Learned

Five insights were learned from reviewing different strands of literature.

- 1) Investors are not fully rational decision-makers. Behavioral finance challenges the traditional view of investors as rational economic agents. In studying the anomalies of financial markets, behavioral researchers draw on the results from psychology to enhance our understanding of actual investment behavior (Benartzi and Thaler, 1995; Shleifer, 2000; Shefrin, 2000; Scharfstein and Stein, 1990).
- 2) There are limits to the rationality of decision-making. Bounded rationality reflects the limited cognitive abilities that constrain human problem solving (Simon, 1979; Cyert and March, 1963). Failure in complex systems arises because

intendedly rational decisions create unintended effects elsewhere in the system (Hardin, 1968; Morecroft, 1983).

- 3) VC research has focused on determinants of decisions and less on the ongoing relationship between decisions and resources. Despite the amount of research on VC decision-making (Tyebjee and Bruno, 1984; Zacharakis and Meyer, 1998; Shepherd 1999a,b,c; Shepherd et al., 2000), very little is known about the interaction between decision processes and resources. A resource perspective is important to understand the relationship between resources and profitability (Wernerfelt, 1984).
- 4) Little is known about how VC industry performance develops over time. The drawback of competitive strategy literature (Porter, 1980) is that it captures a static view of competitive forces in a dynamic world. Warren (2002) suggests a framework to capture the dynamics of the industry as a co-evolution of interdependent resources and decisions.
- 5) Boom-and-Bust results from positive feedback investment strategies. Many forms of boom-and-bust behavior in capital markets (Kindleberger, 1978; Sahlman and Stevenson, 1986; Sahlman, 1998) can be described as positive feedback trading. Positive feedback traders invest when prices rise and retreat after prices fall (Schleifer, 2000).

This study attempts to use the findings of the different streams of literature discussed in this section to fill the two gaps. i) the lack in considering how venture capital investment develops over time; and, ii) the interaction between the decision and resource environments of venture capitalists. 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. 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 chapter.

3 RESEARCH METHOD

This thesis applies the tools and techniques of the system dynamics approach (Forrester, 1961; Sterman, 2000) to capture the complex interrelationships of venture capital investment and the industry. Through this approach, four objectives were pursued:

- 1) Identification of key variables and feedback structures in the venture capital investment process.
- 2) Specification of a causal model capturing venture capital decision processes
- 3) Development of a formal model of venture capital investment dynamics
- 4) Simulation of the model under different investment scenarios to explore the effect of investment speed on VC industry performance.

To achieve these objectives, several research activities were necessary (see Table 1). Extensive literature survey drawing on the domains of: Management, Psychology, Finance, Economics, and System Dynamics over a period of several months. Analysis of the extant literature resulted in the identification of key variables and relationships of the dynamics of VC investment. These artifacts were used to build a ‘skeleton’ or initial model of venture capital investment dynamics which helped to guide the focused and structured interviews with domain experts.

Objective	Activity	Outcome
Identification of variables and feedbacks in venture capital investment process	Literature review, modeling coaching	Skeleton model of VC investment dynamics
Specification of initial systems model	Structured-interviews with experienced VCs, historical document review	Formal model of VC investment dynamics
Development of final model	Structured interviews with experienced VCs, system dynamics modeling	Reviewed model of VC investment dynamics and additional insights for model improvement
Simulation of investment scenarios	System dynamics simulation	Simulation results

Table 1. Research objectives and approaches

Intensive structured-interviews were conducted with persons highly knowledgeable about VC in the Ottawa region. Extensive historical document review on venture capital activity in Ottawa was performed in parallel. The result of this process was the specification of a 'formal' model of venture capital investment dynamics. A formal model in system dynamics is a computer coded version of the system structure that underlies the problem. The formal model was then used in a second round of interviewing, with participants critiquing its underlying relationships and structure. The results of the review of the model helped to develop the final model of venture capital investment dynamics. The final model was used to simulate different investment scenarios and their implications in short- and long-term VC industry performance.

Next, I discuss the modeling technique. Finally, I provide details on the implementation of the research approach.

3.1 Rationale for using System Dynamics

System Dynamics (SD) provides a framework for understanding the role of feedback in complex systems. The behavior of a system is caused by the interactions among the components in the structure of the system. SD is the chosen methodology for this research because it suits nicely the analysis of problems with transient behavior (i.e., continuously changing over time). An understanding of the components and interactions in the system lead to insight about the causes of system behavior. As Forrester (1958, p.40) puts it:

"Feedback theory explains how decisions, delays, and predictions can produce either good control or dramatically unstable operation..."

The components of a system may be regarded as endogenous or exogenous depending on the particular phenomena being studied. In the venture capital domain, VCs 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 information 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 their investments, and have a significant impact on the outcome of investment decisions.

The systems approach has a closed-loop perspective, where all agents or market participants are endogenous to the problem domain. This perspective is supported by the development of a dynamic hypothesis, or a theory about the endogenous causes of the problem behavior (Sterman, 2000).

System dynamics emphasizes formal models of real-world situations. The purpose of a formal model is to run computer simulations of the system under study, and thus provide the opportunity to experiment and learn from hypothetical scenarios. Although there are other modeling techniques of social systems, system dynamics modeling captures well feedback processes and time-based behavior. Both aspects are of great importance to understand the dynamic complexity of a system. While system dynamics (SD) is useful to

model deterministic, continuous-time systems, other techniques such as agent-based modeling (ABM) (see Wolfram, 2002) and discrete event simulation (DES) (see Law and Kelton, 2000) are useful to model stochastic, discrete-time systems.

Using a qualitative approach to model development (Luna and Lines, 2003), this thesis develops a formal model of the dynamics of venture capital investment to explore the causes that lead to the rise and decline of VC. Furthermore, System Dynamics facilitates quantitative simulation-modeling for the analysis of the problem behavior. Simulations are then used to give insight on the impact of investment speed on VC industry performance.

3.2 Research approach

The general approach to develop a system dynamics model draws from (Richardson and Pugh, 1981), which stress the importance of iterative developments to increase the knowledge and understanding of a problem (see Figure 4).

Source: Richardson and Pugh (1981)

Figure 4. Overview of the System Dynamics approach

The modeling process follows best practices for the collection and analysis of qualitative data for system dynamics models (Luna and Lines, 2003). Well-structured interviews for both model formulation and model review were believed to be the best way to target and focus discussion around the development and assessment of the model with domain experts⁵. In this research project the modeling process follows a sequence of three steps.

Step 1: Problem definition and initial system conceptualization

The review of the relevant literature and industry data on venture capital provided the background for the problem definition. This literature was supplemented with informal interviews and discussions with entrepreneurs, venture capitalists, institutional investors, consultants, and scholars at local and international networking events, academic conferences, seminars and presentations. The author carried out this work throughout his research project between Summer 2003 and Summer 2004. The initial analysis of the literature and informal interviews resulted in the specification of a ‘skeleton’ model capturing the key variables and causal relationships in the VC investment process. The ‘skeleton’ model represents a baseline model of the system based on both literature review (Sastry, 1987) and informal interviews (Abdel-Hamid and Madnick, 1990). The ‘skeleton’ model was used as a baseline for further development and improvement during the next stage.

The initial system conceptualization was a synthesis of insights from multiple disciplines, namely: management, psychology, finance, economics, and System Dynamics. During visits and presentations at several international conferences and highly respected US academic institutions, the author had the opportunity to discuss and receive valuable feedback for the early versions of the model. Insightful comments and suggestions for the development of the model were received from Faculty and Senior PhD students in the disciplines noted above.

⁵ Rich’s (2002) qualitative modeling process through intensive interviewing was instrumental in the formulation of this approach.

Step 2: Model Formulation

The structural observations from the previous phase were used to develop a template for a “focused” interview (Selltitz et al., 1976). This type of interview aims at concentrating the attention on a given set of topics that helps to guide and facilitate the discussion with domain experts.

The focused interview investigated the following topics:

- 1) Fundraising
 - Fundraising process
 - Investor expectations
 - Fund policies
- 2) Investment
 - Investment process
 - Portfolio management
 - Valuations
 - Investment policies, goal setting mechanisms
- 3) Exiting
 - Exit strategies
 - Liquidity policies
- 4) For all themes (1 through 3)
 - Time lags
 - Changes during periods of high investment activity
 - Changes during periods of low investment activity

An initial set of structured interviews was conducted with domain experts selected from local venture capital firms in the CVCA (Canadian Venture Capital Association) membership directory. This stage was aimed at eliciting experts’ mental models around VC investment dynamics in real-world situations.

The collection and analysis of rich interview data served to develop the formal model of the venture capital investment dynamics. The formal model represents the evolution of the skeleton (baseline) model, which was refined through several iterations after each

interview. Each iteration reflected new and better understanding of the real system. This stage helped to sharpen the structure and boundary of the model.

Step 3: Model Review and Scenario Analysis

The formal model was used to carry out a second round of interviews. Domain experts, who participated in the previous stage, assessed the structure and underlying assumptions of the formal model. Participants were encouraged to critique the model through structured interviews. This critique was used to validate the initial formulation, and to provide insights into future model development.

A large number of simulations and experiments were conducted on the reviewed model. The purpose was to analyze the role of venture capital investment speed, which could shed some light on the unintended consequences in overall VC industry performance.

The end result of this project is a formal model of venture capital investment dynamics that provides a platform for experimentation with investor decisions or strategies, under different assumptions. The platform can be used to advance our understanding of the causes of the rise and decline of venture capital investment, as well as a consideration of how investment speed influences system behavior.

3.3 Implementation

The structured interviews carried out in this research examined venture capital investment decision processes in the Ottawa region during the 1998-2003 period. I interviewed five domain experts who belonged to four VC firms with offices in Ottawa during the period of interest. All of VC firms were members of the Canadian Venture Capital Association (CVCA). All firms made investments during the 1998-2000 period (market boom) and the 2001-2003 period (market bust). They invested in local technology companies of the telecom sector and experienced similar challenges and difficulties in the transition from boom to bust.

This study started in Winter 2003 and continued until Summer 2004. The research project was structured in four stages as shown in Table 2.

Research Stage	Activity	Period
Problem Definition	Initial Contacts	Winter 2003-Summer 2003
Initial System Conceptualization	Informal Interviews, modeling coaching	Fall 2003-Winter 2004
Model Formulation	Formal Interviews	Spring 2004
Formal Model Review	Follow-up Interviews, model testing	Summer 2004

Table 2. Research Timetable

3.3.1 Problem definition

The first stage of the research was the identification of an interesting problem in the area of venture capital decision-making. This was accomplished by studying the literature on venture capital and several associated research methodologies (Tyebjee and Bruno, 1984; Sahlman and Stevenson, 1986; Sahlman, 1998; MacMillan et. al., 1985, 1987; Sandberg et al., 1988; Hall & Hofer, 1993; Zacharakis and Meyer, 1995; Muzyka et al., 1996; Zacharakis and Meyer, 1998; Shepherd, 1999; Shepherd and Zacharakis, 2002; Shepherd and Zacharakis, 2002; Kemmerer et al. 2003). During this stage a relatively recent problem behavior was identified in the area of VC. This problem involved the sharp fluctuations of VC investment both in the US and Canada in the past five years (1998-2003). Given the dynamic nature of the problem, system dynamics was identified as a suitable methodology to explore how this problematic behavior evolves over time.

A research proposal, discussing the research problem, the method and expected results was prepared. In parallel with the development of the research proposal, contacts were made with academics highly knowledgeable in the field of system dynamics while

attending an international academic conference in New York, US. These contacts provided valuable guidance for the modeling process. This preparatory work required about four months, ending in Summer 2003.

3.3.2 Initial System Conceptualization

In Winter 2004, the research project received internal approval from faculty in the TTM program. In parallel, the author conducted a few informal interviews with venture capitalists, individual investors, and entrepreneurs who could serve as contact points for the research project. These informal interviews resulted from attending networking events, seminars and presentations in the Ottawa region. These interviews were an initial source of awareness about the issues and challenges of the local venture capital community.

During this stage of the research project, the author affiliated to the National Capital System Dynamics Group (NCS DG) in Ottawa where he made acquaintance of Dr. Arif Mehmood, a Senior System Dynamics Consultant. Dr. Mehmood would provide valuable modeling coaching and guidance during the process.

By the end of Winter 2004, a ‘skeleton’ model was in place. This model included key variables and causal relationships identified from literature review (Yepez, 2004a). At this point, a preliminary interview protocol was developed. This instrument was reviewed by 2 academics. One of them had business consultancy experience, and both of them were familiar with venture capital and gave helpful comments to refine the interview instrument.

The refined interview protocol was then ready for a pilot test. Using previous contacts from the informal interviews, two venture capitalists were identified and solicited for interview. Upon their consent, they were interviewed in person. Each interview lasted about one hour and was spaced for a few weeks from each other. This approach proved to be useful since the protocol was tested twice for its clarity and correctness with domain

experts in an iterative manner. Their feedback was valuable to develop the final version of the instrument.

3.3.3 Model formulation

Once the interview protocol was ready, an application to carry out the field-work for this project was sent to the Ethics Committee at Carleton University. The approval, with minor corrections, took about a month and was received in Spring 2004.

In order to ensure relevant data sources for this study, the author established the following selection criteria for data collection:

- Industry Sector: Telecommunications
- Period: 1998-2000 (Boom) and 2001-2003 (Bust)
- Sample: Venture capital firms with offices in Ottawa during both periods
- Participants: Individual venture capitalists who invested in the Ottawa region during both periods.

Using the members' directory of the CVCA, several candidates from local venture capital groups were identified for this research. The interviewees included participants with experience in several areas of the VC investment process. I had exposure to Limited Partners, General Partners, Entrepreneurs, and Venture Capital Consultants. Interviewees ranged from senior and well-seasoned managers with top-line responsibility for an LP fund, a venture capital group, or a startup company; to venture capitalists involved in the daily operations of the venture business. Many of the practitioners had local, national, and international experience

Seven venture capitalists were solicited for interview. An invitation letter to the study was sent to each of them via electronic mail or fax. The author followed up the invitation in the next day or so by calling each of them by telephone in order to answer any questions that they might have and with the hope to enlist them in the project. Five of them consented; two of them were unreachable. Those who consented were interviewed in person. The location usually was the participant's office or a public place such as a

cafeteria or a restaurant. The interviews were structured and focused around topics related to the investment decision process. I used open-ended questions and probing questions to explore other relevant lines of inquiry when necessary. Each interview lasted between 1 to 2 hours. The interviews were taped and later transcribed. At the end of the interview each participant was solicited for a follow-up interview to complete the study. All of them agreed.

After taping each interview, the researcher made the transcript of each interview in the next day or so. Each transcript was sent via electronic mail to the respective interviewee soliciting him or her to review it, and to confirm whether or not the transcript truly reflected his or her views discussed during the interview. Four participants sent back the reviewed transcripts via electronic mail, fax, and regular mail. The response time to review the transcripts was between two to four weeks. The transcript review process revealed no or, at worst, a few minor modifications.

The formal model that resulted from the interviews reflected a better and improved understanding of the system. The impact of supply and demand and the competitive factors in the venture capital investment process were widely accepted among the experts. Most of them were managing partners in their firms and had respectable track-records making technology investments in Ottawa. All firms went through a period of prosperity (1998-2000) and struggle (2001-2003).

By the end of Spring 2004, the 'formal' model, named VENTURE1, was coded. VENTURE1 is a fully specified formal model, complete with equations, parameters, and initial conditions. The VENTURE1 model was peer-reviewed, and presented in two international academic conferences in Pittsburgh, USA and Oxford, England during Summer 2004 (see Yepez, 2004b; Yepez and Mehmood, 2004).

3.3.4 Review of formal model and scenario analysis

The fourth stage of the project included the evaluation and critique of the model structure and underlying assumptions by domain experts. To facilitate analysis and discussion, the

model structure was divided into micro-structures or causal loops. Each micro-structure depicted a relevant aspect of the investment decision process.

A structured interview protocol was prepared that asked domain experts to review each micro-structure, its key variables and causal relationships. The interview protocol was in the form of a workbook. A review workbook is deemed an appropriate instrument for the assessment of system dynamics models (Vennix, 1996; Rich, 2002; Luna and Lines, 2003). The workbook was pilot tested with one VC who previously participated in the pilot process.

Most interviews were scheduled at least two weeks in advance to allow for the additional modeling work that resulted from the previous phase. Constraints in the availability of two participants forced a re-schedule of their interviews shifting the original schedule of the research project by 2 weeks. Four of the interviews were conducted in person and one interview was conducted by telephone. Due to technical constraints, only the first four interviews were taped and transcribed. Interviews were conducted between Spring 2004 and Summer 2004.

The interviews were coded under two dimensions. First, the general impressions about each micro-structure of the model were gathered. Second, suggestions about changes and improvements to the model were encouraged. This resulted in valuable feedback to refine the variables and causal relationships in the model, and throughout the process, to improve the understanding of the problem being modeled.

Furthermore, the VENTURE1 model was tested following best modeling practices (Forrester and Senge, 1980). Testing included extreme conditions tests and other structural tests (see Chapter 7) that are necessary to discover flaws in the model and later build confidence on the model results.

Finally, once the model review process was completed, the VENTURE1 model was ready for simulation and analysis. Four scenarios based on VC investment speed were

designed and simulations were run to gain insight on the impact of time delays on VC industry performance.

3.4 Summary

This chapter presented the research method used to develop and validate a systems model of venture capital investment. A multi-method approach was used, including literature review, intensive interviewing, historical document review, and simulation to formulate a model of the dynamics of venture capital investment. Additional interviews were conducted to review the model variables, relationships and assumptions. The reviewed model is intended to build confidence on the results and insights derived from simulations.

4 A CASE STUDY ON VENTURE CAPITAL INVESTMENT DYNAMICS

In this chapter the history of a regional case of venture capital investment in Canada is described. The case study is based on the Ottawa VC boom-and-bust that occurred between 1998 and 2003. The case contributes to the development of a dynamic causal model for understanding the boom-and-bust of venture capital.

This chapter is organized as follows. First, I provide a background about the reasons of venture capital investment in technology clusters. Second, I suggest the preconditions that set the stage for the boom and bust of venture capital investment in Canada. Third, I describe a case of venture capital boom-and-bust based on the Ottawa cluster between 1998 and 2003. Finally, I discuss the findings of this case and how they relate to the development of a dynamic causal model of venture capital investment.

4.1 VC and geographical clusters

By the end of the 90s and the beginning of the new millennium, the venture capital industry went through a dramatic cycle of boom-and-bust. For example, in the U.S., VC investments increased and decreased by more than 500% between 1998 and 2003. The boom-and-bust cycle was mainly driven by the, so-called, Internet bubble (Perkins and Perkins, 2001). The Internet bubble origins may be traced back to Netscape's IPO in August 1995. This event started a 'hot' period of VC investment followed by a large numbers of IPOs and acquisitions of Internet startups. Inevitably, bubbles are followed by crashes, which resulted in vast losses for a large number of investors and startups.

In the Canadian venture capital industry a similar boom-and-bust phenomenon took place. VC investments in Canada increased and decreased by more than 350% between 1998 and 2003. Interestingly, the rise and fall of venture capital in Canada was not driven the Internet bubble. The Ottawa case provides a fertile ground for exploring the causes of the boom-and-bust behavior in the Canadian venture capital industry. The study of this

case may shed some light on the systemic pressures and contextual circumstances that generate such anomalous dynamics.

The literature on industrial clustering suggests that geographical location factors explain the economic success of firms. Underlying sources of agglomeration economies such as the specialized labor, market skills, or knowledge spillovers related to best-practice technology have been identified relevant to enhance the opportunities of firms located in a region (Globerman, 2001).

Given the close relationship between venture capital and entrepreneurial activity, it is reasonable to surmise that VC investments are geographically localized around technology based industrial clusters (Saxenian, 1994; Stuart and Sorenson 2003; Babcock-Lumish, 2003). These findings suggest that VC investment activity concentrates in relatively small and usually well dispersed geographic areas that form regional clusters of firms. Thus, studying the context of investment activity in a technology cluster basis is important to better understand the circumstances and factors that explain specific modes of VC investment behavior.

In a study of geographical locational spillover effects in Canada, Globerman et al. (2003) use a sample of 244 Canadian information technology (IT) firms during the period of 1998-2000 and identify the geographical distribution of firms per province and per Census Metropolitan Area (CMA). More than 80% of the sample firms are located in three main Canadian provinces: Ontario (60.1%), British Columbia (12.5%) and Quebec (11.3%). Most importantly, the major share of technology firms per CMA is concentrated in four cities:

- Toronto (40.7%)
- Ottawa (15.7%)
- Vancouver (10.5%)
- Montreal (8.9%)

Taken at face value, this evidence alone suggests why venture capital groups tend to concentrate their activity in clusters located over substantial geographical distances. The concentration of venture capital activity in a regional basis is an anchor for this study, which explores the VC boom-and-bust in the Ottawa technology cluster. Ottawa would turn into a hub for venture capital investment during the 1998-2003 period.

Table 3 shows the amount of VC investment in the Ottawa region during 1998-2003. The Ottawa-technology cluster went from almost negligible investment activity in 1998, to reach one quarter of the total VC investments made in Canada by year 2000, and almost a third by 2002. The Ottawa cluster is characterized by high levels of entrepreneurial activity in the telecommunications industry; particularly the photonics, semiconductors, and networking sectors. Overall, more than \$3.5 billion (Canadian dollars) were invested in more than 200 startups in the Ottawa region during 1998-2003.

	1998	1999	2000	2001	2002	2003	Total
Amount of VC investment in the Ottawa region (\$M CAD)	\$74.26	\$274.38	\$1,261.26	\$921.77	\$734.80	\$287.00	\$3,553.47
Number of VC deals in the Ottawa region	41	52	75	54	51	26	299
Average deal size (\$M CAD)	\$1.9	\$5.3	\$16.9	\$17.1	\$14.5	\$11.1	\$11.9
Amount of VC investment in Canada (\$M CAD)	\$1,558.00	\$2,650.00	\$5,778.00	\$3,715.00	\$2,529.00	\$1,486.00	\$17,716.00
% of \$ for Ottawa	4.8%	10.4%	21.8%	24.8%	29.1%	19.3%	20.1%

Source: Entrepreneurship Centre, OCRI. CVCA\Macdonald & Associates Ltd. Factiva database.

Table 3. VC Investment Activity in the Ottawa Region

Additional evidence that VCs were seriously investing in Ottawa during that period is included in Tables 4 and 5 which show a historical summary of the most representative venture capital investments made in Ottawa between 1998 and 2003. The Ottawa companies included in the tables are those which qualified between the 10 largest sized venture capital investments made in Canada each year. It can be observed that since 2000, more than five out of the ten largest sized Canadian deals were made in the Ottawa region. This evidence suggests that the Canadian VC boom-and-bust was significantly

influenced by the investments made in the Ottawa region between 1998 and 2003. Furthermore, the majority of these investments were closely related to the telecommunications industry (e.g., photonics, semiconductors, and networking).

Year	Company	Invested (\$M CAD)	VC Group	Sector
1998	Cambrian Systems Corp.	14.25	Vengrowth, Celtic House, Newbridge, Ontario Teacher's Plan, Royal Bank Capital	Photonics
1999	Eftia OSS Solutions Inc.	45.00	Spectrum Equity Investors, InSight Capital	SW
	Catena Networks Inc.	43.95	Morgenthaler Ventures and Canadian investors including BCE Capital	Networking
2000	Innovance Networks Inc.	115.00	Morgenthaler Ventures, Thomas Weisel Partners, Azure Capital, Advanced Technology Ventures, Bank of America and KPL Ventures	Photonics
	Catena Networks Inc.	91.20	Goldman Sachs and Berkeley International Capital	Networking
	Silicon Access Networks(1)	86.00	Soros Private Equity, Morgan Stanley Dean Witter, Raza Venture Fund, Pivotal Asset Management, Norwest Venture Partners, The Sprout Group, Intel Communications Fund, Dado Banatao, Synopsys Anthelion Capital, Comdisco Ventures	Semiconductors
	Ubiquity Software Corp.	63.80	Celtic House, Alcatel, CapVest Equity Partners, JK&B Capital	SW
	Metrophotonics Inc.	62.50	Yorkton Securities Inc., HSBC	Photonics
2001	Ceyba Inc. (former Solinet Systems) Inc.	144.50	Venture Partners, U.S Venture Partners and New Enterprise Associates	Photonics
	SS8 Networks Inc.*	96.10	Warburg Pincus, Woodside Fund, Onset Ventures and CDP Sofinov	SW
	Tropic Networks Inc.	93.00	Crescendo Ventures, Goldman Sachs and Raza Foundries, Altamira, Celtic House	Photonics
	Accellight Networks Inc.(2)	93.00	Menlo Ventures and Venrock Associates, CDIB Ventures, Granite Global Ventures, Mitsubishi Corporation, NIF Ventures, Stonewood Capital Management, Vertex Management, Western Technology Investment and Whitecap Venture Partners.	Photonics
	Mobile Satellite Ventures(3)	85.25	Telcom Ventures llc, Columbia Capital, Spectrum Equity Investors	Wireless
	Quake Technologies Inc.	46.50	Bowman Capital, Cisco Systems, Mitsubishi and Davidow Ventures	Semiconductors

Source: CVCA, Entrepreneurship Centre, OCRI, National Post, Corporate VC firms' websites

Notes: (1) Ottawa R&D center. Headquarters in San Jose, CA. (2) Ottawa R&D center. Headquarters in Pittsburgh, PA. (3) Joint venture between TMI Communications and Motient Corp. of Reston, VA. (4) Biotechnology publicly traded company. (5) Ottawa R&D center. Headquarters in Acton, MA.

Table 4. Ottawa region companies among the Top 10 VC deals made in Canada (by size), 1998-2001

Year	Company	Invested (\$M CAD)	VC Group	Sector
2002	Catena Networks Inc.	112.50	J&W Seligman & Co., Munder Capital Management, WestAM, Morgenthaler, Menlo Ventures, Berkeley International Capital, Worldview Technology Partners, Goldman Sachs Group, Inc., Bessemer Venture Partners, BCE Capital and Silicon Valley BancVentures	Networking
	Innovance Networks Inc.	88.00	JDS Uniphase, Corning Inc. Advanced Technology Ventures, Morgenthaler, Thomas Weisel Capital Partners, Azure Capital, Banc of America Securities LLC, Kalkoven, Pettit & Levin Ventures and Archery Capital	Photonics
	SiGe Microsystems	64.20	BDC Venture Capital, CDP Capital - Technology Ventures, VenGrowth Capital Partners	Semiconductors
	Silicon Access Networks(1)	58.50	Soros Private Equity Partners and Norwest Venture Partners. Pilgrim Baxter, Van Wagoner Capital Management, Parker Price Venture Capital and Glynn Capital.	Semiconductors
	Trillium Photonics Inc.	43.50	Sprout Group, Tallwood Venture Capital and Synopsys.	Photonics
2003	Meriton Networks Inc.	25.50	Covington Fund II Inc.	Photonics
	Adherex Technologies(4)	29.40	VentureLink Capital Corp	Biotech
	Tropic Networks Inc.	28.00	HBM (Zurich), Vengrowth, OrbiMed (NY)	Photonics
	Engim Canada(5)	25.90	Celtic House, Crescendo Ventures, Goldman Sachs Canada Inc., Kodiak Venture Partners, Teachers' Merchant Bank	Semiconductors
	BeIAir Networks	21.00	Bessemer Venture Partners, Matrix Partners	Wireless
	Atreus Systems	18.20	J.P. Morgan Partners, (Vengrowth & BDC 1st)	SW
			Meritage Private Equity Funds, SAIC Venture Capital, Telus Ventures and others	

Source: CVCA, Entrepreneurship Centre, OCRI, National Post, Corporate VC firms' websites

Notes: (1) Ottawa R&D center. Headquarters in San Jose, CA. (2) Ottawa R&D center. Headquarters in Pittsburgh, PA. (3) Joint venture between TMI Communications and Motient Corp. of Reston, VA. (4) Biotechnology publicly traded company. (5) Ottawa R&D center. Headquarters in Acton, MA.

Table 5. Ottawa region companies among the Top 10 VC deals made in Canada (by size), 2002-2003

4.2 Preconditions

To understand the boom and bust phenomenon in venture capital is important to look back at the contextual circumstances or environment that surrounded the telecommunications industry before 1998 in North America.

4.2.1 The Internet

The Internet is arguably the most important technological breakthrough of the past fifty years. The Internet became widely relevant for the public at large with the famous Netscape IPO in 1995. A couple of years later, following Amazon's IPO in 1997, the e-commerce business became a significant business model driving innovators and investors to create and finance hundreds of Internet startups (Perkins and Perkins, 2001).

4.2.2 Telecom Deregulation

Deregulation intensified in the 1990s, best exemplified by the 1993 Canadian Telecommunications Act and the 1996 U.S. Telecommunications Reform Act. The purpose of these acts were aimed at promoting competition and reducing regulation in order to achieve lower prices, higher quality services and rapid deployment of new technologies. As a result, the opening of the monopoly of local telecom markets to long distance operators, cable operators and competitive local exchange carriers (CLECs) was pivotal to the industry development. Analysts, investors, and innovators focused their attention on the emergence of the huge and yet unexploited market that resulted from this wave of deregulation (Christensen et al. 2001).

4.2.3 Telecom Wars: Cisco, Nortel, Alcatel and Lucent

During the late 1990's, the Cisco business model of 'growing through acquisitions' became popular in the telecom sector. Cisco had a long story, using stock to acquire 73 companies from 1993 through 2001. Cisco used the model to remain the dominant player in network routers. However, beginning in 1996, they acquired StrataCom to enter the optical networks sector (Carpenter et al., 2002). This acquisition poised Cisco to enter the telecom arena. The year 1996 also witnessed the incorporation of Lucent Technologies, a

division that was spun-off from AT&T. Lucent was set to play an active role in the telecom wars that followed suit.

As a result of the structural changes in the industry, the second half of the 90's witnessed the advent of the 'new world' of telecom. The buzzword of the industry was 'convergence'. Incumbent operators assumed that their age-old telephone networks needed to be totally revamped in order to offer the whole array of next-generation broadband services made possible by the Internet. Their pressure was evident, since broadband was the de-facto infrastructure used by cable operators and the new players (Competitive Local Exchange Carriers or CLECs, Internet Service Providers or ISPs). For the telecom vendors this also was a huge structural change. They were not capable of innovating at the speed demanded by the new telecom market. The Cisco model then started to make a lot of business sense to the traditional telecom vendors. The time-to-market pressure drove a paradigm shift from the traditional NIH (Non-Invented-Here) policy of the telecom's R&D groups. The signal was clear: it was time to buy or die.

In 1998, rumors circulated about potential bids from Nortel, Lucent, Alcatel, Ericsson and Siemens for an optical networking company, Bay Networks⁶. By August 1998, Nortel acquired Bay Networks for \$7 billion in stock. This was Nortel's big move in the area of optical networks, Cisco's traditional arena. For similar reasons, in June 1999 Lucent acquired Ascend for \$24 million. And for the same reasons, Alcatel bought Newbridge Networks, arguably the most prominent company in Ottawa, for \$7.1 billion. Rumors circulated that other two European telecom vendors, Siemens and Ericsson, became also interested in Newbridge⁷. These acquisitions represented the telecom vendors' shot at 'convergence', the delivery of voice, data and video over a single network.

⁶ Source: Bay Networks Up 15% On Controversial Published Report. Dow Jones News Service, May 13, 1998. Factiva database, <http://www.factiva.com>

⁷ Source: Pritchard, T. (2000). Alcatel Will Buy Newbridge Networks for \$7.1 Billion. The New York Times. February 24, p. C.4.

On the macro level, acquisitions of optical systems companies had the clear purpose to enter a new market. On the micro level, a lot of acquisitions were taking place for a different reason. Now that Cisco, Nortel, Lucent and Alcatel could compete on the same markets they needed 'more' to differentiate.

It is important to remember that the traditional telecom vendors have a long tradition with their roots dating back more than 100 years ago. Nortel came from Bell Canada (Canada, 1895), Lucent from AT&T (USA, 1872), and Alcatel had its roots on the Compagnie Generale d'Electricite (France, 1898). Conversely, Cisco (USA, 1984) was a 'leaner and meaner' company. Cisco was setting the standard in acquisitions. Perhaps to achieve a competitive advantage against Cisco and peers, or perhaps for inertia, the telecom vendors would look to differentiate using their 'tried-and-tested' formula of 'carrier-class products'. Therefore, on the micro level, many of their acquisitions may well have been aimed at buying the 'best-in-breed' technology companies.

4.2.4 Public market

By the end of the 1990's the US. public market for high-technology stocks (NASDAQ) had the largest boom in its history. From 1998 to 2000 the prices of high-tech stocks, including those of the telecom companies, increased to record levels. However, starting on the 3rd quarter of 2000 the NASDAQ started a steady decline extending well into 2002 (see Figure 5). The telecom companies were similarly affected with a declining stock price (see Figure 6).

Figure 5. NASDAQ composite

Cisco (CSCO), Nortel (NT), Lucent (LU) and Alcatel (ALA). Source: Yahoo finance

Figure 6. Stock performance of Cisco, Nortel, Lucent, and Alcatel (10 year)

The boom in telecom was driven by the belief that broadband networks would meet the demand that the Internet age had opened up. The quick adoption of the Internet led the telecom market to believe that bandwidth usage would increase very quickly. This belief created an extreme demand for capacity and products. Such was the case of optical networks and components companies, which offered ways to expand bandwidth

efficiently and effectively. Similarly, the collapse of the public market for the telecom companies was in part due to a substantial slowdown in the demand for optical equipment from the service providers (Harvey, 2002), in turn, driven by the low demand of their customers.

Along these lines Carpenter et al. (2002) study the impact of the public market on the corporate strategy of the major optical networking companies (Cisco, Nortel, Lucent and Alcatel) and find evidence that the public market was a significant factor in the way they competed by using their corporate stock as an acquisition currency. This finding suggests that the propensity of the optical networking companies to buy was influenced by their highly valued stock.

The above preconditions set the stage to what went on in the Ottawa VC boom-and-bust during 1998-2003, which is discussed next.

4.3 VC Boom-And-Bust in Ottawa

Venture capital investment activity in Ottawa went from \$74 million in 1998 to over \$1.2 billion (Canadian dollars) in 2000, which was a significant rise of investment in two years alone. Between 1998 and 2003, more than \$3.5 billion (Canadian dollars) were invested in more than 200 Ottawa startups. How did this sudden upsurge of VC investment take place in Ottawa? How was Ottawa poised to confront the structural challenges and market opportunities that lay ahead? What impact, if any, had the early successes of Ottawa's startups in the development of the local venture capital community? Why did the VC investment exuberance could last? As steps towards answering these questions, I provide a historical recount of the rise and fall of VC in Ottawa.

4.3.1 Beginning

Ottawa appeared in the map of both investors and acquirers in June 1997, when Cisco decided to acquire a local startup, Skystone, for \$89 million. The Cisco deal was

significant for two reasons: i) Ottawa was recognized as a technology hub for telecommunications, particularly optical , ii) Cisco's first foreign acquisition alerted the local players: Nortel and Newbridge. As Callahan (2004) noted, the "game had changed":

"The acquisition of Skystone by Cisco in June 1997 for \$89M (U.S.) in Cisco shares and cash marked the start of the "bubble economy" in the Ottawa region. The company had been in business for only a couple of years. It was developing optical networking chips.

The acquisition made its founder Antoine Paquin a household name in the region. If so much could be made in so little time, the "game had changed."

The VCs who had invested in the company and shared a big payday were Celtic House and a prominent Boston firm, Furneaux & Company run by David Furneaux. Furneaux & Company later changed its name to Kodiak Venture Capital."

At the time, Celtic House was the only 'private' VC firm in Ottawa. Celtic House started to play an important role in the development of venture capital in the region. Although Celtic House was a 'private' VC firm, it was not the traditional limited partnership firm. Terry Matthews⁸ founded Celtic in 1994 by with his own \$25 million – he was its sole investor. Andrew Waitman, managing partner at Celtic House pointed at Skypoint as indicative of the company's strategy:

*"We stole Skystone from Kleiner Perkins [a leading US VC]...we were able to do that because we wired [Skystone] US\$500,000 non-refundable before the legal [paperwork] was done. There's no way you could do that with certain fiduciary responsibilities. We can be a little more accommodating because we're only working for one individual."*⁹

Limited partnerships represent the majority of venture capital investment structures in the US. In Canada on the other hand, labor-sponsored funds, government sponsored funds, and Corporate VCs played a primary role in financing new companies¹⁰. The case in Ottawa was no different. Up to 1997, the investment capital for technology startups in

⁸ Terry Matthews is, arguably, the most successful entrepreneur that the Ottawa region has seen.

⁹ Hanson, K. (2000). Matthews has \$250-million for tech startups: 'Contact sport': Savvy investments have drawn U.S. attention. National Post, August 3, p.C.3.

¹⁰ Best, A., and Mitra, D. (1997). The venture capital industry in Canada. *Journal of small business management*. April (1997). pp. 105-110.

Ottawa was slight and it was usually provided by a mix of local, provincial, and in some exceptional cases (such as the Skystone deal) foreign groups¹¹.

Table 6 shows the private equity investment structures active in the Ottawa region up to 1997:

Investor type	Group
Angels	Led by Terry Matthews and other wealthy individuals
Corporate VCs	Newbridge Affiliates program and Severn Bridge Investments (also related to Newbridge)
Labour Sponsored Venture Capital (LSVCC) funds	Capital Alliance Ventures, Working Ventures (Toronto), and Vengrowth (Toronto)
Private VCs	Celtic House (the private independent VC firm of Terry Matthews), Furneaux & Company (Boston, US)
Government VC funds	Business Development Bank of Canada (BDC, Ottawa office)

Table 6. Main private equity investment groups active in Ottawa prior to 1998

The fact that the Skystone deal was surrounded by US VC interest was also important because it showed that Ottawa was a fertile ground for outside investment. Perhaps Vengrowth (an institutional and LSVC investment fund from Toronto) was the largest outside investor in Ottawa. Prior to 1998, Vengrowth had a history of investing more than \$20 million into Ottawa-based companies¹².

¹¹ Refer to Callahan and Charbonneau (2004) for a detailed overview of the history of venture capital in the Ottawa region.

¹² Ibid.

4.3.2 Cambrian¹³

Cambrian Systems was a Kanata based company that developed metropolitan optical technology based on DWDM (dense wavelength division multiplexing). This technology would speed up the flow of traffic between metropolitan areas and the Internet backbone networks.

The company was founded in early 1997 by Gino Totti, Dave Milton, Don Smith, and Phil Wilkinson. Totti and Milton were former Nortel colleagues, Smith was executive of AiT, and Wilkinson was former co-founder, together with Milton, of Plaintree Systems. Another key member of the Cambrian team was Tom Valis, who had recently joined Celtic House. Valis worked as research analyst at Eagle & Partners, a Toronto-based securities firm. In particular, Valis had a PhD in Fiber Optics and helped the technical team to come up with Cambrian's technology platform called Optera¹⁴. After the Optera concept was proven, the company engaged in fast product development. As a result, Cambrian started to aggressively increase its workforce. With Totti's network of contacts, Cambrian soon attracted a good pool of optical engineering talent from Nortel. Cambrian grew from few than a dozen in the spring to about 100 employees by the end of 1997. Not only Nortel employees were rushing towards Cambrian, investors were too. In May 1998, Vengrowth invested \$2 million. This was the third Ottawa company in which Vengrowth had invested¹⁵. Several other investors had also stakes at Cambrian, which raised \$14.25 million in 1998 alone. This was a record amount considering the standards of the Ottawa region to that date. Investors' in Cambrian included:

- Newbridge
- Terry Matthews
- Celtic House

¹³ Sources include: Bagnall, J. (2001). Takeover: Nortel's metro-optical technology is one of the few units showing signs of promise. *Ottawa Citizen*, December 20, p.F.2.; Canada NewsWire (1998). Nortel Networks Announces Successful Completion of Cambrian Systems Acquisition. *December 15*; Interview data.

¹⁴ Soon after, Valis would return to Celtic House. He became member of Cambrian's board of directors.

¹⁵ Vardy, J. (1998). ADVENTURES IN HIGH TECH: The Ottawa area has more than 700 technology companies. *Financial Post*, August 15, [Special report: IT monthly]. IT2.

- Vengrowth
- Ontario Teachers' Fund
- Royal Bank Capital

Cambrian was regarded as a player with quality technology that was simply out ahead of the marketplace by a year. It is also important to note that by 1997 Nortel was not yet an optical heavy-weight company, so a Nortel takeover of Cambrian made a lot of sense. It would take Nortel at least 6 months to catch up with Cambrian's state-of-the-art technology. However, Nortel was not alone in its interests for Cambrian. By fall 1998, Cisco and Lucent were preparing rival bids. Rumors were that Matthews pushed for an all-cash bid and that Lucent was willing to pay in cash. By late 1998, just over a year after Cisco's acquisition of Skystone, and less than 6 months after its \$7 billion acquisition of Bay Networks, Nortel decided to buy Cambrian Systems for \$300 million in cash. Not only did Cambrian prove to be the richest acquisition in Ottawa's history to that date, but it was the first of a string of Nortel acquisitions of optical startups¹⁶.

Ottawa then became a big deal. Skystone was not an isolated acquisition any more. The Cambrian deal gave an estimated 31X return to its investors. After the Cambrian deal, both acquirers and investors started to seriously turn their attention towards the Ottawa cluster. The Cambrian deal contributed to set the stage to what would later turn into a VC revolution in Ottawa.

4.3.3 Momentum

The extraordinary early successes of Ottawa startups brought a lot of wealth to the city. There were many new high net-worth individuals who wanted to grow the entrepreneurial community in the region. Some of these wealthy individuals became individual investors in the nascent local venture capital groups. One such group is Skypoint Capital Corp. Skypoint was founded in 1998 by Leo Lax and Andy Katz. Lax was manager in the successful Newbridge Affiliates corporate fund and Katz worked for Deloitte & Touche,

¹⁶ Nortel would later pay more than US\$6 billion for California-based Xros and Florida-based Qtera.

handling the Newbridge account¹⁷. They raised their Fund 1 with \$54 million from institutional and individual investors. Lax had a proven track record running Newbridge's corporate VC fund and the timing was ideal to raise funds. Skypoint was the first limited partnership fund incorporated in Ottawa and it set a new stage in the maturity of the venture industry in Ottawa.

The next year, 1999, was marked by the IPO of Tundra Semiconductors, another successful Ottawa company spun-out from Newbridge¹⁸. Early investors in Tundra included BDC and Capital Alliance. Vengrowth also invested \$5 million early in 1999 prior to the IPO¹⁹.

This year was also important because it marked what would be a consistent flow of American VCs investing in Ottawa²⁰. Two startups got big money financing with US investors playing a key role:

- 1) Eftia OSS Solutions, a developer of telecom network management software received a first round of \$45 million from two US VCs: Spectrum Equity and Insight Capital.
- 2) Catena Networks²¹ raised \$43.95 million from a US VC, the lead investor, Morgenthaler Investments²² and other Canadian investors including BCE capital. Catena's product concept was simple, a chipset that allows telephone companies to deliver voice and high-speed data to customers on the same telephone line. By 2000, its founders (ex-Nortel employees and managers) had secured a second round worth \$91.2 million from two other influential American investors: Goldman Sachs and Berkeley International Capital.

¹⁷ Callahan and Charbonneau. Op.cit. p. 36.

¹⁸ See Callahan and Charbonneau. Op.cit. p. 8.

¹⁹ Source: The Entrepreneurship Centre, OCRI.

²⁰ See US VC component in Appendix 1. Ottawa region's share on Top 10 VC deals in Canada (by size).

²¹ Sources: Bagnall, J. (2004). How the Catena deal was done. *Ottawa Citizen*, February 20, p.E.1);

Bagnall, J. (2004). Catena's cold choice. *Ottawa Citizen*, April 22, p.F.1.; The Entrepreneurship Centre, OCRI.

²² Morgenthaler Investments is a top-tier venture capital firm based in Silicon Valley and Boston.

By 2000, investor interest in Ottawa startups (particularly in the optical sector) became so intense that the largest deal (by size) in Canada was made into a 6-month old optical networking company called Innovance Networks²³. Innovance raised \$115 million (Canadian dollars) of seed financing from a US VC syndicate of six American investors led by Morgentaler Ventures and Thomas Weisel Partners²⁴. A few months earlier, MetroPhotonics, another 6-month old optical company, secured \$62.5 million (Canadian dollars) of financing led by the Vancouver-based Yorkton Securities Inc²⁵. Five of the 10 largest deals in Canada were made in Ottawa alone, from these five at least four had an important American VC component. By this time it was clear that the US VC industry had developed a serious interest to invest in Ottawa.

There were more relevant events for the local VC community as well. Claude Haw established a new limited partnership firm, Venture Coaches. At the very peak of the boom, Venture Coaches became the second limited partnership fund in Ottawa. It raised \$40 million in cash from Institutional investors and individual investors²⁶. Haw also had a successful track record managing Severn Bridge Investments, a corporate VC fund of Newbridge²⁷. Another event was the opening in July 2000 of an Ottawa office by the Vancouver-based Ventures West Management. Ventures West was one of the most prominent private VC firms in Canada, with roots dating back to the 70s. Marc Wickham, who previously worked at BDC, was appointed to run the Ottawa office²⁸.

Celtic House then became the most successful private VC firm in the region. In 2000, Celtic's Fund I was worth \$1.2 billion, this was the year of Celtic's extraordinary 'home-

²³ National Post Business Magazine (2001). The venture capital top 50: Our exclusive ranking of the leading Canadian venture capital deals of 2000, April 1. p.76.

²⁴ Interestingly Morgentaler Ventures did not participate in Catena's second round of financing.

²⁵ Tuck, S. (2000). Ottawa startup lands financing, six-month-old MetroPhotonics gets almost double the money it sought from investors. *Globe and Mail*, October 31, p.B.5.

²⁶ Source: Presentation by Claude Haw, Venture Coaches, presentation at Carleton University, November 18, 2003.

²⁷ Also note that in early 2000 Alcatel had acquired Newbridge for \$7.1 billion in shares.

²⁸ Hanson, K. (2000). Ventures West pumping bucks into startups. \$50M this year: Vancouver-based firm has also opened office in Ottawa. *National Post*, July 27, p.C.10.

runs'²⁹. In its most prominent exits, Celtic sold the Vancouver-based Abatis Systems Corp. to Redback Networks Inc. of California for US\$636 million in its biggest-ever success³⁰. Celtic and three other venture capital investors also sold the Kanata-based semiconductor company, Externe Packet Networks to PMC Sierra of Burnaby, B.C. for US\$415 million³¹. In yet another exit, Celtic and three other VCs sold the Waterloo-based video-over-IP company, Pixstream to Cisco for \$369 million in shares³². Later in 2000, Celtic opened its Fund II with \$250 million that Terry Matthews agreed to add, basically reinvested from the proceeds of the first fund.

4.3.4 Inertia

By mid-2000 there were clear signs that the boom would end, particularly for optical networking companies. One sign was Nortel's unmet revenues goal of optical products between Q2 and Q3 of 2000. Apparently, customer demand for optical networks was not meeting growth expectations³³. Another conspicuous sign was the consistent decline in the NASDAQ, which started by Q2 2000 (refer to Figure 5).

Perhaps because Canada traditionally lags behind the US, the ripple effect of the public market crash did not stop the continued flow of investment capital into the Ottawa region. Another explanation would be that the effect of the Internet Bubble was significant in the US and not Canada, since in the latter investments were heavily skewed towards telecom. Yet another explanation would be that, by 2001, the American VC industry had a \$106 billion overhang to deploy at exactly the worst time. It is reasonable to think that the US VCs desperately needed the new markets and technological opportunities being

²⁹ Sources include: Hasselback, D. and Vardy, J. (2000). PMC-Sierra cuts \$1.3B in buyout deals: Ottawa firm strikes gold. *National Post*. *March 4*, p.D.1.; Hanson, K. (2000). Payback time for venture capitalists: Terry Matthews among early investors to cash in. *National Post*. *September 1*, p.C.5.; Ibid (3); Celtic House corporate website, http://www.celtic-house.com/portfolio_successes.html

³⁰ In 1998 Celtic made a seed investment of \$3 million in Abatis.

³¹ The other three investors were Furneaux and Co. of Boston, Centara Corp. of Winnipeg and Blackboard Ventures, the venture-capital arm of the Ontario Teachers' Pension Plan. The four have invested a total of \$9.7-million in Externe Packet, \$6.7-million of it in a second round that was completed in early 2000.

³² Other investor's included Vengrowth, BDC and J.L. Albright Venture Partners. Overall the four VCs turned \$57 million in funding over a three-year period into \$545 million (Canadian dollars). Celtic seed funded Pixstream with \$3 million in 1997 and \$1.3 million in a second round. Celtic's proceeds were valued about \$58 million.

³³ Nortel Networks Corporation (2003), Annual and Quarterly Reports (1998-2000)

developed across the border³⁴. In any case, from 2001 to 2003 the American VCs consistently played an important role in the financing of Ottawa's technology companies.

By 2001, three out of the five largest deals in Canada were made in Ottawa-based optical companies. Ceyba had the single largest transaction in the Canadian VC industry with a record second round of financing worth \$144.5 million (Canadian dollars). Another prominent transaction in an optical company was a second round for Tropic Networks worth \$93 million. A third one was that of Accelight Networks which was similar to that of Tropic. Interestingly, only one local firm, Celtic House, participated in one of these large financings (perhaps due to their early involvement with Tropic). Not surprisingly, foreign investors' names started to become more common in the region, particularly some major American investors. Among those involved in Ottawa were³⁵:

- CDIB Venture Management
- Davidow Ventures
- Granite Global Ventures
- Menlo Ventures
- Mitsubishi, New Enterprise
- Newbury Ventures
- NIF Ventures
- Stonewood Capital Management
- Venrock Associates
- Vertex Management
- Warburg Pincus
- Western Technology Investment
- Woodside Fund

³⁴ Overhang is the amount of un-invested capital that has been raised by venture funds. Source: Dignan, P. (2002). Putting the venture capital overhang into perspective. Venture Capital Journal, December. P.1-3.

³⁵ Sources: The venture capital industry in 2001: An overview. CVCA website, http://www.cvca.ca/statistical_review/index.html; MacDonald&Associates Ltd.

The American VCs were comfortable investing at higher valuations since they had 'deep pocket' funds, which suggests that the local VCs were unable to participate in the big deals due to their 'smaller' funds.

In 2001 VCs were still very active in Ottawa. Evidence of this is the opening of Ottawa offices for three VC groups who were already familiar with the region. In late 2001, Vengrowth, the Toronto-based LSVCC/institutional VC group appointed Mark Janoska and Pat diPietro as general partners to run the Ottawa operation. Janoska was a former Newbridge employee and was one of the founders of Extreme Packet Networks. diPietro was a former VP at Nortel Networks. Another Ottawa office was opened earlier that year by the Boston-based Kodiak Venture Partners. Kodiak appointed Bruce Gregory, ex-CEO of Extreme Packet Networks to run the local operation³⁶. Also the California-based Newbury Ventures was affiliated with a local investment firm, Eagle One Ventures, run by two ex-Newbridge executives³⁷.

4.3.5 Meltdown

By the second half of 2001 things would soon start to look bad. There were no major exits of Ottawa-based startups between 2001 and 2003³⁸, and fundraising activity for VC firms would become increasingly difficult.

Liquidity events for VC-backed companies dried up. This was especially true for the local telecom startups. What was more common during the meltdown was the shutting down of portfolio companies and in soft-exits (a 'soft-exit' means that the VC group has to sell at a loss or on a marginal return). For example, Solidum Systems was sold to IDT for \$10 million in 2002 (out of \$23 million invested). Another sale was that of Akara Systems to Ciena in 2003 for \$45 million (about \$45 million invested)³⁹.

³⁶ Bagnal, J. (2001). Catch of the day: Vengrowth aims for one; lands two over lunch. *Ottawa Citizen*, November 5, p.D.3.

³⁷ Vardy, J. (2001). U.S. venture capitalists head back to Ottawa: Lured by hot photonics. *National Post*, June 12, p.C.8.

³⁸ Hill, B. (2004). Sizzle returns to technology stakes: After four dry years, a fat payday for investors who took a risk. *Ottawa Citizen*, February 20, p.E.1.

The fundraising climate was tough as well. On the macro level, the national pool of VC funds was consistently reduced between 2001 and 2003. Supply of capital went from \$4.7 billion in 2001 to \$3.2 billion in 2002 (a 30% decrease), and then to \$2 billion in 2003 (a 40% decrease)⁴⁰.

On the micro level, the environment for private VCs was no different. During 2001, Skypoint was successful in raising \$40 million to open its Fund II. However, with the events of the 9/11 terrorist attacks and the public markets declining, the financial climate changed drastically and most investors would put everything on hold. However, Skypoint was able to close a \$100 million fund by early 2002⁴¹. Another success story was that of Celtic House. Celtic was a one-investor (Matthews) VC fund. Nonetheless, during an inhospitable financial climate, Celtic successfully evolved into a traditional limited partnership fund⁴². Between 2002 and 2003 Celtic raises \$90 million from institutional investors⁴³ to complete its Fund II.

From the deal flow perspective, in 2002, investments were still underway. This time Catena Networks led the largest sized deal in Canada. Catena still looked promising and was able to raise \$112.5 million (Canadian dollars) from a syndicate of 11 investors (mainly Americans) led by Morgenthaler Ventures⁴⁴. It is important to note that this time the conditions were different, since this was a down-round where Catena's post-money value was estimated on \$225 million⁴⁵ (after the \$112.5 million investment). Other prominent optical financings were Innovance (\$88M) and Trillium Photonics (\$43.5M). One year later, in 2003, only one photonics company received a major financing. Tropic

³⁹ Ibid.

⁴⁰ Interestingly, more than 50% of the capital inflows came from funds raised by LSVCCs. Consistent with a somewhat stable supply of capital from retail investors.

⁴¹ Bagnall, J. (2002). Betting on a telecom recovery: Skypoint's Leo Lax targets \$100M U.S. Fund. *Ottawa Citizen*, April 18, p.E.6.

⁴² Sources include: The venture capital industry in 2002: An overview. CVCA website, http://www.cvca.ca/statistical_review/index.html; MacDonald&Associates Ltd.; Ottawa Business Journal Staff (2003). Waitman sitting on multimillion-dollar fund, *Ottawa Business Journal*, February 9.; Idem. UPDATE: Celtic House gets US\$10M from Goldman Sachs, *Ottawa Business Journal*, March 28.

⁴³ Institutional investors included: Goldman Sachs' Private Equity Group, Canada Pension Plan, Ontario Teachers' Pension Plan Board, Ontario Municipal Employees Retirement System, Paul Capital Partners and Matthews himself.

⁴⁴ Ibid (13).

Networks, which raised \$28 million in a third round led by Celtic and other American investors.

4.3.6 Aftermath

The meltdown period set the stage to what can be considered a 'photonics wasteland' of Ottawa startups. Prominent failures in the photonics space include: Trillium (2002), Innovance (2003), Ceyba (2003), and Optovation (2003). By the end of 2003 the only survivor in the sector was Tropic Networks.

Locally, at the VC-firm level, consolidation took place. Two LSVCC funds, the London, Ont. based Technology Investments Management Corp. (TIMCO) merged with Capital Alliance Ventures (CAVI) under the name Fullarton Capital Corp⁴⁶. Two private VC funds, Venture Coaches and Skypoint merged under the Skypoint name. These mergers reflected the poor market for venture capital and the decreased confidence of investors in the VC industry. Perhaps the mergers are intended to increase the likelihood of raising funds in the coming 2004-2005 timeframe⁴⁷.

4.4 Discussion

The boom-and-bust in the Canadian VC industry is better understood by studying it from a regional perspective. The Ottawa region captured a significant portion of the Canadian VC boom-and-bust phenomena that occurred between 1998 and 2003.

The preconditions that set the stage for the boom might be explained by telecom deregulation, a rising public market, and the technological breakthrough of the Internet.

The increasing competition on the basis of 'growth by acquisition' forced telecom vendors to escalate prices into higher and higher valuations for companies that they thought would provide them with technological and market advantages perceived by the

⁴⁵ Ibid.

⁴⁶ In 2002 a new LSVC fund emerged in Ottawa. Axis Capital Corp.

⁴⁷ Outside the Ottawa region two other LSVCs merged in 2003. The Vancouver-based GrowthWorks Capital Ltd. merged with the Toronto-based Working Ventures under the GrowthWorks name.

industry as strategic. The increasing number of acquisitions gave both entrepreneurs and investors plenty of confidence to start and finance new ventures. The levels of investment and innovation were so high that the supply of capital and innovations exceeded any realistic expectations of customer demand. Perhaps this was one of the reasons why the public market crashed. With the crash, the market capitalization of the telecom vendors went down to a fraction of what it was worth at the peak of the boom. As a result, telecom vendors stopped buying startups.

As supply lagged demand, investments continued into flagging startups which later turned into real failures. The decrease in liquidity expectations, led investors to reduce their commitments into venture funds. With less availability of capital, less money went into financing new and existing startups, which resulted in still poorer returns performance⁴⁸.

In Ottawa, the boom-and-bust started with Cisco and Nortel's strategic acquisitions of local startup companies. As success was created in the region, the desire for high profits brought in more and more outside investors. Many of these investors were American investors, most of which were unfamiliar with the local market. They came to Ottawa and aggressively invested in telecom companies with the hope of a quick return. American investors had 'deep pockets' and were willing to bet high on local companies, which reduced the ability of local investors to participate.

Who is to blame? It should be noted that the venture capital industry in the US was over-competitive during 1998-2000. US VCs had a lot of money to deploy but nowhere close to invest. They came into Ottawa chasing the deals they could not find locally. The inflow of US investors into Ottawa led to increased competition driving up valuations. Additionally, many US VCs would bring their American syndicate partners, which further contributed to increase the valuations. It soon became evident that in order to achieve a reasonable return, the exit valuations would need to be extremely high. Rising

valuations combined with a dry market for acquisitions resulted in prominent failures of ambitious startups. As investors retreated, valuations dropped. The end result: fewer exits, fewer investors, and lower supply of capital, and potentially, still more failures.

As the day follows the night, investment and entrepreneurship seemed to return to fundamental and historical levels. Industry consolidation took its toll and a dim light looms ahead. The ability of the local VCs to survive will greatly depend on the outcome of their current portfolio companies. These companies should be ready to harvest in the next few years (2004-2006). In the meanwhile, the current market conditions present themselves favorable for investment. In an environment with less competition, reasonable valuations, and less threatening deal terms, both VCs and entrepreneurs are poised to create real value.

The next chapter combines the findings of the interview data with the observations from the case study into a formal simulation model. This model considers the effects of investor behavior and competitive dynamics on the outcomes of the venture capital system.

⁴⁸ Additionally, during the meltdown, the macro-economic context was not favorable at all. As North America got hit by recession, terrorism, war, and epidemics; investors became more cautious and a contraction of the whole industry occurred.

5 ELEMENTS OF A DYNAMIC CAUSAL MODEL

This chapter presents the content analysis of the data obtained through intensive interviews with venture capitalists in the Ottawa region. The interviews contributed to the development of a dynamic causal model for understanding the dynamics of the VC investment process.

5.1 Background

Figure 7 shows the boom and bust in Canada during 1998-2003. VC investment activity experienced significant growth (over 200% of its historical values), which reached record levels in 2000 when more than \$6 billion (Canadian dollars) were invested. A large fraction of this VC money was invested in Ottawa. Over this period, Ottawa flourished as a respectable technology cluster which came to be known as “Silicon Valley North” drawing many investors’ interest. Sadly, the rapid growth of the region was followed by a sharp decline, which was reflected in the bankruptcies of several promising startups.

The venture capital boom and bust was not limited to Canada, nor is it an object of academic interest alone. Similar boom and bust behaviors were observed in the US venture capital and the European venture capital industries. The dynamics were even more dramatic in the case of the US, where venture capital is a well established and mature industry. In the case of the US, the venture capital boom and bust was mainly driven by the Internet or dot-com bubble (Perkins and Perkins, 2001). US VCs funded thousands of dot-com companies in a speculative mania that may be comparable to the Dutch Tulipmania of the 1630s, the SouthSea bubble of 1720, and other famous price bubbles described by Kindleberger (1978).

In the case of Canada, and particularly Ottawa, the boom and bust was driven by new ventures in the optical sector. Service providers competed for bandwidth and telecom

vendors competed for performance, which led the high growth of new venture creation and financing in the region.

Source: Macdonald & Associates Ltd.

Figure 7. VC Investment activity in Canada during 1998-2003

5.2 Fieldwork on the dynamics of venture capital investment

I investigated the boom and bust phenomenon by interviewing individuals highly knowledgeable about venture capital in the Ottawa region. The interviews were both formal and informal, and the interviewees included senior management practitioners and highly respected academics with research interest in the venture capital field.

My goal was to identify the mental models that investors use to guide investment decisions. In particular, I was interested in understanding the dynamics of venture capital investment. What are the positive feedbacks driving investment activity? What are the negative feedbacks preventing its growth? Did investors account for critical delays in the investment process? Did VCs account for the implications of delays fluctuations in their decision variables?

Eliciting mental models of domain experts through interviews is a difficult process. Respondents may consciously avoid giving you the details about sensitive company information such as the operation and performance of their investment portfolio, or how specific investment decisions were made in their firm. They may prefer to comment on other people's investment decisions rather than their own. They may even tell you what they think you want to hear.

Recognizing the above caveats, in the formal interviews I began initially by asking generic and neutral questions about the venture capital investment process. The aim was to encourage interviewees to share their experience on how they make investment decisions, how they raise a fund, how they exit companies, and what factors are important in the investment decision. Second, I asked questions about what was specific to the boom (1998-2000) period, the investment environment, and how they made investment decisions during those years. Finally, I asked questions about what was different during the bust (2001-2003) period. How did their perceptions change, what were the challenges they faced, and what was their reaction during the downturn.

The aim during the interviews was to identify the key variables that market participants regarded as relevant when making decisions during the 1998-2003 period. In particular, I wanted to identify how different the investor behavior was during the upswing and later during the decline, and what pressures accumulated during the investment process.

Surprisingly, when asked about the lessons learned from investing in the boom-and-bust years, almost none of them spontaneously recognized feedbacks, time delays, or the supply line of deals (e.g., the deal flow of the firm) as a possible source of the problem behavior. One experienced VC, whose descriptions focused heavily on the detailed complexity of the venture business - how to pick the right market to invest, the quality of the partners, best practices, and so on - illustrates this point:

"Across all time we have been very focused. Successful VCs invest in areas that they know. You want to have a good understanding of the business that is trying to be built, what are the technology and market risks, and who the strategic partners can be. Having a network of contacts is very important. In doing the due diligence, you want lots of people whom you can call."

My approach to the interviews was intended to gain a clearer understanding of how the domain experts think about the whole venture capital investment cycle. The following recount of experts' views is organized under three broad categories used to study the venture capital investment cycle, namely: fundraising, investment, and exiting. What aspects were perceived by the experts to be relevant in their decision process? I was interested to identify what the key variables were (i.e., resources, information cues, and delays), and to discover the relationships between these variables. In particular, I wanted to identify what pressures accumulated over time, pressures that could explain the shift in dynamics from boom to bust.

5.2.1 Fundraising

As one Limited Partner explains, fundraising is influenced by the track record of the VC firm and a healthy public market. Investors form expectations from recent returns data and the activity of the public market in order to make their decisions on the allocation of capital to VC funds. Their investment decisions are influenced by the discrepancy between perceived and desired goals.

"The track record of the VC group is probably the most important factor when raising funds... if you provided a good ROR [Rate of Return] to your LPs [institutional investors] in the previous fund, and if you had a healthy number of exits. Statistically, you are interested to know if they [the VCs] compare well, which means top quartile compared to other VCs in the sector that you invest (e.g., telecommunications, IT, biotech, etc.). Those are the primary numerical indicators that will let you know whether you should be confident when going to raise a fund. The second one would be the team. A team that has been together for a while, that they have experience in all phases...new deals, follow-on, and exits. The last one of course, which is very important, is whether the public equity markets are reasonably healthy...they are a driver towards M&A activity and even IPO. But M&A activity is even more important. The ROR expectation from the LPs is at least one that is greater than the weighted average of the listed exchange, and certainly greater than the NASDAQ or TSE by a couple of points. In terms of metrics, the GPs should have had in their previous fund an appropriate number of positive exits where all of the capital is returned. Also, for the majority of their exits, the entire initial capital should have been returned. And for 20% or more of the exits there should have been an outstanding return. Since that would help to compensate for the percentage of the portfolio companies that they had to write-off."

Investors assess the performance of previous VC funds in terms of realized returns and portfolio company distribution (e.g., number of successes and failures). A seasoned VC concurred:

"We started raising money when things were still looking very good, so there was a lot of momentum, a lot of investors where interested in investing in our fund. The main factor raising our fund was the track record of the GPs... what we did before, how successful we were with exits, and the returns performance of our investments."

The evidence from the interviews suggests that investors' confidence appears to be strongly influenced by the signals of high returns expectations and a healthy market for IPOs or acquisitions. When confidence is high, more investors' money flows into VC funds. As noted by another experienced VC, this was the case of the telecommunications industry in the late 90s.

"In the late 90s we raised funds fairly quickly because investors could see the returns that could be achieved in telecommunications. A large number of companies were able to go public as well as many companies were being acquired"

However, the inflow of capital into VC funds soon creates pressure in VCs to deploy that money into making new deals fairly quickly. As explained by a third experienced VC:

"The entire VC business is based on IRR [internal rate of return]. As soon as you raise a \$X million dollar fund there is a clock running, which means that you have to deploy it or your IRR goes down. There is a certain pacing issue, so when you raise a lot of money you have to get a fair bit of it out relatively quickly to work."

5.2.2 Investment

What drives venture capital investment activity? What was the investment environment in the Ottawa region between 1998 and 2003?

Deal Making:

A healthy public market strongly influences VC investment activity. As the number of successful exits increase, deal-making activity and valuations also increase. As one experienced VC puts it:

"The number of IPOs and M&A transactions has a large influence in VC. For example, the successful exits of companies in the sector [telecommunications] we invest had very high valuations during the boom. That contributed to the pace of investment, the pace of exits, and the value associated with investments and exits."

Another investment professional concurred. A company's product concept or technology becomes more attractive when the market shows signals of demand. One way to provide a salient signal is a liquidity event in the form of IPO or M&A.

"A sector becomes attractive when it becomes competitive. I think VCs start chasing the market when they see the potential is there. They need a validation from the market first, that someone is already in the space...when the [IPO and M&A] markets are open, there is a momentum going. If the window is closed, there is not really a sense of urgency, or a sense that you have to get into the space."

Competition:

VC investors in Ottawa increased from a few local VCs to at least one order of magnitude in the number of new investors (foreign VCs, Angels, boutique funds and others). Competition for deals became intense, which drove valuation prices up. One experienced VC explains how the American VCs would come with 'deep' pockets and pre-empt local VCs from investing as valuations became increasingly higher:

"A lot of the competition was driven by the US VCs. They came in [to Ottawa] and were willing to give huge valuations for local companies. In our case, we didn't play that game. We had the opportunity to co-invest with them for company X and we passed because the valuations were just outrageously high for the stage of that company."

One experienced VC justified the increase in valuations. High valuations provided more financing for startups that would use it to grow faster. Portfolio Companies would use the GBF (get-big-fast) strategy spending lots of money to hire skilled staff and obtain necessary resources to develop and commercialize products faster and better.

"During the boom years you were competing to get into deals, and you were trying to build the companies to get them big fairly quick. You were trying to commit sufficient capital so that they could hire fit people. That model was definitely what was going on in 1998-2000 and to a certain extent in 2001. Partly because of competition, partly because that was what you had to do... In essence, you were trying to get your companies into a critical mass so that they could get acquired relatively

quickly...so in early stage, what everybody did was to compete for various deals which drove up the prices."

By the end of 2000, the IPO and M&A markets for telecom startups declined dramatically. Another experienced VC describes the transitional dynamics between the boom and the bust periods. During the boom the number of new VCs investing in Ottawa increased and valuations were high. After 2000, these VCs started to leave the town and valuations declined.

"The Americans were all through the 90s [investing in Canada]. However, during the boom, there were many investors [US VCs] that were unfamiliar with the Canadian market, who were willing to come and take a look, just because there was a perceived advantage to making investments in Canada, particularly in Ottawa. Therefore, as [portfolio] companies became more mature, there were two likely scenarios. Either they exited and everybody would get liquid, or if there was an up-round, then that was fine and that was led by US VCs in 100% of the cases. After 2000, the majority of the follow-on investments were down-rounds and many of the American VCs were no longer interested in investing in Canada. In those cases many of the investments were led by Canadian VCs."

5.2.3 Exiting

What are the determinants of a healthy market for acquisitions? What limits the increase in the demand for acquisitions?

The bulk of the profits in the venture business are realized when achieving a successful liquidity event in the form of IPO or M&A. As described by one experienced VC, the buyers' motivations for acquiring portfolio companies depend on their strategic objectives, for example the time-to-market advantage.

"Acquisitions [of portfolio companies] are mainly driven strategic objectives of the business groups and not the R&D groups. The latter always tends to be very NIH (Non-Invented-Here) and protect their own turf. The reason for strategic acquisitions is that the business groups identify the advantage of getting into the market earlier than competitors."

One experienced VC outlines how the market for acquisitions in the Ottawa region was driven by competition among telecom providers. As exits gather momentum, more acquirers become interested in having market presence in the market, which drives prices of exit valuations up.

"In 1997 Cisco bought Skystone [an Ottawa startup] for \$89 million dollars...nobody in Ottawa had ever seen such high-tech exit ever. The perception was –Gee, this is a big deal. As Cisco started doing bigger and bigger acquisitions, it looks like Cisco is doing smart things. They are making acquisitions, getting a better stock price and looking widely successful. So what Nortel, Alcatel, Lucent did? Exactly the same thing...one year later Nortel buys Cambrian for \$300 million because they wanted to keep it out of the hands of competitors who were already interested to acquire Cambrian. So what happens is that the metro-optical space becomes one of the hottest spaces to be in business."

When do acquisitions stop? Essentially when there are no more buyers or when the buyers' ability to buy is affected. As one experienced VC notes it, buyers tend to acquire companies with the currency that can give them some cost advantage. They may prefer to buy with stock if they perceive it is over-valued, or they may prefer to buy with cash when they perceive their stock is under-valued.

"Acquirers buy with the currency they perceive has the lowest value. So if they offer cash, they perceive that their stock is under-valued. If they offer stock, they clearly believe their stock is over-valued. Why would they offer currency that has more value?"

5.3 Key delays

Key delays are defined as the time lags associated with each stage of the VC investment cycle. Three salient delays were identified. Fundraising, due diligence, and liquidity delays. Through the interviews, I found evidence that these delays were, on average, shorter during the boom and longer during the bust period.

5.3.1 Fundraising

The typical fundraising cycle in venture capital is 3 years. During this time VCs deploy their fund so that they can realize the majority of the proceeds by the time a fund is completed⁴⁹. During the boom VCs raised funds easier and faster, whereas during the bust VCs had a tough time raising funds. Investors had less confidence in VC funds

⁴⁹ The fund management policy works like this: For a typical fund horizon of 10-years, the first 3 years are the period of time when the VC group builds the portfolio of companies that will consume the investment capital of the fund. The remaining 7 years are the period of time when the VCs expect to realize the exits for their portfolio companies. By year 10 the fund should be completed and all proceeds of the portfolio should have been returned to the investors.

partly because of poor returns performance, and partly because of increased uncertainty about the future liquidity of VC funds.

"In 2000 the climate [for fundraising] was fairly good. Particularly with individual investors...we had a lot of Angel investors in our fund who were feeling pretty good. Most of them had made quite a lot of money through the boom years, at least on paper they had. So they were feeling pretty confident about investing in technology. We raised the first half of our fund in 2000 and that was relatively straightforward. It took us less than 6 months, it was a fairly quick process. 2001 was more difficult since things started to change quite a bit. So we raised our second half in 2001, that one took longer, almost a year. Later on, we tried to raise funds in 2003 and the climate was terrible...I think, in general, investors have been taking more time and are more cautious because they don't know how long it is going to take them to get a ROI."

5.3.2 Due diligence

Due diligence delay refers to the time it takes to evaluate a new deal. During the boom VCs had lower risk perceptions, which was due in part to the higher and quicker availability of company information that was provided by entrepreneurs. Moreover, there was pressure to make the deal faster, otherwise the competition would take it or even its valuation would go up. As a result, VCs performed the due diligence faster.

During the bust, falling customer demand increased the uncertainties about the market, which led an increase in risk perceptions. As a result VCs took longer time to assess a deal. As one experienced VC comments:

"During the boom deals were made in probably 30 days. There were three reasons for this. One reason was that the customers for the companies that we were investing in were much more available and willing to describe their future plans, so the opportunity was much more visible to the investors at a much faster pace. So the amount of study and detailed research required to validate data such as the size of the market, the number of customers that are going to use the product, the amount of money that could be generated, all those things were much more easy to get. Therefore, it was easier to come to a conclusion to make an investment. The second reason is that there was a lot of competition for a particular investment, so the companies were able to provide a lot of substantiated data, because there would be another 3 or 4 VCs asking similar questions. Therefore, the amount of time to study a particular deal was shortened because you had more information. Lastly, because there was more competition for investments, here was a pressure for the VCs not to study the situation forever. Post 2000, there was virtually no competition for investments. So, post 2000, an entrepreneur would get attention maybe of one or two VCs and that would be very good if he did. Therefore, there was no rush, and the VCs could study the situation as much as they would like. More importantly, to get the

information from the market on how the products are going to do in the future was unavailable because the market itself was in disarray. So you needed to study much more and the information was less reliable. That created the impression that the risk for the investment was much higher...a typical due diligence during those days would take around 4 to 6 months."

5.3.3 Liquidity

Liquidity delay is defined as the time it takes from first round of financing until successful exit of a portfolio company. As one VC relates his experience, investors' perceptions about liquidity were different in the transition from the boom to the bust. As the number of successful exits increased, VCs would make new deals expecting to cash out faster than average. As the occurrence of successful exits decreased, VCs perceptions changed, meaning that new and existing deals would be expected to take longer time to reach liquidity.

"[During the boom] you were expecting to be in and out within 1 to 2 years. Today I would say that you are thrilled if you can get out in 3 years. And your expectation is 5 to 7, which is the time it takes to build real value in a company. It's not to say that you can't exit earlier but these days it is unusual to be able to demonstrate something that another company wants to buy."

The next chapter combines these observations from field interviews into a formal simulation model. The model considers the interactions of fundraising, investing and exiting, in the structure of the system.

6 A SYSTEMS MODEL OF VENTURE CAPITAL INVESTMENT DYNAMICS

This chapter presents a systems model of the dynamics of VC investment. The nature of the feedback processes in the structure of the system suggests that the boom-and-bust behavior in venture capital may be endogenous. First, I develop an overview of the VC investment process, describing the main agents interacting in the model. The result is a resource flow structure of the VC industry. Second, I present the rationale of investor behavior to better understand VC investment decisions. Finally, I describe the dynamic hypothesis that may explain the boom and bust behavior in VC.

6.1 Subsystems in a dynamic causal model

System Dynamics provides a framework for understanding the role of feedback, nonlinearities, and time delays in social systems. System dynamics has a rich tradition in exploring the generation of the sharp and costly fluctuations found in capital markets (Paich and Sterman, 1993; Kampmann and Sterman, 1998; Kummerow, 1999; Liehr et al., 2001; Getmansky and Papastaikoudi, 2002; Oliva et al., 2003).

I use system dynamics to explore the dynamics of venture capital investment at the industry level. I model the VC industry as the interaction of market participants who exchange resources and use salient and readily available information to make their investment decisions. The structure of the system helps to explore how the interaction of locally rational market participants (LPs, GPs, Entrepreneurs, and Buyers) may lead to undesired fluctuations in the VC industry as a whole.

Figure 8 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.

Figure 8. Subsystem diagram of the venture capital market

6.2 Resource structure of the venture capital system

Drawing on Warren (2002), the VC system structure is modeled as a dynamic flow of interdependent resources among subsystems where decision rules are based on salient and readily available information flows. As shown in Figure 8, such flows are the flow of cash from LPs to GPs to Entrepreneurs. The flow of company ownership from Entrepreneurs to GPs and from GPs to Buyers. Finally, as the companies get acquired, proceeds flow from the Buyers to the system shareholders (GPs, LPs, and Entrepreneurs).

Figure 9 depicts a dynamic resource system view of the venture capital industry. The boxes represent the stocks of resources, while the valves represent the inflows and outflows controlling those resources. The stocks and flows represent some of the key variables used in the model.

Figure 9. Dynamic resource view of the venture capital industry

Several things happen in the dynamic resource structure:

- 1) Funds are increased by Fundraising and decreased by Spending. The inflow is controlled by the LPs while the outflow is controlled by the GPs.
- 2) Portfolio Companies are increased by the Deal Rate and decreased by the Success, Write-off and Wind-down rates
- 3) The VC pipeline refers to the inflow and outflow of Portfolio Companies. There are three possible outcomes for Portfolio Companies (winners, survivors, and losers).
- 4) VCs investing in a deal are increased by the Entrance Rate of VCs looking for a deal, and are decreased by the Exit Rate when VCs exit their investments.
- 5) VCs are modeled in one of two states to represent the transitional dynamics between potential investor and investor.
- 6) Buyers are increased by the bid rate while the buy rate decreases the stock of buyers.
- 7) Buyers are modeled in one of two states to represent the transitional dynamics between potential buyer and buyer.
- 8) There are time lags in the transitions between stocks (e.g., the transition of Portfolio Companies to Winners depends on the liquidity delay).

6.3 Behavioral foundations of the causal model

The premise of the model is that the boom-and-bust is driven by the unbalance in investors' supply of capital and actual demand (Sahlman and Stevenson, 1986; Sahlman, 1998; Lerner, 2002). This study provides evidence of endogenous factors in the VC system whose interconnections explain the how and why of the sharp rise and decline in VC investment.

Evidence in subsection 5.2 suggests that the motivation of investors (LPs and GPs) is to maximize their cash return/time period ratio. Investors pay attention to market trends and want their cash out sooner rather than later. They avoid unnecessary risks and re-allocate their money to new opportunities quickly.

Three behavioral foundations form the basis of the model. First, investor behavior is driven by maximization of shareholder value that is, LPs allocate money into VC funds when expected returns are higher than desired returns. Second, market participants are boundedly rational (Simon, 1979). That is, LPs and GPs decisions are led by simple and readily available information 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 adequately for feedbacks and time lags in their decision process (e.g., funding allocation is led by LPs expectation of realizing the returns they are observing “right now”).

6.4 Dynamic Hypothesis

This subsection posits the dynamic hypothesis of the model, in other words, a theory about the evolution of the problem behavior over time.

How does the boom-and-bust arise? Figure 10 shows the causal structure of the VC market. The demand for Portfolio Companies depends on a ‘hot market’ for new products in a particular technology sector. The greater the number of Buyers scouting for companies in the sector, the higher the number of acquisitions of Portfolio Companies, increasing the number of successful exits. When the number of successful exits increases, so does the number of new investments in the sector. The greater number of investments leads to the increase in the supply line of Portfolio Companies and still further successful exits in a reinforcing loop (loop R1). On average, it takes a long time (2-5 years) for Portfolio Companies to be ready for an exit.

On the supply side, the increase of successful exits boosts exit valuations of Portfolio Companies and hence the profitability of existing VC funds. When successful exits are increasing, returns from VC funds are high and VCs can raise funds more easily. High expected returns in the sector attract new VCs, who compete to finance new startups thereby driving the price of deal valuations up. VCs have no shortage of funding since investors are eager to realize the high returns expected from VC funds (loop R2). Many

new investments are made, swelling the supply line of Portfolio Companies. After some time, there are no more Buyers to make acquisitions in the sector (loop B1), the price of exit valuations falls, and successful exits in the sector stop, dragging down returns of VC funds. As returns in the sector diminish, so do fundraising and deal-making. Negative loops then dominate attempting to control for non-performing Portfolio Companies through other liquidity events (loop B2).

Figure 10. Feedback structure of VC Investment

In the next chapter I present how the model structure was reviewed by domain experts, and their reactions are discussed.

7 MODEL REVIEW

In this chapter I present a review of the formal model of the dynamics of venture capital investment with domain experts. The first section explains the goals of the review, and the rationale that led to the choice of an interview-based protocol to obtain expert feedback and reflection. Next follows a description of the protocol and its administration. The analysis of the interviews is presented, along with a summary of the indicated strengths and weaknesses of the formal model.

7.1 Approach to Model Review

The model developed in the previous chapter formalizes a dynamic causal model of venture capital investment. It evolved from a 'skeleton' model at the initial system conceptualization stage, to a formal model specification, which permits the simulation of possible investment scenarios based on different assumptions of decision variables influenced by VCs. The next step in the modeling process is to consider how well the formal model captured the mental models of the participants in the field study. Expert reflections on the variables and causal relationships in the model structure help to build confidence, particularly when it promotes further inquiry.

An iterative review of the model's outcomes with the domain experts was believed to be the best available technique (Homer, 1986; Lane, 1994). The main goal of the review design was to determine if the hypothesized structures were credible given a statement of the constraints of the environment. Would the experts agree with a particular model structure and its explanation? If the structures made sense, they would provide confidence on further study of model behavior resulting from the simulations. If the structures or the relationships were controversial, they would stimulate further discussion around its logic and, if necessary, guide to what changes should be considered. Therefore, the approach to model building taken in this research was iterative.

7.2 Interview Protocol

Highly structured interviews were used to conduct the expert interviews with the objective of targeting and focusing the discussion on review and criticisms of the model⁵⁰. In the earliest stage of this process, I conducted one pilot interview with one domain expert who had previously participated in the first pilot study. The pilot interview was helpful to check the design and clarity of the interview workbook. I conducted four interviews face-to-face with each venture capitalist. The fifth and final interview was conducted by telephone. The duration of the interviews ranged between 1 to 2 hours. The length of the interviews basically reflected the degree of expertise and involvement in the model review.

Considering that domain experts could be unfamiliar with the concepts of system dynamics modeling, great care was taken to design the interview workbook in order to ensure that the variables, relationships, and explanations of the structures were clear. The interview workbook followed the focused and structure approach, it used the categories of the initial interviews, with some expansions were applicable, to review each of the micro-structures of the formal model. The workbook described a fictitious microworld and its underlying assumptions. It included a consent form, instructions, and definitions of variables (see Appendix 2 for model review document). The microworld showed a virtual venture capital industry where investments were made in a new and rapidly growing market sector. The microworld was also presented specifying the assumptions and boundaries of the model, depicting the subsystem, resource structure, and micro-structure (i.e., causal loop) diagrams. In the interview section of the workbook, diagrams of several micro-structures were simplified to facilitate discussion. The definitions of variables were provided to ground the explanations of the model micro-structures.

The interview was structured into three blocks:

⁵⁰ Rich (2002) approach to model review through focused interviews was instrumental in the formulation of this approach.

- 1) Background: The first block included a consent form for both the participant and the researcher to sign in. This portion of the workbook served to ground the discussion of the micro-structures in the microworld, rather than the real world. Understanding of the restrictions and limitations of the model were presented up front, so that the informants would be able to focus on the causal issues of the simulation.
- 2) Micro-Structures: The second block presented five micro-structures or causal loop diagrams (deal-making, fundraising, market saturation, competition, demand) developed from the formal model formulated after the initial set of interviews.

At the beginning of each micro-structure, a short description of the causal loop was read to the interviewee. A graph of each causal loop was presented, and an explanation of each loop was read aloud by the interviewer. The workbook contained both the graph and the text description to permit the interviewee to follow along. After the description and explanation of the causal loops, the interviewee was asked if he or she believed that the key variables and relationships in each micro-structure were plausible, within the constraints of the microworld. Comments and suggestions were encouraged.

The causal-loop section of the interview served two purposes. First, it reviewed the assumptions of each micro-structure with expert practitioners in venture capital. This gave the participants the opportunity to contrast and integrate their own experience with those of the model. Second, it helped to identify areas that were omitted in the model and that were important for the understanding of the venture capital investment processes. By discussing the micro-structures, the participants exposed more areas of their mental models of how the system works.

- 3) Model Extensions: The final part of the formal interview protocol provided the opportunity to learn more about what the domain experts considered important in future models of venture capital investment decision-making. The microworld

made assumptions about the boundaries of the system, the key variables and relationships, and the micro-structures describing the investment process. The closing questions asked the participants to identify any other areas where the model could be enhanced or extended.

7.3 Interview Administration

Preparation: The second stage of the field research was conducted between May and June 2004. These follow-up interviews were agreed upon beforehand with participants during the initial set of interviews. The model review workbook was prepared simultaneously with the initial interviews using refined versions of the skeleton model and later pilot-tested with one domain expert, outside the sample frame. This pilot test was used to revise the structure and sequence of the questions from the original draft instrument, with particular attention to ensuring that the informant's observations about the workbook were heard before those of the researcher. The workbook was submitted to Carleton University Ethics Committee in order to complete the required internal submission procedure for research with subjects. The Ethics Committee acknowledged receipt of this document on June 2004.

Recruitment of subjects: After the first round of interviews, participants were asked to schedule a follow-up interview. In some cases, re-scheduling via electronic mail was necessary to allow for last minute changes due to pressing contingencies of participants. Therefore, of the original five participants, five were interviewed again for this research. These interviews were in addition to the pilot tests made in the earlier stages of the process.

Each participant in the second round of interviews was asked to schedule 60 minutes to prepare and complete the workbook. The interview workbook was sent in advance of the scheduled follow-up interview. All of the participants received the booklet at least one day in advance for two reasons. One was the consideration that due to their busy agendas most participants do not read the introductory material until immediately before the

scheduled time. The other one was to use it as a strategic reminder of the imminence of the interview next day.

Data capture: The interviews were taped, with the consent of each subject, except for one telephone interview which could not be taped. The interviews lasted between 1 to 2 hours, including time for debriefing and questions by the subjects about the research. After the interview was concluded, the tapes were reviewed, transcribed and the responses summarized.

The reaction of the participants to the causal relationships and the explanations of each micro-structure were captured in several ways. The participant rated each indicator on its plausibility under the assumptions of the microworld. The final comments for each micro-structure, which identify missing causal factors and relationships were also captured and summarized. The final information captured in the interviews related to the areas where the model could be extended.

7.4 Expert reaction to model structure

This section provides a summary on how the participants reacted to the micro-structures of the model. Reactions to the key relationships in each micro-structure are tabulated, with each column of the table presenting the reaction of participants to a particular causal relationship or causal loop explanation. Each row summarizes the reaction across all indicators for a particular subject. Changes to the model mentioned by the participants are discussed in Section 4.5.

- 1) Deal Making Loop. In this loop, VCs decide on new investments based on two decision rules. Reactions to the causal relationships on this loop were favorable (see Table 7). All except one participant agreed that causal loop was plausible. One participant had some reservations about the explanation of the loop.

Participant	Sector Attractiveness & Deal Rate	Liquidity Expectations & Deal Rate	Explanation of Deal Making Loop
1	P	P	P
2	P	P	P
3	P	P	U
4	P	P	P
5	P	P	P

Legend: P: Plausible, U: Uncertain, N: Not Plausible

Table 7. Deal Making Loop Indicator Reactions

- Sector Attractiveness and Deal Rate: All the participants believed that the relationship was plausible. One wondered on the way the sector was defined and if it would be affected by venture-backed winners alone.
 - Liquidity Expectations and Deal Rate: All the participants believed that the relationship was plausible. One noted that, in his experience, the relationship explains the momentum behavior of VCs. Another mentioned that this relationship and the previous one above are strong for hyper-growth markets and weak for well-known markets.
 - Causal Loop Explanation: All but one of the participants considered the explanation of the causal model for making deals was plausible. One had some reservations about what could be a missing negative effect of failures into new investment activity. Another wondered if such increasing investment activity would really occur while ignoring the people/relationships aspect of the venture business.
- 2) Fundraising Loop. In this loop, LPs allocate capital into venture funds based on two decision rules. A third decision rule is formulated by the effect of the supply of capital on VCs willingness to invest. Overall reactions to the causal relationships on this loop were favorable (see Table 8). One participant did not

know about a particular aspect asked in one indicator in the loop and preferred not to comment on it. The reflections of another participant, one with LP experience, provided additional confidence into the validity of this particular loop.

Participant	Funds, Pressure to Invest & Deal Rate	Expected Returns & LPs Confidence	Liquidity Expectations & LPs Confidence	Explanation of Fundraising Loop
1	P	P	P	P
2	P	P	U	P
3	P	P	P	P
4	P	P	P	P
5	P	P	P	P

Legend: P: Plausible, U: Uncertain, N: Not Plausible

Table 8. Fundraising Loop Indicator Reactions

- Funds, Pressure to Invest & Deal Rate: All the participants believed that the relationship was plausible. One noted that the effect of the availability of capital works more as an incentive rather than a pressure to invest.
- Expected Returns & LPs Confidence: All the participants believed that the relationship was plausible. Two or three noted that, in their experience, the supply of capital is highly bounded (LPs have a relatively narrow range of available funds that they place in private equity). They commented that, for the effects of the model, the fluctuation in fundraising would happen within the already allocated share for the private equity asset class (e.g., 2% of available funds).
- Liquidity Expectations & LPs Confidence: Most of the participants indicated that the relationship was plausible. One preferred not to comment on this indicator due to being uncertain about LPs considering liquidity as an issue during their decision process. Another one, when prompted, remarked that expectations for liquidity and return expectations are both correlated.

- Causal Loop Explanation: All the participants considered the explanation of the causal model for fundraising was plausible. One noted that LPs are risk-adjusted profit maximizers. LPs make an investment decision when returns exceed, consistently over different periods of time (1, 3, 5, and 10 years), their expectations. Another one, the one with LP experience, reflected that although LPs talk about the long term (i.e. 10 years), yet their actual behavior in allocating money into venture for the last couple years has been different. That is, actual behavior is more in agreement with the loop.
- 3) Market Saturation Loop. In this loop, the increasing number of successful exits of portfolio companies competing in the market sector presents a natural limit to the number of further successful exits that can be achieved. Reactions to the causal relationships on this loop were favorable (see Table 9). All of the indicators were questioned by at least one participant, and two of the five participants had some reservations about the explanation of the loop.

Participant	Sector Attractiveness & Success Rate	Explanation of Market Saturation Loop
1	P	P
2	P	P
3	P	U
4	P	U
5	P	P

Legend: P: Plausible, U: Uncertain, N: Not Plausible

Table 9. Market Saturation Loop Indicator Reactions

- Sector Attractiveness and Success Rate: All the participants indicated that the relationship was plausible. Two wondered if the Sector Attractiveness would only be influenced by the number of exit transactions and under the circumstance of a fixed market size. One noted that displacements of already

established companies can occur due to competitive market pressures making the sector still attractive for further exits.

- Causal Loop Explanation: Three of the five participants considered that the explanation of the causal model for market saturation was plausible. Two of the five had some reservations about the loop. One thought that the number of successful exits should impact positively the attractiveness of the sector and that the size of the market should be variable. Another reflected that the loop could probably be accurate, not at the macro-level but a micro-level, for a finite period of time. Since, for a finite period of time, the basis of competition might be considered constant. He noted that, under a changing market size, other things would happen.

- 4) Competition Loop. In this loop, the competition among VCs drives valuation prices up. Overall reactions to the causal relationships on this loop were favorable (see Table 10). All participants agreed that causal loop was plausible.

Participant	VCs competing for deals & Pre-money valuation	Explanation of Competition Loop
1	P	P
2	P	P
3	P	P
4	P	P
5	P	P

Legend: P: Plausible, U: Uncertain, N: Not Plausible

Table 10. Competition Loop Indicator Reactions

- VCs competing for deals & Pre-money valuation: All the participants believed that the relationship was plausible. One noted that, although competition is the primary driver, the perception of higher exit valuations drives prices higher as well. One noted that, depending on the firm, VCs do not invest only in a

single company of a particular sector, but may invest in several companies of the sector as a diversification strategy. Another one, remarked that pre-money value is affected by terms and conditions. In order to compensate for rising pre-money values, VCs started to inject terms such as preferred shares and liquidation preferences to ensure that they would get the effective return they would have got at reasonable pre-money values. He mentioned that, during the boom, it was not at all uncommon to have liquidation preferences greater than one.

- Causal Loop Explanation: All the participants considered the explanation of the causal model for competition was plausible. Three recommendations emerged from the discussions with the experts. First, VCs have concentration restrictions. VCs cannot have more than X percentage of their fund in a particular company, which is the mechanism used by LPs to ensure that the VCs diversify. Therefore, the number of companies in a VC portfolio is almost determined ahead of time. Second, the supply of capital does not affect the deal rate. If the supply of capital increases, then the effect is that it creates more competition since there is more money chasing fewer deals. Third, there should be a control mechanism in the deal rate. Assuming a fixed ownership per company, when the valuation prices go up less deals should be made.
- 5) Demand Loop. In this final causal loop, the increasing number of buyers making acquisitions in the sector drives exit valuation prices up. Initial reactions to the causal relationships on the loop were mixed (see Table 11), which lead to an additional iteration of the loop. All of the indicators in the original loop were questioned by the second participant because the loop did not meet his expectations. As a result, three recommendations emerged from discussions with the second participant. He remarked that the demand for acquisition by public market investors arises out of three factors: competition among buyers, over-valued stock, and strategic reasons (i.e. desire for expansion). Therefore, exit valuations are higher with competition. Thus, the loop was modified to reflect the expert recommendations and then tested against the remaining three interviews.

The results of the modified loop with the remaining three interviews were favorable.

Participant	Buyers & Success Rate	Competition for Exits and Exit Valuation	Explanation of Demand Loop
1	-	-	P
2	-	-	N
3	P	P	P
4	P	P	P
5	P	P	P

Legend: P: Plausible, U: Uncertain, N: Not Plausible

Table 11. Demand Loop Indicator Reactions

- Buyers & Success Rate: Most of the participants believed that the relationship was plausible. Two noted that, after a representative buyer makes the first acquisition, the majority of other potential buyers have no choice but to follow.
- Competition for Exits and Exit Valuation: Most of the participants believed that this relationship reflected their experience when exiting companies. One noted that, as exit valuations go up the number of exits should go down. That is, the buy rate is affected by price. Another wondered if prices would really rise given the fact that, generally, the best companies are sold at higher prices first.
- Causal Loop Explanation: Most the participants considered the explanation of the causal model for demand was plausible. The key recommendations for model changes were made early in the process, which helped to incorporate the changes for the rest of the interviews. Reflecting on the explanations of the loop, one participant noted that in his experience, competition for a single deal is the single most significant driver of exit prices.

7.5 Indicated changes to the model

The experts gave strong support for most of the indicated relationships and explanations of the 5 micro-structures (see summary in Table 12). One of the micro-structures, the Demand Loop, had to be modified early in the process to reflect expert recommendations. Subsequent favorable support from the experts provided confidence in the new iteration of this particular micro-structure. In another micro-structure, the market saturation loop, two participants wondered if a fixed market size was a realistic assumption.

Participant	Deal Making	Fundraising	Market Saturation	Competition	Demand
1	P	P	P	P	P
2	P	P	P	P	N
3	U	P	U	P	P
4	P	P	U	P	P
5	P	P	P	P	P

Table 12. Causal Loop Explanation Reactions

A review of the discussions made during the second set of interviews provided additional insight into where and how the formal model of the dynamics of venture capital investment developed in the previous chapters might be improved.

- 1) Model Relationships. The experts indicated that the hypothesized relationships for the different micro-structures would be closer to their expectations if the following changes were considered:
 - Effect of losers and survivors on the system. One participant suggested that non-performing portfolio companies (i.e. losers and survivors) have an impact on both LPs and GPs investment decisions. An explicit indication of effect of losers and survivors on deal rate was suggested.
 - Control loop for rising valuations. Two or three participants felt that as valuations increase the number of transactions should decrease. An explicit indication of this effect was suggested.

2) Model indicators. During the discussion of the model, several changes and additions were suggested. The first change was to add the effect of the displacement of winners in the market sector. A second change suggested a variable market size. A third change suggested the addition of the people aspect to the venture business. Finally, renaming the model's concept of "Pressure to invest" more specifically tied to "Incentive to invest" or "Supply of capital to invest" would be useful modification for the definition of that particular variable. The most important suggestions are summarized below:

- Mortality rate for winners. One participant suggested that competitive forces can drive winners out and give room for new entrants. Therefore, winner companies can exit the market sector and give room for further exits.
- Dynamic market size. Two participants felt that the size of the market was not adequately addressed by setting a fixed limit. One respondent said: "For the purpose of your microworld is fine, but that does not happen in the real world". A recommendation for a variable market size emerged from their discussions. The argument was that the variability in the size of the market affects the success rate. When the market size shifts from being very big to being very little, that shift creates a dampening system.
- Human dynamics. One participant suggested that factors such as relationships, trust, and quality of the management team are very important determinants of LPs/GPs predisposition to invest.

This chapter presented the review of the formal model, or microworld, of a virtual venture capital industry. While the small sample must moderate the interpretation of the results, it is an indication that the feedback structure of the model is plausible. The hypothesized indicators and relationships in the market saturation and demand loops produced a great deal of comment and discussion of the structures that support them. The other three causal loops, each representing a different part of the investment process, were found to be plausible and reasonable explanations of the VC investment process. In the next chapter, the implications of this feedback on the venture capital investment dynamics model are presented.

8 MODEL TESTING

The previous two chapters discussed the development and review of a dynamic causal model of venture capital investment, called VENTURE1. In this chapter I present the purpose of the model, making explicit its boundary, limitations and assumptions. Next, I discuss the limits and level of aggregation of the model. Finally, I describe the tests performed to build confidence in the model.

8.1 Model Goals

A model can never capture every aspect of a system. A good system dynamics model is built with a clear purpose. The VENTURE1 model discussed in Chapters 5 and 6 was built with the following goals:

- Understand the causes underlying the rise and decline in VC
- Identify the key variables and relationships of the VC investment process
- Identify the key feedback processes driving VC investment activity
- Capture the behavior of market participants and its impact on the VC system
- Explore the role of time delays on VC industry performance

In the next section I describe the boundary of the model in order to help the readers decide for themselves whether the model is appropriate for its intended purpose. I should add that, from the experience gained discussing the model with domain experts and academics, I found it important not to hide the assumptions of the model from potential critics. Uncovering flaws and errors provides the opportunity for others to give the modeler valuable feedback to improve his work. Finally, it constitutes a visible reminder of the caveats to the results and limitations of the model.

8.2 Model Boundary

System Dynamics seeks endogenous explanations for a problem through the interaction of the agents and variables in the system being modeled (Sterman, 2000). Models are simplifications of complex phenomena, they are meant to include only the important concepts addressing the problem. Without a well-defined boundary, models can be extended indefinitely as one incorporates further aspects of real-system structure which, even if accurate, are not necessary for the particular purpose.

The VENTURE1 model presented here has important boundaries. Most importantly, it does not model the IPO and public markets. Both markets may also be significant to determine whether or not VC investment goes through a boom-and-bust. Modeling these dynamics would have introduced a great degree of complexity in the VENTURE1 model that would have made the analysis much more difficult to carry out given the available time and resources to complete this thesis. Furthermore, it has been argued throughout this thesis that the purpose of the VENTURE1 model can be achieved by focusing the attention on a smaller piece of this complex system. This piece lies in recognizing the behavior of market participants inside the venture capital industry.

The VENTURE1 model is also based on M&A transactions as the exit mechanism. This is justified by two reasons. i) The volume of exits of venture-backed companies is much higher for M&A transactions than for IPO transactions, and ii) The vast majority of exits of venture-backed companies in Ottawa during the period of interest were M&A transactions.

Table 13 presents the boundary chart of the VENTURE1 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	Entrepreneur 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		Public market
Spending		IPO Market
Fundraising		GDP
Proceeds		Growth rates
Returns		

Table 13. VENTURE1 Model Boundary Chart

The VENTURE1 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 VENTURE1s 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 mechanism for 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 VENTURE1 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 an industry-level view of VC. This level of aggregation was chosen to meet the goals of the VENTURE1 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 concerning individual companies' metrics of revenues, stock price, and customer demand 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 (e.g., funds, investments, financing rounds, and information lags), 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.

8.3 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 VENTURE1 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 VENTURE1 model develops a plausible hypothesis of the

problem behavior based on evidence found from intensive interviews, extensive document review and one case study.

- 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 (refer Chapter 6). 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 VENTURE1s 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 VENTURE1 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 VENTURE1 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.

8.4 Further Testing

The VENTURE1 model has been developed with the assistance of Dr. Arif Mehmood, a Senior System Dynamics Consultant at Delsys Research in Ottawa. Several versions of the model have been evaluated and criticized in four conference papers submitted to peer review, as well as during several presentations at international conferences in the US and the UK. The model was also discussed with PhD students and Faculty in several disciplines (Management, Economics, Finance, Psychology and System Dynamics) with interest in venture capital and/or system dynamics applications at distinguished universities in the US and the UK. The author received insightful comments and suggestions from these experiences. Many of them agree that marrying research on Venture Capital with the System Dynamics approach is a relevant and novel contribution to our state of knowledge. Although much work remains to be done in the dynamics of venture capital investment, this study is considered as one positive step towards filling this gap.

This chapter presented the purpose of the model. It made explicit its boundary, limitations and assumptions. Finally, it described the tests that were performed to discover inconsistencies and improve model formulation. In the next chapter, the model is simulated and the results are discussed.

9 MODEL SIMULATION AND SCENARIO ANALYSIS

This chapter presents and discusses the simulation results of running the VENTURE1 systems 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 which includes two parts. i) the design and simulation of four investment scenarios based on investment speed. ii) the simulation of an exogenous shock representing a public market crash in order to evaluate its impact on the system behavior. The scenarios are compared to the “benchmark” on the basis of several metrics commonly used in the venture capital industry. Finally, the results obtained from the simulations of the model are discussed.

9.1 Base Run⁵¹

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, market participants’ 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 could be used to compare against other scenarios in the next sub-section.

9.1.1 Key parameters

A summary of the key parameter values of the VENTURE1 model are shown in Table 14.

⁵¹ The full model is available in a Vensim PLE formal (*.mdl file). The model file can be obtained from the author by contacting him at: cvepez@sce.carleton.ca. If the reader does not already own system dynamics software, s/he may run the model by downloading and installing Vensim PLE software from www.vensim.com. Note that Vensim PLE supports running, but not building, models with multiple “Views”.

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

Table 14. Parameter values for the VENTURE1 model

9.1.2 Model Behavior Metrics

In order to assess the pattern of behavior of the virtual venture capital industry, the following model variables are used:

- 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. Aggregate returns for the virtual venture capital industry. This variable is calculated from total cumulative commitments and total cumulative proceeds.

$$Re\ turns = \frac{Pr\ oceeds}{Commitments} - 1$$

VC Industry Performance in the simulation is measured with the Returns variable, which constitutes a key metric to attract new capital into the VC industry⁵².

9.1.3 Base run Behavior

A summary of the simulation results for the base run is shown in Figure 11 (refer to Appendix 1. Simulation results). The base run is calibrated with the parameters specified in Table 14 and is used as a “benchmark”. An overview of the metrics 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.

9.2 Scenario Analysis

This section presents the design and simulation of four investment scenarios based on investment speed. Four investor types are proposed based on their speed to make deals and exit portfolio companies. Drawing on Valliere and Peterson (2004), this study matches the four investment speed scenarios with the cognitive behaviors of VCs investing during boom-and-bust periods. The analysis of the model behavior of each investor type sheds light on the impact of investment speed in VC industry performance.

9.2.1 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.

⁵² Returns are computed continuously, so the modeler can measure them at any time within the simulation interval (e.g., 20 years). Short-term Returns are measured within a 5-year period, whereas long-term Returns are measured within a 10-year period. Also note that the variables ‘Proceeds’ and ‘Commitments’ represent stocks that do not deplete over time, they only accumulate. For example, Returns at year 5 are calculated from cumulative Proceeds and Commitments between $t_0=0$ and $t_1=5y$. Returns at year 10 are calculated from cumulative Proceeds and Commitments between $t_0=0$ and $t_1=10y$.

- 1) Due Diligence delay. This variable represents the average time that VCs take to assess a prospect startup for venture capital financing. Evidence found from intensive interviews and document review (see Chapter 5) suggests that 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 VC 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). Evidence found from intensive interviews and document review (see Chapter 5) suggests that 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 VC industry performance.

The resulting four investment speed scenarios are illustrated in Table 15.

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

Table 15. Scenarios based on Investment Speed

The rationale for the VC investor-speed type according to the four scenarios of Table 15 draws on the findings on VC investment behavior during periods of boom-and bust identified elsewhere (see Valliere and Peterson, 2004).

- 1) Focused Investors are a passive type of VC. They take time to identify new companies based on individual merits. However these investors are not very involved in the working and particular management of a company, suggesting that, on average, they may take longer to cash-out their companies.

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 of specific sectors. However, they are not operationally involved with their companies affecting the likelihood of cashing out those companies 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.

For the purpose of comparison purposes between scenarios, VC types with low liquidity delay (e.g., focused and diversified investors) are defined as ‘passive’ investors, whereas VCs with high liquidity delay (e.g., sector speculators and company creators) are defined as aggressive investors.

9.2.2 Comparison of VC investment speed scenarios with base run

Figures 12 to 20 show the simulation results for the four investment speed scenarios compared with the base run. Table 16 presents a summary of the observed behaviors.

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

1) Focused Investors – Outcome: Slow but steady.

- No system collapse. Deal-making and liquidity activities remain at its lowest levels.

- Competition is never high enough meaning low pre-money valuations.
 - High and sustained exit valuations due to the increasing number of buyers waiting for companies to be ready for harvest.
 - Break even by year 4, two years after benchmark.
 - Successful exits reach 50% of optimum value.
 - High long-term returns (90%) for the industry as a whole
- 2) Sector Speculators – Outcome: Faster is not better.
- System collapse. The sharpest and fastest rise and decline in investment and liquidity activities. This scenario creates the highest investment peak (as measured by number of portfolio companies), exceeding more than twice the benchmark.
 - 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 value by year 3.
 - Short-term returns peak 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 few, terrible for most.
- System collapse. Peaks of investment and liquidation activity are lower and come 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 value 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 liquidity activities 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 value.
- Short-term returns slightly superior to Focused Investors scenario.
- High long-term returns (90%) similar to Focused Investors scenario.

The results obtained from the simulations above appear to be counter-intuitive since they suggest that the rewards would 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 explore 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 16. Summary results for investment speed scenarios

9.2.3 Market Crash Scenario

The previous investment speed scenarios suggest that passive VCs, when given all their time, would fare better than benchmark. Would this hold if VCs were faced by an unexpected event at some point in time? What should happen to the VC system if it was impacted by a sudden crash in the public market? The VC system analyzed in the previous section assumes that Buyers have the propensity and ability to buy Portfolio Companies at all times. In order to model the impact of a sudden crash in the public market in the VC system, I argue that the ability of Buyers to acquire companies is affected by their share price. I base this argument on previous research (Carpenter et al., 2003; Warner, 2003) and the data I gathered from interviewing domain experts. Therefore, when the currency (e.g., company's shares) used for acquiring companies is affected due to a public market crash, Buyers retreat and stop doing acquisitions.

In this experiment, the public market crash is modeled by applying an external shock to the stock (i.e., level) of buyers which depletes it at time 36 or year 3 of the simulation. The impact of the public market crash in the different investment speed scenarios is presented in figures 21 to 27. Table 17 presents a summary of the observed behaviors.

	Portfolio	Exit Distribution (%)			Returns (%)		
	Companies	Winners	Losers	Survivors	Break-even	Short-term	Long-term
Base							
Peak Value	5 firms	20%	60%	20%	-	60%	20%
Peak Time (month)	48	48	96	96	24	48	84
Focused Investors							
Peak Value	2 firms	20%	53%	27%	-	- 1%	-20%
Peak Time (month)	2	84	120	120	-	48	108
Diversified Investors							
Peak Value	3 firms	20%	53%	27%	-	8%	3%
Peak Time (month)	6	60	96	96	36	48	96
Company Creators							
Peak Value	13 firms	20%	53%	27%	-	130%	8%
Peak Time (month)	44	40	120	120	14	36	96
Sector Speculators							
Peak Value	20 firms	20%	52%	28%	-	80%	9%
Peak Time (month)	30	34	84	84	12	24	84

Table 17. 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 public market crash.

1) Focused Investors – Outcome: Irrelevant.

- No system collapse. Deal-making and liquidation activity remain at its lowest levels.
- Competition is never high enough (e.g., 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 better.

The simulation results are similar with or without the public market contingency.

3) Company Creators – Outcome: Great for a few, bad for most.

The simulation results are slightly affected by the public market contingency in a few key aspects:

- System collapse. However peak values for investment and liquidity activities 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 liquidity activities remain at low levels.
- Lowest trend in pre-money valuations. Low trend in exit valuations.
- Breaks even by year 3.
- Successful exits reach 30% of optimum value.
- Short-term returns low but positive (8%). Long-term returns lower but still positive (3%).

The results obtained from the simulation runs considering the external market pressure of a public market crash suggest that passive VCs fare the worst. A few remarks are worth noting.

- Aggressive exit scenarios accentuate the boom-and-bust dynamic and have similar trends in both pre-money and exit valuations with or without the public market crash.
- Sector Speculators are the only ones able to reach the optimum value of successful exits before the market crashes, all other investment speed scenarios under-perform under this metric.
- Passive exit scenarios never take-off. The effect of slowing down the process of investing and liquidating firms impacts negatively the VC industry performance. Evidence shows that not only the public 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 public market crash in year 3, the best scenario continues to be the benchmark which maintains the returns performance of the VC industry within reasonable values.

9.3 Discussion

The overall simulation results suggest that the impact of investment speed is critical in two aspects. i) exacerbating or attenuating the boom-and-bust dynamic of VC investment, ii) influencing the short and long-term returns performance of the VC industry as a whole. These results hold with or without the public market crash. The market crash only helps to assess the impact of an external market pressure on the VC system. However, not only the public 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 is produced endogenously. The reason is found in a strong positive feedback between the speed at which companies

reach a successful exit and the speed at which new deals are made. Successful exits reach the limits to growth set by the finite number of buyers of portfolio companies.

- Faster is not always better. Although aggressive exit scenarios reward a few VCs with handsome returns, long-term VC industry performance is poor and lower than benchmark.
- Spending more does not necessarily mean investing smarter. Aggressive exit scenarios spend and receive the most money on absolute values. However long-term returns are poorer than benchmark.
- Valuations, both pre-money and exit, rise and decline sharply due to the high competition produced by aggressive exit scenarios.
- With the public market crash, passive exit scenarios under-perform the benchmark at all times.
- Company Creators cause the highest rise and decline in pre-money values. This result is counter-intuitive since these investors do not produce the highest peak in investment activity (e.g., number of Portfolio Companies). A closer look into the stock-and-flow structure of the VC system 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.
- Passive exit scenarios tend to maintain the VC system in equilibrium. However, the issue of performance is a different one. Passive VCs would be rewarded in the long-run with exemplar returns if there were no market pressures. With a market pressure such as the public market crash, these investors become irrelevant to the industry.
- The tried and tested average investment speed values of the 'benchmark' show that, even with the market crash, they produce better outcomes for the VC 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 a successful exit is not likely to change with public market swings.

This chapter discussed the simulation runs of the VENTURE1 model that resulted from pursuing the research on the dynamics of venture capital investment. With the design and simulation of four investment speed scenarios, an effort was made to provide insight on

the influence of investment speed on short and long-term VC industry performance. These results also shed light on the influence of investment speed in accentuating and attenuating the boom-and-bust dynamic. . Simulations were run controlling for the public market crash contingency. The simulation results suggest that the boom-and-bust dynamic has an endogenous component, even without external market pressures.

The next chapter will discuss the conclusions drawn from pursuing this study, as well as a discussion of future avenues of research to enhance and expand current work.

10 CONCLUSIONS, LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The objective of this thesis was to develop and simulate a model of venture capital investment dynamics. The model captures how the intended rationality of market participants' decisions and their interactions contribute to the boom-and-bust in VC investment.

A computer simulation model was developed using data from ten practitioner interviews, literature review, and one research case anchored around the VC boom-and-bust in the Ottawa technology cluster between 1998 and 2003.

This final chapter is arranged in six subsections. First, the key findings of the study are discussed. Second, the answers the research questions that motivated this study are discussed. Third, the conclusions of the research are provided. Fourth, the contribution of this study to the literature is identified. Fifth, the limits of the research project are explained. Finally, the avenues for future research are outlined.

10.1 Key findings

The key findings of this study are drawn from different stages pursued throughout the research effort:

10.1.1 Review of the literature

- 1) Decision processes. Despite the amount of research on VC decision-making, still very little is known about the dynamic decision processes that VCs execute in the real world. The importance of dynamic decision processes lies in the possibility of exploring ongoing effects of investment decisions on complex problem behaviors such as the boom-and-bust phenomenon. The mutual interactions between the decision process and the resource environment of the VCs can shed light on how such problem behavior develops over-time.

- 2) Momentum investment. Evidence suggests that price bubbles are generated by to positive feedback investment strategies (Kindleberger, 1978; Schleifer, 2000; Perkins and Perkins; 2001). VCs tend to follow positive feedback investment strategies by chasing deals in 'hot' markets. Many studies (Helwege and Liang, 2001; Stoughton et al., 1999; Benveniste et al., 2002) argue that 'hot' markets occur in industry clusters with abundant technological innovations and high growth prospects. 'Hot' markets drive a 'herding effect' that pushes forward high levels of entrepreneurship and investment activities (Scharfstein and Stein, 1990) creating a positive feedback process.
- 3) Bounded rationality. In addition to being boundedly rational (Simon, 1957; Cyert and March, 1963), VCs tend not to account for crucial feedbacks and time delays in the structure of complex systems (Sternan, 1989). The behavioral aspects of human decision-making are embodied in the feedback structure of system dynamics models (Morecroft, 1983).
- 4) Investor psychology. Behavioral explanations anchored around psychological knowledge are germane for a better understanding the, so-called, anomalies in 'efficient' financial markets. Under certain situations, the judgment of VCs may shift from the assumptions of perfect rationality. Such 'sophisticated' investors may herd and invest in 'hot' markets that other investors select to avoid falling behind and looking bad (Scharfstein and Stein, 1990).

10.1.2 Intensive interviews and historical document review

- 5) VC can be better understood from a cluster perspective. Entrepreneurship and venture capital investment activities are concentrated around technology clusters that provide a natural ecosystem for innovation (Babcock-Lumish, 2003). For example, in the U.S., the two largest hubs of VC firms are concentrated at geographically opposite points, Silicon Valley in California and Boston (Route 128) in Massachusetts.
- 6) Preconditions for the Ottawa VC boom-and-bust. Although price bubbles may arise of potential profit opportunities with high growth prospects, this phenomena is better understood by studying the preconditions that can explain the particular

context and factors surrounding it. The preconditions that set the stage for the boom-and-bust of VC in Ottawa can be traced back to: i) the technological breakthrough of the Internet, which increased innovation and the creation of new business models; ii) the telecom deregulation that led to increased competition among telecom vendors; iii) telecom vendors' adoption of the model of 'growth by acquisition'; iv) a booming market of technology stocks that provided telecom vendors with over-valued currency to make acquisitions.

- 7) Drivers of acquisitions. Technology absorption through acquisitions was a primary driver of telecom companies to rapidly gain technological advantage in highly competitive telecom markets. However, this argument is not enough by itself. Acquisitions are also related to the resources and preferences of buyers. For example, Warner (2003) suggests that prior acquisition experience and firm capitalization measures are strong predictors of acquisitions. Telecom vendors such as Nortel, Alcatel, Lucent and Cisco had very high market capitalizations during the boom which greatly facilitated their strategy of growth by acquisitions.
- 8) VCs are not 'unsophisticated' investors. Although evidence abounds that during the boom VCs made investments at significantly higher valuations, they were not 'unsophisticated' at all. With rising valuations, VCs started to protect their downside risk by injecting tight terms and conditions to the entrepreneurs. During the boom it was not at all uncommon to have liquidation preferences greater than one.
- 9) Competitive pressures and key delays. Evidence from interviews with domain experts shows that during the boom the time for fundraising, due diligence, and liquidity shortened. Conversely, during the bust the time to fundraising, due diligence, and liquidity lengthened. Competitive pressures forced the agents to compress or expand time delays. For example, during the boom if a VC waited for a week to make an investment decision, the deal price would increase, or worse, the deal would be lost to a competing investor. Conversely, during the bust a VC could take an extra month to evaluate a deal because, due to absence of competition, it was likely that the pre-money valuation of the company would

decrease as time went by. The impact of these changes contributed to accentuate the boom-and-bust dynamic.

- 10) Deal and exit valuations are not always correlated. Evidence from the outcomes of VC-backed companies shows that only a small number of portfolio companies meet the return expectations of VCs. During the boom higher pre-money valuations reflected higher competition among VCs, whereas higher exit valuations reflected higher competition among buyers. Different agents have different dynamics, which explains the dysfunctional dynamics in the trends of deal and exit valuations.
- 11) Supply of capital creates incentive to invest. Capital inflows have been found to influence VC investment decisions (Gompers and Lerner, 2000). The function of VCs is to maximize the profits for their investors. As a result, fundraising gives VCs the incentive to invest. Certain pacing requirements are implicit in the management of a VC fund. VCs need to deploy the capital sooner rather than later. As one seasoned VC commented: “As soon as you raise a fund, there is a clock running”.
- 12) Retreating is not the answer. Previous research (Sahlman, 1998) shows investors and VCs stop investing at the wrong time. The bust period is a period of contraction and it is also a period where the market returns to fundamentals. As expectations for liquidity are low, investors commit less money into VC funds and VCs make fewer investments. However, after the bust there is less noise. Competition is low, valuations are low, and there are less tight terms and conditions for making deals. Such factors should be ideal for investment activity.

10.1.3 Modeling

- 13) Reinforcing feedback between exits and deals. Evidence suggests that there is a strong feedback process linking deal-making and liquidity activities. The higher the number of successful exits (M&A or IPO) in a sector, the higher the number of new investments in the sector.
- 14) Limits to growth. A balancing feedback loop controls for the number of successful exits in a given market sector. This is determined by the limited

number of potential buyers of companies in the sector. As the number of successful liquidity events increases, the number of buyers of portfolio companies decreases.

- 15) Other balancing feedbacks. There is a natural control mechanism for under-performing deals that dominates the system when there are no more successful exits. This balancing feedback leads to the decline in investment activity. The higher the number of investment failures in a sector, the lower the number of new investments made in the sector.
- 16) Fundraising process. Fundraising is driven by investors' confidence on VC performance measured by returns expectations, track-record, and liquidity activity. The higher the returns expectations, and the higher the number of successful exits in venture capital, the higher the investors' confidence and the higher the commitments to VC funds.
- 17) Over-supply of capital impacts VC industry performance. The simulations results show that high short-term returns expectations attract more capital to the VC industry, which in turn creates incentive in VCs to invest in either more companies or at higher valuations. However, investing more does not necessarily mean investing smarter. Aggressive exit scenarios invest and receive more money on absolute values but overall returns tend to be poorer than benchmark. This finding supports previous studies (Sahlman, 1998; and Lerner, 2002) contending that over-investment leads to poor returns performance.
- 18) Higher deal valuations mean diminishing returns. Higher valuations lead to higher investments. When deal valuations increase, exit valuations need to increase proportionately in order to yield the expected returns. This does not often happen. The result is diminishing returns.

10.1.4 System dynamics simulations

- 19) The boom-and-bust phenomenon has an endogenous component. The boom-and-bust in the VC industry is intrinsic within the capital market physics. This problem behavior is modeled as a byproduct of the structure of a system were the

interaction of locally rational market participants (LPs, GPs, Entrepreneurs, and Buyers) leads to unintended behavior of the VC industry as a whole.

- 20) Time delays explain the generation of boom-and-bust endogenously. Simulation results show that aggressive exit scenarios increase the number of successful liquidity events in the short-run, which leads to still higher investment activity in a reinforcing loop.
- 21) Time-delays impact VC industry performance. The simulations studied the effect investment speed on VC industry performance. The results suggest key delays (due diligence and liquidity delay) have an important effect on the short and long-term returns performance of the VC industry as a whole.
- 22) Exogenous market pressures accentuate the boom-and-bust. The simulation explores the effect of an external shock in the form of the public market crash contingency. The results suggest that this external shock helps to accentuate the boom-and-bust dynamic.
- 23) Faster is not always better. The simulation results show that aggressive exit scenarios exacerbate the boom-and-bust dynamic and lead to poor performance for the VC industry as a whole. Short delays in investing and liquidating Portfolio Companies greatly increase the deal inflow. However, outflow of successful exits is not significantly affected. The cause of the problem behavior is found in the interaction of these non-linear effects.
- 24) Slower is not good either. The simulation results show that, without market pressures, passive exit strategies take too long to achieve desired returns. With market pressures, passive exit strategies under-perform the benchmark at all times. Long delays in investing and liquidating Portfolio Companies reduce the deal inflow as well as the outflow of successful exits leading to poor performance of the industry as a whole.
- 25) Investment speed might be better off remaining constant. The simulation results show that the average industry values, even with the market crash contingency, produce better long-term outcomes for the VC industry as a whole. This finding suggests that 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 a successful exit is not likely to change with public market swings.

10.2 Answers to Research Questions

The following are the answers to the questions that guided the pursuit of this research effort:

- 1) What were the reasons for the rise and decline of VC investment in Ottawa during 1998-2003? The boom-and-bust of VC in the Ottawa region faced similar systemic pressures to those found in the literature exploring the boom-and-bust in capital markets (Galbraith, 1972; Kindleberger, 1978; Sahlman and Stevenson, 1986; Sahlman, 1998; Perkins and Perkins, 2001). A displacement event or 'good news' of successful exits of venture-backed firms in Ottawa increased investment activity in the region. New and unfamiliar investors with the region came to invest in Ottawa, thereby increasing competition and leading to higher valuation prices. Liquidity activity soon dropped due to the limited number of telecom vendors making acquisitions in Ottawa (e.g., Cisco, Nortel, Alcatel, Ciena). As perceptions of low liquidity were updated, investors reduced investment activity and retreated, which drove valuation prices down. Declining company valuations further decreased the likelihood of successful exits and led to diminishing returns. Lower returns expectations lessened investors' confidence in VC, which committed still less capital into VC funds.
- 2) What role do market participants play during cycles of boom-and-bust? Many forms of boom-and-bust behavior in capital markets (Kindleberger, 1978; Oliva, Sterman et al., 2003) can be described as positive feedback trading of market participants who invest when prices rise and retreat after prices fall (Schleifer, 2000).

Bounded rationality (Simon, 1979; Cyert and March, 1963) and Misperceptions of Feedback (Sterman, 1989) help us to understand the fact that during periods of significant rise and decline in VC investment, market participants make decisions that are not in their long-term interest.

The VENTURE1 model assumes that decision-makers act rationally within their cognitive limitations. Decisions are based on measurable data that is readily available to the decision-maker. In the VENTURE1 model, the aggregate effect of market participants' intendedly rational decisions is what contributes to generate the boom-and-bust dynamic endogenously.

- 3) How do market conditions affect market participants' judgment? Researchers have found that VCs are not fully rational decision-makers (Zacharakis and Meyer, 1998; Shepherd 1999 a,b; Zacharakis and Meyer, 2001; Shepherd and Zacharakis, 2002; Wheale and Amin, 2003; Valliere and Peterson, 2004). There is also a notion that 'Hot' markets occur in industry clusters with abundant technological innovations and high growth prospects (Helwege and Liang, 2001; Stoughton et al., 1999; Benveniste et al., 2002). 'Hot' markets may drive VCs herding behavior, where they mimic each others decisions by investing in 'hot' markets that other VCs select (Scharfstein and Stein, 1990).

From field research, I found evidence that during the boom more information became quickly available to investors, which facilitated to come to a conclusion to make an investment decision. Due to high competition for investments, the entrepreneurs were able to provide a lot of substantiated data during the due diligence process. For example, there could be 3 or 4 VCs that would have asked an entrepreneur different questions, and the VCs would receive their answers and even more. Additionally, during the boom a lot of information from the market was readily available, whereas during the bust information about the market and the demand for products was unavailable because the whole telecom industry was in disarray (see Kalba, 2002).

Researchers (Zacharakis and Meyer, 2001) have found that more information increases VCs confidence in their estimates of investment decisions, but it also leads to lower performance. It can be surmised that during bust periods the lack of reliable information leads to greater uncertainty, which increases risk perceptions. The higher the perceived risk, the lower the confidence in investment decisions, which contributes to the decline in investing.

- 4) What are the key variables, relationships and feedbacks in the VC investment process that generate the boom-and-bust? The key variables in the VC investment process refer to three things. First, the resources controlled by market participants (e.g., Funds, Portfolio Companies), which build and deplete over time. Second, the decision rules used by market participants to manage the accumulation and depletion of those resources (e.g., the proportion of successes and failures influences deal-making, fundraising is influenced by expected returns and track-record, this latter defined as the ratio of failures to total outcome distribution of Portfolio Companies). Third, the time delays related to the VC investment process (e.g., due diligence, liquidity delay).

The relationships refer to the causal linkages between the variables in the model (e.g., more successes attract more VCs, more Funds lead to more deal-making).

Finally, there are three key feedbacks in the VC investment process that contribute to the generation of the boom-and-bust dynamic. First, a positive loop that links successful exits with deal-making accelerating the growth of investments. Second, a negative feedback that links successful exits with a finite number of acquirers causing growth to slow-down as market limits are approached. Third, a negative feedback loop that controls for under-performing companies in the VC pipeline leading to the decline of investments in the sector.

- 5) What is the impact of investment speed in VC industry performance?

Delays between making a decision, taking an action, and assessing the outcome are widespread in many settings. In VC in particular, there are important delays between evaluating a deal and making an investment decision; and between the inception of a new Portfolio Company and the discovery of its quality, just to name a few.

During the boom competitive pressures led VCs to increase the speed at which they made investment decisions, conversely during the bust VCs decreased investment speed. At the VC industry-level this means that when the due diligence delay shortens, the speed (i.e., rate) at which new investments are made increases. Similarly, when the liquidity delay (i.e., time to exit companies) shortens, the speed to liquidate Portfolio Companies increases. The dynamic

process is such that whenever the speed of investment exceeds the speed of liquidation there is an accumulation process that leads to growth; and conversely, if Portfolio Companies are liquidated faster than the speed of new investments, a depletion process takes place which leads the decline.

Studies of decision speed at the organizational level have shown that there is a complex relationship between time pressure, speed, and performance (Oliva and Sterman, 2001; Repenning, 2001; Perlow et al., 2002). In this thesis, the simulation results show that increasing the speed to make deals and the speed to exit companies increases the overall returns performance in the short-run; however, on the long-run, returns performance is lower than benchmark. These results suggest that investment speed matters. Speed in VC is an important factor in determining returns performance of the overall VC industry, and hence, the ability of VC to attract new capital inflows in the future.

10.3 Conclusions

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

- 1) The boom-and-bust in VC investment has an endogenous component. The boom-and-bust is generated by three key feedback processes: a positive loop linking successful exits with deal-making, which accelerates the growth of investments; a negative feedback linking exits with acquisitions, which causes the growth to slow-down as market limits are approached; another negative feedback that controls for under-performing deals.
- 2) The simulation results suggest that 'faster is not always better'. Aggressive investors exacerbate the boom-and-bust dynamic resulting in poor VC industry performance. There is no incentive for passive investors either, at least when they are faced with market pressures. Passive investors 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 VC investment process

(due diligence delay and liquidity delay) have a significant impact on both the boom-and-bust dynamic and VC industry performance.

- 4) This study demonstrates how 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 and at higher valuations. Second, during periods of boom-and-bust, exit valuations are not necessarily correlated with deal valuations. Therefore, the greater the pre-money valuations, the lower the overall returns performance.

10.4 Contributions

This thesis offers at least four contributions to the academic literature and management practice.

- 1) A case study of the VC boom-and-bust in the Ottawa-region that anchors the research efforts around a 'real world' situation. The Ottawa case focuses on one of the most relevant technology clusters in Canada which greatly contributed to the boom-and-bust in the Canadian VC industry. The case provides the regional context and the pre-conditions that contributed to create the overall problem behavior.
- 2) The key variables and causal relationships in the VC investment process. The key variables refer to three things. First, the key resources controlled by decision-makers (e.g., capital, company ownership), which build and deplete over time. Second, the decision rules used by market participants to manage the accumulation and depletion of those resources. Third the time delays involved in the VC investment process. The causal relationships refer to the linkages between the variables in the model. Moreover, this study recognizes the behavioral motivations of market participants, which are deemed as important explanatory factors in the study of anomalous phenomena, such as the boom-and-bust dynamic.
- 3) A system dynamics model that captures the key feedbacks of the VC investment process. Based on intensive interviews and extensive document review I find

evidence of the existence of positive feedbacks that reinforce investment activity, which are coupled with negative feedbacks that limit its growth. The causal model was reviewed by domain experts and was deemed as a plausible representation of the venture capital investment process. The model was also submitted and presented for academic review in several international conferences.

- 4) A framework to appreciate the impact of VC investment speed. By running computer simulations on the model, this study explores the impact of investment speed on VC industry performance. The results of the simulations suggest that faster is not always better. Market participants are prone to fail in accounting for the impact of critical time delays and feedbacks in making investment decisions. Rapid investment decision-making may lead, in the long-run, to unintended poor performance of the VC industry as a whole.

10.5 Limitations

There are several limitations of this research that constraint what was achieved, and what inferences can be made from its findings. Each stage of this research had limits and constraints. While the use of multiple methods to gather and analyze data helped to mitigate these problems, some important concerns remain.

- 1) Limitations of sample size. The field research is based on voluntary interviews with local VCs in the Ottawa-region. The selected respondents were contacted at networking events and most interviews were conducted face-to-face. As there was no prior contact with many other non-local VCs, they were not successfully recruited for the study. Therefore, the intensive interviews were limited to a somewhat small sample size of five practitioners for the formal interviews, plus two additional practitioners for the pilot interviews.

The sample represents six out of eight local VC firms⁵³ investing in Ottawa between 1998 and 2003. Although the sample size may raise some concerns about the generalizability of the findings, it may be argued that the additional

⁵³ Ottawa VC firms members of the CVCA.

knowledge gained by the author from interviewing the fifth practitioner was marginal compared to that already gained from previous interviews.

- 2) Limitations of sample selection. This study does not include interviews with U.S. VCs investing in Ottawa during (1998-2003). U.S. VCs were instrumental in leading to the boom-and-bust in Ottawa between 1998 and 2003. In this study, all evidence about U.S. VC investment activity in Ottawa comes from secondary data (document review and interviews with local VCs). From this evidence we know that during the boom dozens of US VCs, unfamiliar with the local market, invested in Ottawa at very high valuations. They had large pools of capital and aimed for quick exits. They also brought in complex terms-and-conditions to the table. In this study U.S. VCs are assumed to have the same motivations as the local VCs. Arguably, it could be surmised that the their motivation of U.S. VCs was more of a 'sector speculator' type of VC (e.g., interested in quick profits), whereas the local VCs were more of a 'company creator' type (e.g., interested in creating value to develop the region). Since the evidence in this study is not conclusive, the absence of interview data with U.S. VCs becomes a limitation.

Another limitation is that the study does not include interviews with Angel investors. Therefore, it is not clear to what extent Angel investors may have influenced the boom-and-bust dynamic. However, informal interviews with Angels and field research results did not provide substantiate evidence on the existence of important feedbacks relating Angels to the problem behavior. It is known that during the boom Angels retreated due to the greater size of deal valuations and the 'unfair' terms and conditions required by U.S. VCs. Usually though, Angel financing is a sign of credibility for VC financing. This retreat by Angels may have had an impact on the quality of the deals made by VCs during the boom which is not included in the research study.

- 2) Limitations of causal and formal modeling. The causal model developed in this study has several weaknesses. As an abstraction of a complex system of the real world of VC investment, there is a certain amount of uncertainty around the adequacy of the researcher's synthesis and elicitation of the underlying mental models. Other data elicitation techniques such as group model building (Vennix,

1996) can be used to facilitate and improve the accuracy of causal models. Such effort would require the coordination of all the participants in this study to meet in a workshop-type of setting in order to discuss the model. This was not likely to happen due to their very busy agendas. Therefore, the synthesis of the work was left to the researcher. However, the use of interview transcripts revised by the participants themselves, as well as the follow-up interviews to review the causal model should mitigate this bias somewhat.

The system dynamics modeling process itself has limitations and assumptions that must be understood. The structures in the model are arguably over-simplifications. However, without simplifications system dynamics models may get quickly overly complex and lose their intuitive appeal and explanatory value. The important findings of this work are not in the percentage differences between scenarios. Rather, the importance comes from the insights derived from analyzing the impact of investment speed on different model behaviors over time.

- 3) Limitations of quantitative data. The absence of time series data of VC fundraising and investing is another limitation. The model relies on the subjective judgment of the researcher and a few respondents to provide best estimates of parameter values. This fact adds concerns on the generalizability of the results. Having access to numerical data of VC firms and investee companies (e.g., valuations, investment rounds, earnings, and growth rates) would be useful to enhance and expand the model, calibrate its parameters, and test the fit of historical data to simulations. This would increase confidence in the model and the simulation results. It may be argued though, that such numerical data may never be available for public scrutiny, due to its confidential nature.

10.6 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 thesis 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’ performance making investments 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”.

- 5) 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)

References

Abdel-Hamid, T. and S. Madnick (1991). *Software project dynamics*. Prentice Hall. Englewood Cliffs, NJ:.

Babcock-Lumish, T. (2003). The dynamics of innovation investment communities: the spatial structure of networks and relationships. *School of Geography and the Environment, Oxford University working paper*, 1-39.

Bakken, B. (1993). Learning and transfer of understanding in dynamic decision environments. PhD thesis, MIT Sloan School of Management, Cambridge, MA 02142 (unpublished).

Benartzi, S. and R. Thaler (1995). Myopic loss aversion and the equity premium puzzle. *Quarterly Journal of Economics*, **110**(1), 73–92.

Benveniste, L., W. Busaba and W. Wilhelm (2002). Information Externalities and the Role of Underwriters in Primary Equity Markets. *Journal of Financial Intermediation*, **11**(1), 61-86.

Black, B. S. and R. J. Gilson (1998). Venture capital and the structure of capital markets: Banks versus stock markets. *Journal of Financial Economics*, **47**, 243-277.

Callahan, J. and S. Muegge (2003). Venture capital's role in innovation: issues, research and stakeholder interests. In: *The International Handbook on Innovation* (L.V. Shavinina, ed.) pp. 1-71. Elsevier Science, New York.

Callahan, J. and K. Charbonneau (2004). The role of venture capital in building technology companies in the Ottawa region. In: *Silicon Valley North* (L.V. Shavinina, ed.). Elsevier Science, New York.

Carpenter, M., W. Lazonick, and M. O'Sullivan (2002). The stock market, corporate strategy, and innovative capability in the 'new economy': The optical networking industry. *INSEAD R&D working paper*, 1-41.

Christensen, C., S. Anthony, and E. Roth (2001). Innovation in the telecommunications industry. Separating hype from reality. *Clayton M. Christensen and Associates*, 1-47, October (<http://www.claytonchristensen.com>).

Cyert, R. M. and J. G. March (1963/1992). *A behavioral theory of the firm*. 2nd Ed. Blackwell Business, Cambridge, MA:.

Diehl, E. and J. Sterman (1995). Effects of feedback complexity on dynamic decision making. *Organizational Behavior and Human Decision Processes*, **62**(2), 198-215.

Fama, E. (1970). Efficient capital markets: A review of theory and empirical work. *Journal of Finance*, **46**, 1575-1617.

Foddy, W. (1993). *Constructing questions for interviews and questionnaire: Theory and practice in social research*. Cambridge University Press. Cambridge, UK.

Forrester, J. (1958). Industrial Dynamics. *Harvard Business Review*, **36**(4), 37-66.

Forrester, J. (1961). *Industrial Dynamics*. MIT Press, Cambridge, MA:.

Forrester, J. (1968). Market growth as influenced by capital investment. *Sloan Mgmt. Rev.* **9**(2), 83-105.

Forrester, J.W. (1992). Policies, decisions, and information sources for modeling. *European J. Operational Res.*, **59**(1), 42-63.

Forrester, J. and P. Senge (1980). Tests for building confidence in system dynamics models. *TIMS Studies in the Management Sciences*, **14**, 209–228.

Galbraith, J. K. (1954/1972). *The great crash 1929*. Houghton Mifflin Company Boston, Boston, MA:.

Getmansky, M. and J. Papastaikoudi (2002). Extrapolating expectations: An explanation for excess volatility and overreaction. *Proceedings of the 20th International Conference on System Dynamics. ISDC 2002, Palermo, Italy*. 1-30.

Globerman, S., D. Shapiro, and A. Vining (2003). Location effects, locational spillovers and the performance of Canadian information technology firms. *Simon Fraser University working paper*.

Gompers, P. (1996). Grandstanding in the Venture Capital Industry. *Journal of Financial Economics*, **43**, 133-156.

Gompers, P. and J. Lerner (1999). *The venture capital cycle*. MIT Press. Cambridge, MA:.

Gompers, P. and J. Lerner (2000). Money chasing deals? The impact of fund inflows on private equity valuations. *Journal of Financial Economics*, **55**, 281-325.

Hall, J. and C. Hofer (1993). Venture capitalists' decision criteria and new venture evaluation. *Journal of Business Venturing*, **8**(1), 25-42.

Hardin, G. (1968). The tragedy of commons. *Science*, **162**, 1243-1248.

Harvey, P. (2002). The capex cloud. *Light Reading*. January 16.

Helwege, J. and N. Liang (2001). Initial Public Offerings in Hot and Cold Markets. *Ohio State University working paper*.

Homer, J. B. (1996). Why we iterate: scientific modeling in theory and practice. *System Dynamics Review*, 12(1), 1-19.

Jeng, L. and P. Wells (1997), The determinants of venture capital funding: An empirical analysis. *Unpublished working paper. Harvard University*.

Kalba, K. (2002). Telecom in the time of crash. *Incidental paper. Center for Information Policy Research. Harvard University*.1-41.

Kampmann, C. and J. Sterman (1998). Feedback complexity, bounded rationality, and market dynamics. *Working paper, System Dynamics Group, MIT Sloan School of Management, Cambridge, MA 02142*.

Kemmerer, B., S. Mishra, and P. Shenoy (2003). Bayesian causal maps as decision aids in venture capital decision making: Methods and applications. *Entrepreneurship Division* (forthcoming). 1-30.

Kindleberger, C. P. (1978). *Manias, panics, and crashes*. Basic Books. New York.

Kummerow, M. (1999). A system dynamics model of cyclical office over supply. *Journal of Real State Research*, 18(1), 233-255.

Lane, D. (1994). Modeling as Learning: A Consultancy Methodology for Enhancing Learning in Management Teams. In J. D. W. Morecroft & J. D. Sterman (Eds.), *Modeling for Learning Organizations* (pp. 85-117). Portland, OR: Productivity Press.

Lakonishock, J., Schleifer, A., Thaler, R., and Vishny, R.(1991). Window dressing by pension fund managers. *American Economic Review Papers and Proceedings*, **81**, 227-231.

Law A. and Kelton D. (2000). *Simulation modeling and analysis*. McGraw Hill, Boston.

Lerner, J. (1994). Venture capitalists and the decision to go public. *Journal of Financial Economics*, **35**, 293-316.

Lerner, J. (2002). Boom and Bust in the Venture Capital Industry and the Impact on Innovation. *Federal Reserve Bank of Atlanta Economic Review*, **87**(4), 25-39.

Liehr, M., A. GroBler, M. Klein, and P. Milling (2001). Cycles in the Sky: understanding and managing business cycles in the airline market, *System Dynamics Review*, **17**(4): 331-332.

Luna, L. and D. Lines (2003). Collecting and analyzing qualitative data for system dynamics: methods and models. *System Dynamics Review*, **19**(4), 271-296.

MacMillan, I., R. Siegal, and P. SubbaNarasimba (1985). Criteria used by venture capitalists to evaluate new venture proposals. *Journal of Business Venturing*, **1**, 119-128.

MacMillan, I., L. Zemann, and P. SubbaNarasimba (1987). Criteria distinguishing successful from unsuccessful ventures in the venture screening process. *Journal of Business Venturing*, **2**, 123-137.

Mandel, M. (2000). *The Internet depression. The boom, the bust, and beyond*. Basic Books, New York.

Miller, G. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, **63**, 81-96.

Morecroft, J. (1983). System dynamics: Portraying bounded rationality. *OMEGA the International Journal of Management Science*, **11**(2), 131-142.

Muzyka, D., S. Birley and B. Leleux (1996). Trade-offs in the investment decisions of European venture capitalists. *Journal of Business Venturing*, **11**, 104-114.

Morecroft, J. (1983). System dynamics: Portraying bounded rationality. *OMEGA the International Journal of Management Science*, **11**(2), 131-142.

Nesheim, J. (1997/2000). *High Tech Startup*. Free Press. New York.

Oliva, R., J. Sterman (2001). Cutting corners and working overtime: Quality erosion in the service industry. *Management Science*, **7**, 894-914.

Oliva, R., J. Sterman and M. Giese (2003). Limits to growth in the new economy: exploring the 'get big fast' strategy in e-commerce. *System Dynamics Review*, **19**(2), 83-116.

Odean, T. (1998). Are investors reluctant to realize their losses?. *Journal of Finance*, **53**, 1775-1798.

Paich, M., and Sterman, J. (1993). Boom, bust, and failures to learn in experimental markets. *Management Science*, **39**(12), 1439-1458.

Perkins, A. B. and Perkins, M. C. (2001). *The Internet bubble, revised edition*. HarperBusiness, New York.

Perlow, L., G. Okhuysen, N. Repenning (2002). The speed trap: Exploring the relationship between decision making and temporal context. *Academy of Management Journal*, **45**(5), 931-955.

Porter, M. (1980). *Competitive strategy: Techniques for analyzing industries and competitors*. New York. Free Press.

Repenning, N. (2001). Understanding fire fighting in new product development. *Journal of Product Innovation Management*, **18**, 285-300.

Rich E. 2002. Modeling the dynamics of organizational knowledge. Unpublished PhD Dissertation, School of Information Science and Policy. University at Albany. Albany, NY.

Richardson G., A. Pugh (1981). *Introduction to System Dynamics Modeling with DYNAMO*. Cambridge, MA: Productivity Press. (Now available from Pegasus Communications, Waltham, MA.)

Rogers, E. (1995). *Diffusion of Innovations*, 4th ed. Free Press. New York.

Ruhnka, J., H. Feldman and T. Dean (1992). The 'living dead' phenomenon in venture capital investments. *Journal of Business Venturing*, **7** (2), 137-155.

Ruhnka, J. and J. Young (1987). A venture capital model of the development process for new ventures. *Journal of Business Venturing*, **2**, 167-184.

Sahlman, W. and H. Stevenson (1986). Capital market myopia. *Journal of Business Venturing*, **1**, 7-30.

Sahlman, W. (1998). The horse race between capital and opportunity. *The Venture Capital Review*, Spring 1998, 17-25.

Sandberg, W., D. Schweiger, and C. Hofer (1988). The use of verbal protocols in determining venture capitalists' decision processes. *Entrepreneurship Theory and Practice*, Winter, 8-20.

Sastry, M. A. (1997). Problems and paradoxes in a model of punctuated organizational change. *Administrative Science Quarterly*, 42 (6), 237-275.

Saxenian, A.(1994). *Regional Advantage*. Cambridge, MA: Harvard University Press.

Selltiz, C., L. Wrightsman and S. Cook (1976). *Research methods in social relations*. 3rd ed. Holt, Rinehart and Winston, New York.

Scharfstein, D. and Stein, J. (1990). Herd behavior and investment. *American Economic Review*, 80, 465-489.

Shefrin, H. (2000). *Beyond Greed and Fear*. Boston, MA:. Harvard Business School Press.

Shepherd, D. (1999a). Researchers of VC's decision making, beware! Unpublished manuscript. J.L. Kellogg Graduate School of Management.

Shepherd, D. (1999b). Venture capitalists' introspection: A comparison of 'in use' and 'espoused' decision policies. *Journal of Small Business Management*, 37(2), 76-85.

Shepherd, D. (1999c) Venture capitalists' assessment of new venture survival. *Management Science*, 45(5), 621-636.

Shepherd D., R. Ettenson, and A. Crouch (2000). New venture strategy and profitability: A venture capitalist's assessment. *Journal of Business Venturing*, 15(5-6), 449-467.

Shepherd D. and A. Zacharakis (1999). Conjoint analysis: anew methodological approach for researching the decision policies of venture capitalists. *Venture Capital*. 1(3), 197-217.

Shepherd D. and A. Zacharakis (2002). Venture Capitalists' Expertise - A Call for Research into Decision Aids and Cognitive Feedback. *Journal of Business Venturing*, 17(1), 1-20.

Schiller, R. (1984). Stock prices and social dynamics. *Brookings Papers on Economic Activity*, 2, 457-498.

Shleifer, A. (2000). *Inefficient markets. An introduction to behavioral finance*. Oxford University Press. New York.

Simon, H. (1957). *Administrative behavior; a study of decision-making processes in administrative organization*. Free Press. New York.

Simon, H. (1979). Rational decision-making in business organizations. *American Economic Review*, 69, 493-513.

Smith, R. and J. Smith (2000). *Entrepreneurial Finance*. Wiley Text Books. New York.

Stein, J. (2001). Agency, information and corporate investment. In: *Handbook of the Economics of Finance* (G. Constantinides, M. Harris and R. Stulz, ed.), 1-89. Boston.

Sterman, J. (1985). A behavioral model of the economic long wave. *Journal of economic Behavior and Organization*, 6, 17-53.

Sterman, J. (1989). Misperceptions of feedback in dynamic decision making. *Organizational Behavior and Human Decision Processes*, 43(3), 301-335.

Sterman, J. (2000). *Systems dynamics modeling: tools for learning in a complex world*. McGrawHill, New York.

Stoughton, N., K. Wang and J. Zechner (1999). IPOs and Product Quality. *Unpublished manuscript. University of California at Irvine, University of Hong Kong and University of Vienna*.

Stuart, T. and O. Sorenson (2003a). Liquidity Events and the Geographic Distribution of Entrepreneurial Activity. *Administrative Science Quarterly*, **48**, 175-201.

Stuart, T. and O. Sorenson (2003b). The geography of opportunity: Spatial heterogeneity in founding rates and the performance of biotechnology firms. *Research Policy*, **32**, 229–253.

Tversky, A. and D. Kahneman (1973). On the psychology of prediction. *Psychological Review*, **80**, 237-251.

Tversky, A. and D. Kahneman (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, **47**, 263-291.

Tversky, A. and D. Kahneman (1981). The framing of decisions and the psychology of choice. *Science*, **211**, 453-458.

Tyebjee, T. and A. Bruno. (1984). A Model of Venture Capitalist Investment Activity. *Management Science*, **30**(9), 1051-1066.

Valliere, D. and R. Peterson (2004). Inflating the bubble: examining dot-com investor behavior. *Venture Capital*, **6**(1), 1-22.

Vennix J. (1996). *Group model building: facilitating team learning using system dynamics*. Wiley: Chichester.

Warner, A. (2003). Do acquisitions substitute for exploration? Data from the information and telecommunications industry 1995-2000. *Pennsylvania State University – Erie working paper*, 1-19.

Warren, K. (2002). *Competitive strategy dynamics*. John Wiley & Sons, Chichester.

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal*, 5, 171-180.

Wheale, P. and L. Amin (2003). Bursting the dot.com ‘bubble’: A case study in investor behavior. *Technology Analysis & Strategic Management*, 15(1), 117-135.

Wolfram, S. (2002). *A new kind of science*. Champaign, IL, Wolfram Media.

Yepez, C. (2004a). A generic dynamic model of venture capital investment. *Proceedings of the 13th International Conference on Management of Technology*, IAMOT 2004, Washington D.C.

Yepez, C. (2004b). A behavioral model of venture capital bubbles. *Proceedings of the North American Association for Computational Social and Organizational Science (NAACSOS) Conference 2004*. Pittsburgh, PA.

Yepez, C. and A. Mehmood (2004). Dynamics of venture capital investment during periods of market boom and bust. *Proceedings of the 22nd International Conference of the System Dynamics Society (ISDC) 2004*. Oxford, England.

Zacharakis, A., Meyer, G. (1995). The venture capitalist decision: understanding process versus outcome. *Front Entrepreneurship Res.*, 57-76.

Zacharakis, A., Meyer, G. (1998). A lack of insight: Do venture capitalists really understand their own decision processes? *Journal of Business Venturing*, 13(1), 57-76.

Zacharakis, A., Shepherd, D. (2001). The nature of information and overconfidence on venture capitalists' decision making. *Journal of Business Venturing*, 16, 311-332.

Glossary

Aggressive investor: In the model, refers to investment speed scenarios with low liquidity delay.

Boom-and-Bust: Sudden and significant rise and decline of investment in capital markets.

Bubble: Price bubbles are characterized by a systematic increase in prices without much news due to noise trading behavior. Noise traders in price bubbles react to past price changes, as opposed to particular news (Schleifer, 2000).

Flow: The movement or flow of the resource from one stock to another

Feedback process: A closed causal loop.

Investment Speed: The rate at which VCs make investment and exit decisions. Investment Speed in VC has two components, it involves: i) the number of new investments per time period (due diligence); ii) the number of successful exits per time period (liquidity delay).

Market Participant: The economic agent in the VC market. Market participants include venture capitalists, institutional investors, entrepreneurs and buyers of portfolio companies.

Negative (balancing) feedback: A self-correcting process. Negative loops counteract and oppose change.

Passive investor: In the model, refers to investment speed scenarios with high liquidity delay.

Peak time: The time at which a variable reaches its maximum value.

Peak value: The maximum value of a variable over time.

Portfolio Company: Privately held high-technology company being financed by a VC.

Positive (reinforcing) feedback: A self-reinforcing process. Positive loops tend to reinforce or amplify whatever is happening in a system.

Public Market: A market for the trading of publicly held company stock and associated financial instruments.

VC Industry Performance: Measured by the returns made from existing VC funds at any given period of time. Performance is computed continuously throughout a simulation run.

VC Market: Set of all actual and potential Market Participants in VC.

VC Pipeline: The supply line of deals needed to replenish the portfolio companies that VCs require to operate their business.

VC System: Causal structure of the VC market.

Stock: The accumulation of resource (tangible or intangible)

Stock-and-Flow diagram: Diagram showing the relationships among variables that have the potential to change over time.

Track record: The ratio of failures to the total outcome distribution of Portfolio Companies.

Appendix 1. Simulation results

Figure 11. Summary of base run behaviors

Figure 1 is a line graph showing the number of firms in different portfolio company categories over time (0 to 240 months). The Y-axis represents the number of firms (0 to 20). The X-axis represents Time (Month). The legend indicates five categories: Creators (solid line with circles), Speculators (dashed line with triangles), Diversified (dotted line with squares), Focused (dash-dot line with diamonds), and Baserun (solid line with crosses). The Baserun category shows a steady increase from 0 to 5 firms by month 240. The other categories show peaks at different times: Creators peak at month 24, Speculators at month 48, and Diversified at month 72. Focused and Baserun categories show a decline after their respective peaks.

Time (Month)	Creators	Speculators	Diversified	Focused	Baserun
0	0	0	0	0	0
24	20	2	1	1	1
48	15	15	2	2	2
72	8	8	18	3	3
96	4	4	10	4	4
120	1	1	5	5	5
144	0	0	2	2	2
168	0	0	1	1	1
192	0	0	1	1	1
216	0	0	1	1	1
240	0	0	1	1	5

Figure 12. Portfolio Companies

success rate

Figure 13. Success Rate

Figure 14. Outcome Distribution

Figure 15. Pre-Money Valuations (New deal)

Figure 16. Pre-Money Valuations (Follow-on)

Figure 17. Exit Valuations

Figure 18. Commitments

Figure 19. Proceeds

Figure 20. Returns

Figure 21. Portfolio companies with public market crash

Figure 22. Success rate with public market crash

New Deal Valuation

Figure 23. Pre-Money Valuations (New deal) with public market crash

Follow-on Valuation

Figure 24. Pre-Money Valuations (Follow-on) with public market crash

Figure 25. Exit valuations with public market crash

Figure 26. Returns with public market crash

WINNERS

Winners : Creators&Crash
Winners : Speculators&Crash
Winners : Diversified&Crash
Winners : Focused&Crash
Winners : Baserun&Crash

Survivors

Survivors : Creators&Crash
Survivors : Speculators&Crash
Survivors : Diversified&Crash
Survivors : Focused&Crash
Survivors : Baserun&Crash

LOSERS

Firms Losers : Creators&Crash
Firms Losers : Speculators&Crash
Firms Losers : Diversified&Crash
Firms Losers : Focused&Crash
Firms Losers : Baserun&Crash

Total Portfolio Companies

Firms Total Portfolio Companies : Creators&Crash
Firms Total Portfolio Companies : Speculators&Crash
Firms Total Portfolio Companies : Diversified&Crash
Firms Total Portfolio Companies : Focused&Crash
Firms Total Portfolio Companies : Baserun&Crash

Figure 27. Outcome distribution with public market crash

Appendix 2

Venture Capital Microworld

Model Review Booklet

Carlos Yepez
Telecommunications Technology Management Program
Department of Systems and Computer Engineering
Carleton University
June 2004

Contents

1. Introduction
2. The Virtual Venture Capital Industry
 - 2.1. The Venture Capital Microworld
 - 2.2. Simplified View of Venture Capital Investment Activity
3. Microworld Structure Review
 - 3.1 Definitions
 - 3.2 Resource Structure of the Venture Capital Microworld
 - 3.3 Causal Loop Diagrams
 - A. Deal Making Loop
 - B. Fundraising Loop
 - C. Market Saturation Loop
 - D. Competition Loop
 - E. Demand Loop
4. Closing Questions

Consent Form

This booklet includes a questionnaire to be used for validation purposes. The booklet is part of a second and final interview that completes my participation in the study conducted by the researcher, **Carlos Yepez**, from the **Department of Systems and Computer Engineering** at **Carleton University**.

Signatures:

Participant,

Date

Researcher,

Date

1. Introduction

In this research project, I have developed a microworld featuring a virtual venture capital industry in a very simplified business environment. In the microworld, venture capitalists invest in early stage companies that develop new products in a single market segment. The effects on investment activity in the venture capital microworld change according to the dynamics of the resource system.

The microworld is built on information that you and your colleagues provided about important features of the venture capital investment process. Your help is needed to review and comment on the structure of the model, its assumptions, and components.

Please review the description of the microworld to learn about its structure (Sections 2 and 3). When we speak, I will show you several micro-structures of the model. After describing each micro-structure, I will ask you a few questions about your reactions to the model.

There are no right or wrong answers – your comments and questions about what you see are the important data for the project.

Again, thank you for your participation. If you have any questions about this research, please feel free to contact me at cyepez@sce.carleton.ca

Carlos Yepez

2. The Virtual Venture Capital Industry

As depicted in Figure 1, the virtual venture capital industry is a model that assumes a simple structure for the aggregate of venture capital firms. In this model, there are two main resources controlled by venture capitalists (VCs). First, one single fund of funds representing the aggregate of funds of all venture capital firms. Second, one single portfolio of companies representing the aggregate of companies funded by VCs within a specific market sector.

Figure 1. Virtual Venture Capital Industry

For the purpose of this virtual model, the resources managed by VCs are a single stock of Funds and a single stock of Portfolio Companies. The state of these stocks depends on several things:

- Fundraising increases the stock of Funds available for investment. The stock is depleted by the Investments made on Portfolio Companies (i.e., both new investments and follow-on investments).
- New deals made by VCs increase the stock of Portfolio Companies under management. While in the portfolio, these companies require additional Investments until they are eventually exited. Exits decrease the stock of Portfolio Companies.

2.1. The Venture Capital Microworld

The venture capital microworld is based on the simplifying assumption that VCs have decided to invest in companies that commercialize a new product in a specific market sector. Therefore, only new deals within a similar product offering are accounted for in this microworld. Investments are made with the expectation that Portfolio Companies will eventually reach a successful exit (e.g., IPO or M&A) based on the great potential of the market sector.

The microworld divides the venture capital environment into five basic subsystems (Figure 2), as follows:

- **Limited Partners (LPs)**, which represents the set of individual or institutional investors that provide the money to venture capital funds. LPs can 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.
- **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.
- **Buyers**, which represents the set of potential acquirers of Portfolio Companies. In the case of acquisitions 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).
In the microworld, the Buyers subsystem provides an information source used for several market participants decisions.
- **Market**, which represents the information source on the changing market attractiveness as a function of successful exits (e.g., IPOs or M&As) into the market. The market is assumed to have a fixed size, which sets a limit to the total number of successful exits that can compete profitably in the long run.
- **Entrepreneurs**, which represents the pool of early stage companies developing new products within the specific market sector.

Microworld Model Boundary

Figure 2. Subsystem diagram of the Venture Capital Industry Microworld

2.2.Simplified View of Venture Capital Investment Activity

In this microworld the venture capital investment activity is represented by the resource flow of cash and company ownership between market participants (i.e., between subsystems). The boundary of the microworld is limited to the above market participants only. Finally, the venture capital industry microworld is based on the following rules:

- Investment activity requires funds. Fundraising depends on the confidence of investors in venture capital. Investors' confidence is assumed to be influenced by liquidity expectations and returns expectations of venture capital investments. When confidence increases, the amount of funds increases.
- New deals are made as a result of an attractive market sector for technology investments and the expectation of successful exits for those investments (e.g., IPOs or M&As). As new deals are made, the portfolio of companies increases.
- Portfolio companies age, require follow-on investments, and are eventually exited. There are three possible outcomes for portfolio companies: successful exits, failed exits, and living-dead companies. Each type of outcome provides a different payoff to VCs.
- The size of the market is fixed and constant. Market Size sets a limit to the total number of successful exits (e.g., IPOs or M&As transactions) that can compete profitably in the long run. Once the limit is reached, no more successful exits will take place.

The microworld attempts to show how these simple rules can interact to create a short-term upswing and subsequent decline in investment activity for the aggregate venture capital industry.

3. Microworld Structure Review

In the following sections I will walk you through up to five different micro-structures, or causal loops, that compose the main structure of the microworld. These causal loops are:

- Deal Making Loop**, which depicts how new investments are made.
- Fundraising Loop**, which depicts how funds are raised.
- Market Saturation Loop**, which depicts how the increasing number of successful exits eventually saturates the market sector.
- Competition Loop**, which depicts how competition for investments drives price changes in deal valuations.
- Demand Loop**, which depicts how raising demand for portfolio companies drives price changes in exit valuations.

To illustrate each loop, I will show you a causal loop diagram that represents the hypothesized feedback relationship(s) among key variables in the investment process. After each loop, there is a short description of how a particular piece of the investment process is driven. I will ask you to give your opinion on the explanation provided. Is the

explanation plausible within the constraints of the model? I will also want to know if the loop reflects any aspects of your own experiences in venture capital investment.

Finally, I will ask you to provide some guidance on how to extend this research so that it can be more useful for the understanding of venture capitalists' decision processes.

3.1 Definitions

As a preliminary step to the analysis of the causal loops in this microworld I will provide you with a brief definition of each of the key variables used in the loops.

- **Funds**, the amount of money available for VC investment.
- **VCs looking for a deal**, the population of venture capital firms that can potentially invest in the market sector.
- **VCs investing in a deal**, the amount of venture capital firms currently investing in the market sector.
- **Entrepreneurs**, the number of startup companies under scrutiny of VCs.
- **Portfolio Companies**, the number of private companies being financed by VCs.
- **Prospect Buyers**, the number of potential acquirers of portfolio companies in the market sector (e.g., public traded companies)
- **Buyers**, the number of buyers currently bidding for portfolio companies in the market sector.
- **Winners**, the number of VC-backed companies that reach successful exit via IPO or M&A.
- **Losers**, the number of VC-backed companies that exit as failures (i.e., at a loss).
- **Survivors**, the number of VC-backed companies labeled as living-dead, which eventually are exited at no gains (e.g., an asset value sell).
- **Deal Rate**, the number of new deals made per period of time.
- **Success Rate**, the number of companies successfully exited per period of time.
- **Write-off Rate**, the number of companies exited as failures (i.e. at a loss) per period of time.
- **Wind-down Rate**, the number of survivor companies wound down per period of time.
- **Entrance Rate**, the number of venture capital firms that enter the market sector per period of time.
- **Exit Rate**, the number of venture capital firms that exit the market sector per period of time.
- **Buy Rate**, the number of buyers competing for an acquisition per period of time.
- **Bid Rate**, the number of buyers that enter the sector and bid for acquisitions per period of time.
- **Fundraising**, the amount of money allocated to venture capital funds per period of time.
- **Spending**, the amount of money invested by VCs per period of time.

- **Disbursements**, the amount of money being spent in new and follow-on investments per period of time.
- **Reimbursements**, the amount of money made from exiting investments per period of time.
- **Liquidity Activity**, this dimension captures the pattern (i.e., increasing, stable, or decreasing) of the Success Rate.
- **Liquidity Expectations**, this dimension models expectations for IPO or M&A transactions. It sets the projected “Liquidity Activity” to the belief about the recent, or historical “Liquidity Activity”.
- **Returns**, this dimension measures the ROR from the total contributions made to venture capital investments during the overall period of investment activity. It is calculated from cumulative reimbursements and cumulative disbursements.
- **Expected Returns**, this dimension models the expectations about venture capital returns. It sets the projected “Returns” to the belief about the recent, or historical “Returns”.
- **Pressure to Invest**, this dimension represents the implicit pacing requirements in the deployment of a venture capital fund. It relates the total funds available for investment to the time horizon in which the fund should be completed.
- **Sector Attractiveness**, this dimension measures how attractive the market sector is for VC investments. It is formulated as a decreasing function of the ratio between the number of successful exits in the sector and the size of the market.
- **Market Size**, is the total number of “Winners” that can compete profitably in the market sector in the long-run. Its value is assumed constant.
- **LPs confidence**, this dimension represents how favorably investors look at venture capital investments. It is formulated as a function of two factors: “Expected Returns” and “Liquidity Expectations”.
- **VCs competing for deals**, the current number of venture capital firms interested to make a particular deal (new, and follow-on), at a particular time. It is formulated as a fraction of the total number of venture capital firms that could potentially invest in the sector (VCs looking for deals).
- **Competition for exits**, the number of Buyers bidding for Portfolio Companies ready to exit in the sector.
- **Pre-money Valuation**, this dimension represents the current value of investments made by VCs (new and follow-on). Its price change is influenced by the VCs competing for deals.
- **Exit Valuation**, this dimension represents the current value of the companies that reach a successful exit. Its price change is influenced by buyer’s demand for IPO or M&A transactions.

3.2 Resource Structure of the Venture Capital Microworld

Figure 3 depicts a dynamic resource system view of the venture capital microworld. The boxes represent the stocks of resources, while the valves represent the inflows and outflows of those resources.

Figure 3. Funds, venture capital firms, investments, and buyers

Several things happen in the dynamic resource structure:

- Funds are increased by Fundraising and decreased by Spending
- Portfolio Companies are increased by the Deal Rate and decreased by the Success, Failure and Wind-down rates
- VCs investing in a deal are increased by the Entrance Rate of VCs looking for a deal, and are decreased by the Exit Rate when VCs exit their investments.
- Buyers are increased by the bid rate or entrance rate of Prospect Buyers that start bidding for Portfolio Companies in the sector.
- Time lags exist between the transitions between stocks (e.g., Portfolio Companies to Winners). Time lags will be included in the formal model.

For simplicity and clarity, the micro-structures in the following section will not depict all the resources just presented above but pieces of it. Therefore, the stocks and flows are assumed to be implicit in the micro-structures to follow.

PLEASE STOP READING AT THIS POINT UNTIL THE INTERVIEW.

3.3 Causal Loop Diagrams

A. Loops R1 and B1: The Deal Making Loops

The loops in Figure 3 depict the decision process for making new deals. Here, there are two main assumptions. First, new investments are made only in new, profitable, and rapidly growing markets. Therefore, the attractiveness of the market sector is a proxy for the investment decision. Second, investments are made in companies with potential for a successful exit (e.g., IPO or M&A). Therefore, liquidity expectations of early successes influence investment activity.

Figure 3. Feedbacks driving Deal-Making activity (R1 and B1)

A.1. What happens?

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).

A.2. Your thoughts about these loops :

Q1. Is the structure of the loop plausible? Does it match your beliefs about how venture capital would work in a scenario such as this virtual venture capital industry microworld, with the conditions of a single market sector and a fixed market size?

Q1 a) Is the relationship of **Sector Attractiveness** with **Deal Rate** plausible?_____

- Why or why not?_____

Q1 b) Is the relationship of **Liquidity Expectations** with **Deal Rate** plausible?_____

- Why or why not?_____

Q2. Is the explanation of what happens in the loop plausible?_____

- Why or why not?_____

B. Loop R2: The Fundraising Loop

The loop in Figure 4 describes the decision process to raise funds. Fundraising depends on the confidence of LPs in venture capital. LPs Confidence is based on two main assumptions. First, since investors are profit maximizers, they constantly assess the returns performance of venture capital funds. When the returns expectations from venture capital exceed a desired returns goal (e.g., 25% ROR), investors allocate money into venture capital funds. Second, investors allocate money into venture capital funds when the liquidity expectations for successful exits are more certain, that is, after receiving signals of recent activity of IPO and M&A transactions.

Figure 4. Feedbacks generating Fundraising activity

B.1. What happens?

The initial successes of companies that exit, via IPO or M&A, increases the returns expectations for venture capital funds. At the same time, the increasing number of companies reaching successful exits sends signals of increasing liquidity expectations for venture capital investments. LPs, 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).

B.2. Your thoughts about this loop:

Q1. Is the structure of the loop plausible? Does it match your beliefs about how venture capital would work in an scenario such as this virtual venture capital microworld, if funds were raised to invest in a new market sector?

Q1 a) Are the relationships among **Funds**, **Pressure to Invest**, and **Deal Rate** plausible? _____

- Why or why not? _____

Q1 a) Is the relationship of **Expected Returns** with **LPs Confidence** plausible? _____

- Why or why not? _____

Q1 b) Is the relationship of **Liquidity Expectations** with **LPs Confidence** plausible? _____

- Why or why not? _____

Q2. Is the explanation of what happens in the loop plausible? _____

- Why or why not? _____

C. Loop B2: The Market Saturation Loop

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)

C.1. What happens?

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.

C.2. Your thoughts about this loop:

Q1. Is the structure of the loop plausible? Does it match your beliefs about how venture capital would work in an scenario such as this virtual venture capital microworld, with the conditions of a single market sector and a fixed market size?

Q1 a) Is the relationship of Sector Attractiveness with Success Rate plausible? _____

- Why or why not? _____

Q2. Is the explanation of what happens in the loop plausible? _____

- Why or why not? _____

D. Loop B3: The Competition Loop

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)

D.1. What happens?

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).

D.2. Your thoughts about this loop:

Q1. Is the structure of the loop plausible? Does it match your beliefs about how venture capital would work in a scenario such as this virtual venture capital microworld, with the conditions of increasing number of competing VCs?

Q1 a) Is the relationship of VCs competing for deals with Pre-money Valuations plausible? _____

- Why or why not? _____

Q2. Is the explanation of what happens in the loop plausible? _____

- Why or why not? _____

E. Loop B4: The Demand Loop

The loop in Figure 6 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 6. Feedback generating Demand (B4)

E.1. What happens?

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 in the sector. However, the more exits are realized, the less Buyers there are. The decreasing number of Buyers, brings down prices of Exit Valuations, which reduces returns expectations in a balancing loop (B4).

E.2. Your thoughts about this loop:

Q1. Is the structure of the loop plausible? Does it match your beliefs about how venture capital would work in an scenario such as this virtual venture capital microworld, with the conditions of increasing number of Buyers and a single transaction per Buyer?

Q1 a) Is the relationship between **Buyers** and **Success Rate** plausible? _____

- Why or why not? _____

Q1 b) Is the relationship between **Competition for Exits** and **Exit Valuation** plausible? _____

- Why or why not? _____

Q2. Is the explanation of what happens in the loop plausible? _____

- Why or why not? _____

4. Closing Questions

Q3. Would having an extended model be more useful to capture venture capital decision processes?

- ☐ Yes
- ☐ Maybe
- ☐ No
- ☐ Don't know

Q4. What other factors of the venture capital decision process should be added to the model? Please list your suggestions below, with the most important listed first.

(1) _____

(2) _____

(3) _____

**Q5. Are there other micro-structures that would provide additional insight?
Please describe what they would be.**

(1) _____

(2) _____

(3) _____

Thank you again for your assistance. This research project would not be possible without your help.

If you would like a copy of an executive summary of the results of this research project, please check here ? and a copy will be sent to your e-mail address.

Please return the booklet in the enclosed envelope to:

Carlos Yepez
Dept of Systems and Computer Engineering
Carleton University
1125 Colonel By Drive
Ottawa, ON K1S 5B6