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A system dynamics approach to venture capital investments illustrated by cases from singapore

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ABSTRACT
Despite the amount of research on VC decision-making, very little is known about the *dynamic* decision processes venture capitalists (VCs) execute in the real world, paying attention to the systemic interactions within the industry. The importance of dynamic decision processes lies in recognizing that investment decisions in VC take place in complex, rapidly changing, and highly competitive markets where growth and returns are expected to be significantly higher. The objective of this paper is to create and simulate a quantitative model of VC investment dynamics drawing on cases from Singapore. The geographic focus is on Singapore and in terms of methodology, the paper makes use of System Dynamics. As key findings, our model captures how the boom-and-bust phenomenon may be generated by the economic agents' intendedly rational decisions within a competitive VC market, that, however, leads to unintended poor performance for the industry as a whole. Future research could then compare our simulation results not only with each other or to the base run, but also to other kinds of scenarios; for example, an external shock like a market crash scenario.

KEYWORDS
VC; Boom and Bust; Economic Cycles; System Dynamics; Private Equity

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Introduction

From 2004 to 2007, nearly all private equity firms have enjoyed extraordinary growth and returns thanks to favorable financial conditions, but the collapse of the world's debt markets and the deepening economic crisis brought an abrupt end to that boom, and severe consequences for private equity, the companies they own, and the real economy. This worldwide trend is reflected in Figure 1, in the development of total private equity funds raised in Singapore.

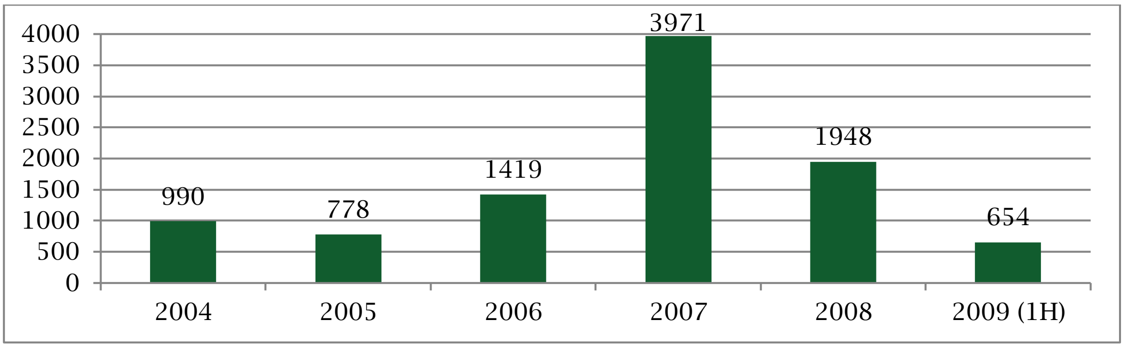

Figure 1. Total private equity funds raised in Singapore (US$ million) Source: AVCJ 2009.

A special subcategory of private equity (more precisely, a specific type of investment strategies) has historically been subject to dramatic swings of such boom-and-bust behavior; namely, *Venture Capital* (VC). VC groups invest in young companies – possibly even raw start-ups – and their investments usually take the form of pure equity, as there is rarely any cash flow available to service loan interest (Fraser-Sampson, 2006). Deploying capital being mainly provided by institutional investors, hedge funds and wealthy individuals, VC is targeted at stimulating the growth of highly innovative start-up companies which, first, makes VC a major source of funding for innovation and, second, has a tremendous impact on economic growth. Accordingly, focusing on and studying the VC industry, VC activities, in general, and VC boom-and-bust, in particular, is not only a very interesting and current topic, but it is also of economic and societal importance.

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The purpose of this paper is to explore the causes and interrelationships underlying the rise and decline in VC. Special attention will be paid to the role and influence of time delays on VC industry performance. Specifically, the following research questions will be addressed:

1) What role do players in the market have during cycles of boom-and-bust?
2) What are key variables and feedbacks in the VC investment process that generate the boom-and-bust?
3) What is the impact of the pace of investment on VC industry performance?

Therefore, an exploratory qualitative model of VC investment decision-making will be introduced, using the system dynamics modeling and simulation approach. The model explains how the boom-and-bust phenomenon may be generated by the economic agents' intendedly rational decisions within a competitive VC market, that leads to poor performance for the industry as a whole. Further, the model suggests that market participants fail to account for the impact of critical delays and feedback processes (i.e. interactions among the components of the system), which results in high levels of investment activity in the short term and lower returns on investments in the long term.

Despite the amount of research on VC decision-making (Tyebjee & Bruno 1984, Shepherd 2000, Blair 2008), very little is known about the *dynamic* decision processes venture capitalists (VCs) execute in the real world. The importance of dynamic decision processes lies in recognizing that investment decisions in VC take place in complex, rapidly changing, and highly competitive markets where growth and returns are expected to be significantly higher (e.g. in some high technology industries). The fact that a new venture passes the evaluation of a VC firm does not mean that the VC firm will make the deal. There are mutual interactions between the decision process and the resource environment of the VC firm that directly affect the VC firm performance.

To the best of this author's knowledge, the present study is the first to i) identify key variables, feedbacks, time delays and behavioral motivations within the VC investment process, ii) to put these components in a system dynamics model of investment strategies and, iii), to propose different scenarios of the pace of VC investment that help us better understand the sources of the system behavior. The results of the computer simulations on the system dynamics model provide two key insights. i) the boom-and-bust dynamics is influenced by the investment horizon, longer-term strategies attenuate the problematic system behavior while short-term strategies accentuate it; and, ii) faster investment decisions create a trade-off between the short and long-term performance of the VC industry.

Literature review

Venture capital boom-and-bust

The boom-and-bust phenomenon is defined as a sudden and significant rise and decline of investments in capital markets (Kindleberger 1978). Recent work has addressed this phenomenon over and over (e.g., Strickland 2021 or García, 2022). Its causes are far from clear. Kindleberger (1978) presents examples of famous price bubbles and distinguishes, systematically speaking, several phases of a bubble: The boom typically starts with a "displacement", a macroeconomic shock (e.g. a new technology, deregulation of an industry), that creates new profit opportunities. In a next step, bank credits feed the boom. At this stage, Kindleberger explains that the financial system often spawns *new* forms of money. This is known as the elasticity of credit, and it facilitates borrowing and speculation. As the cycle churns on, the urge to speculate in e.g. tulips (Dash 2000), sovereign bonds, structured products etc. drives prices higher, and the velocity of money (rate at which money changes hands) expands. This is typical of a *boom* phase – easy credit and the increased wealth that accompanies soaring asset valuations feed a sense of euphoria and the perception that asset values will increase indefinitely, forming a positive (i.e. self-reinforcing) feedback loop. Eventually, at some stage when it comes to overtrading and gearing, a rush for liquidity sets in, culminating in a sudden collapse (crash).

One possible cause of bubbles is excessive monetary liquidity in the financial system (Allen & Gale 2007). In the context of the VC boom-and-bust pattern, previous research suggests that the two critical elements for understanding shifts in VC fund-raising are straightforward and taken from the foundations of macroeconomics: a demand curve and a supply curve (Lerner 2002). Lerner (2002) finds that the quantity of VC raised and the returns it enjoys often do not adjust quickly and smoothly to the changes in supply and demand curves. The often quite slow and uneven adjustment process can lead to substantial and persistent imbalances. Specifically, once the markets do adjust to the changing market conditions, they frequently go too far; shifts are often too large, leading to over- and under-investment.

There are also researchers analyzing the apparent deviation from rationality of VCs and structure the analysis around behavioral finance arguments (Wheale & Amin 2003). Another related explanation of the VC boom-and-bust pattern lies in herd behavior, the fact that investors tend to buy or sell in the direction of the market trend (e.g. Stein 2001). It is also argued that the boom-and-bust can result from aggressive growth strategies (Oliva et al. 2003). Other approaches focus on young VC firms that have incentives to "grandstand" (Gompers 1996); or on the fact that VC groups often finance new enterprises in which policies, products, and markets are chosen in such a way that they predetermine failure (Forrester 1992).

In summary, four lessons are learned from reviewing the literature on VC decision-making and VC boom-and-bust.

1. Agents / investors / VC firms are not fully rational decision-makers (in particular, limitations concern information processing and computing abilities)
2. VC research has focused on determinants of decisions and less on the linkages between decisions and resources
3. Little is known about how the performance of the VC industry develops over time

4. Boom-and-Bust is driven by the imbalance in investors' supply of capital and actual demand and results from positive feedback investment strategies – buy when prices rise and sell when prices fall (cf. Bradford et al. 1990).

Geographical breakdown

In this piece of work, the geographical unit of analysis is the VC industry in Singapore. Since the private equity industry as a whole is geographically concentrated primarily in two countries, the United States and the United Kingdom, the question of why private equity firms based in Singapore are chosen and not in the US/UK needs to be addressed. As a literature review would show (cf. Kästli 2011, chapter 3), extensive research has been conducted on private equity from a North American and Western European perspective, but studies of other geographical markets and contexts are limited. It is, therefore, very important to contribute to the understanding of the investment process and investment strategy of private equity (and VC) investments in the Southeast Asian context where (in good times or bad) Singapore has had the lead over its neighbors in the region (Kästli 2011). Moreover, what makes Singapore particularly interesting from a venture capitalist's point of view is, for example, that in this case the regulatory environment created by the government and its agencies has led to a decrease in agency costs and to a greater development of high-technology start-ups than elsewhere in Asia (Bruton et al. 2002).

Hence, a case study on VC investment dynamics based on the Singapore VC boom-and-bust (see e.g. figure 1) would be desirable in order to address, for instance, the research question of what the reasons for the rise and decline of VC investment in Singapore during 2004-2009 are. However, the research framework of this paper only allows to construct an initial form of a system dynamics model, a skeleton model (see 2.3), which is able to take into account specific characteristics of a Singaporean setting only to a very limited degree. This limitation is not avoidable for mainly two reasons: First, starting from scratch (given the large research gap of applying the theoretical perspective of system dynamics to *dynamic* VC decision processes) only a provisional and qualitative model can be developed in this context that is, in turn, only derived from a review of the relevant literature (where scant attention has been paid to Southeast Asia and Singapore, Kästli 2011). Second, for developing a geographically specific, a more exact/reliable, or quantitative system dynamics model, structured-interviews, workshops and discussions with entrepreneurs, VCs, institutional investors, scholars etc., in short, qualitative data for the specification of the initial systems model and numerical data to test and calibrate the model would have been necessary but is in fact not available.

Some basics on system dynamics

The present study aims at investigating how VC investment develops over time and the interaction between the decision and resource environments of VCs. The decision environment, on the one hand, refers to the decision variables used by investors when looking for profit opportunities. The resource environment, on the other hand, refers to the available resources that firms look at, make use of, or dispose of, when making an investment. The relationships between the decision and resource environments are crucial to explain the dynamics of growth and change in the VC industry. Understanding these relationships and designing a structure through which to examine them is the ambitious endeavor of this study. This structure will be created by drawing on the methods of system dynamics; methods which will be summarized very briefly in the following.

Methods

System dynamics (SD) is a computer simulation and modeling methodology that is used to analyze complex (feedback) systems and to come up with policies that improve their performance (Forrester 1991, Sterman 2001). System dynamics was developed by Jay W. Forrester in the 1950s at the M.I.T. in order to understand and deal with the dynamic behavior of corporations as corporate systems (Forrester 1958). The origins of the methodology relate to complexity science, in general, and to organizational and management cybernetics, in particular. System dynamics sets itself apart on the grounds of endogenous and nonlinear behavior (Richardson 1991, Sterman 2002). Specifically, it draws on nonlinear endogenous feedback structures with delays (Sterman 2000). The dominance of different feedback loops constantly alters the behavior of a nonlinear system over time (Radzicki 2005). System dynamics has many strengths including the ease of calculation, the dynamic behavior, the transparency of the model structure, the visibility of the model outputs and the applicability to almost any field of science.

Results

System dynamics models

Modeling in system dynamics is about "constructing models as continuous feedback systems" (Schwaninger & Grösser 2008). It is an iterative process of structure identification, mapping, and simulation in order to explain and reproduce system behavior and to test actions/policies. Such a model is supposed to grasp the functional linkage among the variables of a system, to formalize them and to make them transparent. Models are supposed to generate "the right output for the right reasons" (Barlas 1996). Good system dynamics modeling heavily contributes to falsifiability as each relation between variables can be evaluated on both logical and empirical grounds (Schwaninger & Grösser 2008) which makes this scientifically well-grounded approach very attractive.

The main structure of system dynamics models consists of stocks, flows and feedback loops (Radzicki, 2005). The major steps involved in system dynamics modeling are (a) problem identification, (b) conceptualization of a causal loop diagram, (c) construction of a formal stock-and-flow model, (d) model analysis and validation, (e) policy design, analysis and implementation (Barlas 1996).

Here, only an initial form of a system dynamics model is developed; that is, a model that combines a first (and necessarily incomplete) causal loop diagram with a stock and flow chart. From a theoretical point of view, the goal is to provide an endogenous explanation of the reference mode behaviour (Oliva 2003), which is a graph of variables the dynamics of which are not fully understood.

System dynamics and vc boom-and-bust patterns

Valuable prior work on the application of system dynamics to the boom-and-bust behavior in dynamic markets (but not in the special context of VC boom-and-bust patterns) was done by Paich & Sterman (1993). Moreover, Oliva et al. (2003) provided a study on model calibration as a testing strategy for system dynamics models and Yepez (2004) presented an initial but still very incomplete systems model for analyzing VC investment dynamics in the Ottawa technology cluster. Building on their analyses, our more detailed conceptual framework can be defined as follows: First, it is important to see that, in order to characterize the phenomenon of boom-and-bust behavior in VC, certain assumptions and limitations are necessary.

Figure 2 presents the scope of the model (which will be introduced in the next section), called SDVC model from now on, by listing which key variables of the system of VC investment processes are included endogenously, which are exogenous, and which are excluded from the model.

Table 1. Model boundary chart

Endogenous	Exogenous	Excluded
VCs investing in a deal	Initial VC population	Start-up population
Portfolio companies	Potential Buyers population	Net income per company
Funds	Initial funds	Market share
Winners		Risk premium
Losers		Supply/demand curves
Survivors		Incumbents
Buyers		Bootstrapped start-ups
Potential Buyers		Stock market
Valuations		IPO market
Spending		GDP
Fundraising		Growth rates
Proceeds		…
Returns		

When considering this list of boundary conditions, it makes sense to highlight that the SDVC will not model the Initial Public Offering (IPO) and public markets. Admittedly, both markets may also be significant to determine whether or not, to explain why, VC investment goes through a boom-and-bust. However, modeling these dynamics would have introduced a great degree of complexity in the modeling process that would have made the analysis much more difficult to carry out, given the available time and resources to complete this paper. Furthermore, it has been argued throughout the literature on general systems theory and cybernetics that the purpose of modeling can be achieved by focusing the attention on a smaller piece of the complex system under consideration. Here this piece lies in recognizing the behavior of market participants within the VC industry.

Apart from that, the SDVC model is based on some key assumptions, including the following:

- Homogeneity of market participants, i.e. decision rules are the same for agents that belong to the same basic subsystem / group (i.e. LPs, GPs, Entrepreneurs and Buyers; see below)
- There is a single fund-of-funds shared by all venture capitalists (VCs)
- Buyers enter the acquisition market gradually, following a diffusion of innovations type of pattern (Rogers 2003)
- Risk-free rate investments
- Fixed ownership per firm
- Competition as the single mechanism for the price formation process

At this point, it is important to note that the boundary conditions and assumptions on which this conceptual framework here is based can affect the degree of the impact and robustness of the insights that can be derived from the SDVC model and simulation. In particular, the exclusion of the stock and IPO markets, the absence of quantitative and sufficiently qualitative data on historical (Singapore-related) VC metrics (e.g. funds, investments, financing rounds, information lags), and the assumption of agent homogeneity are constraints that make it more difficult for the model to enhance our understanding of the VC system.

Finally, the structure of the system which will be analyzed by means of the SDVC model helps explore how the interaction of locally rational market participants may lead to undesired fluctuations in the VC industry as a whole. This system, i.e. the VC environment, consists of four basic subsystems (Smith & Smith 2000).

- *General Partners (GPs)* are the venture capitalists (VCs). They manage the VC 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 up to a certain point in time. Then they sell them via an IPO or via another exit strategy. GPs' main activities in the management of portfolio companies include (Smith & Smith 2000):
  - Board service
  - Recruitment of management team
  - Assistance with external relationships (e.g. customers, suppliers)
  - Arrangement of additional financing
- *Limited Partners (LPs)* are institutional investors (e.g. pension funds) or rich individuals providing the majority of the VC fund's equity capital (Kaplan & Strömberg 2008, p. 4). LPs invest their money for a fixed period of time (e.g. a 10-year lifetime of the fund). Then the capital is returned to them. They are not involved in the management of the fund.
- *Buyers* represent 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). This subsystem provides an information source affecting many market participants' decisions.
- *Entrepreneurs* represent the pool of start-up companies creating new products and solutions within the specific market sector.

The links between these market participants in the system can be depicted as follows in Figure 3:

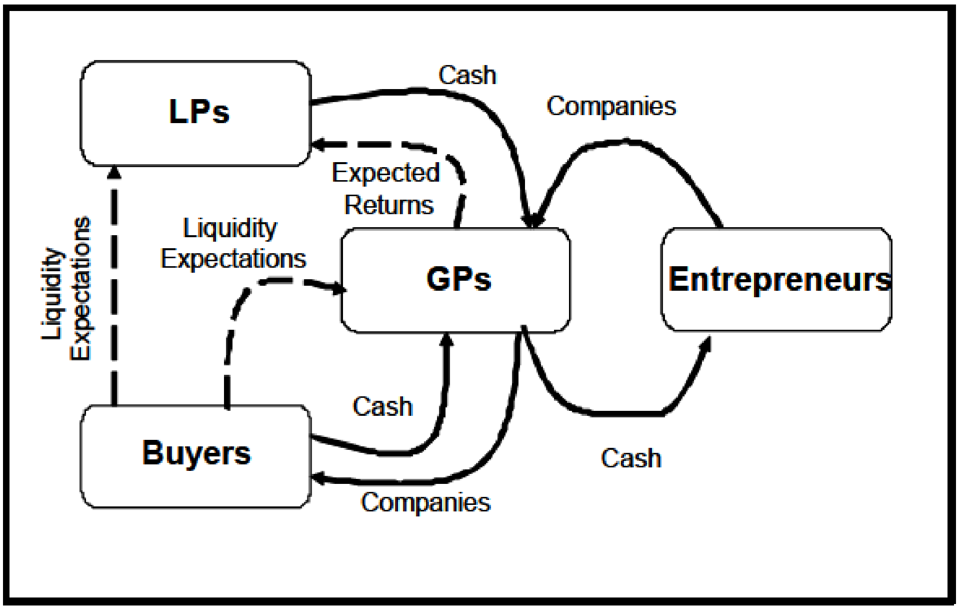

Figure 2. Agents in the VC market. Yepez (2004)

Three premises on the behavior of the market participants form the foundations of the SDVC model. First, investor behavior is motivated by the maximization of shareholder value. Second, market participants are boundedly rational (Simon 1979). In other words, LPs' and GPs' decisions are led by simple and readily available information. Third, market participants have "misperceptions of feedback" (Sterman 1989) which means that LPs, GPs etc. fail to adequately account for feedbacks and time lags in their decision processes (e.g. funding allocation is driven by LPs' expectation of realizing the returns they are observing "right now").

A system dynamics model of venture capital investment

This section presents a systems model on the dynamics of VC investment. Discovering and representing the feedback processes, arising from the structure of the system itself, suggests that an endogenous explanation for the phenomenon of the boom-and-bust behavior in VC can be given. The fundamental feedback and stock-and-flow structure for explaining the boom-and-bust phenomenon in VC is identified, mapped and illustrated in Figure 4.

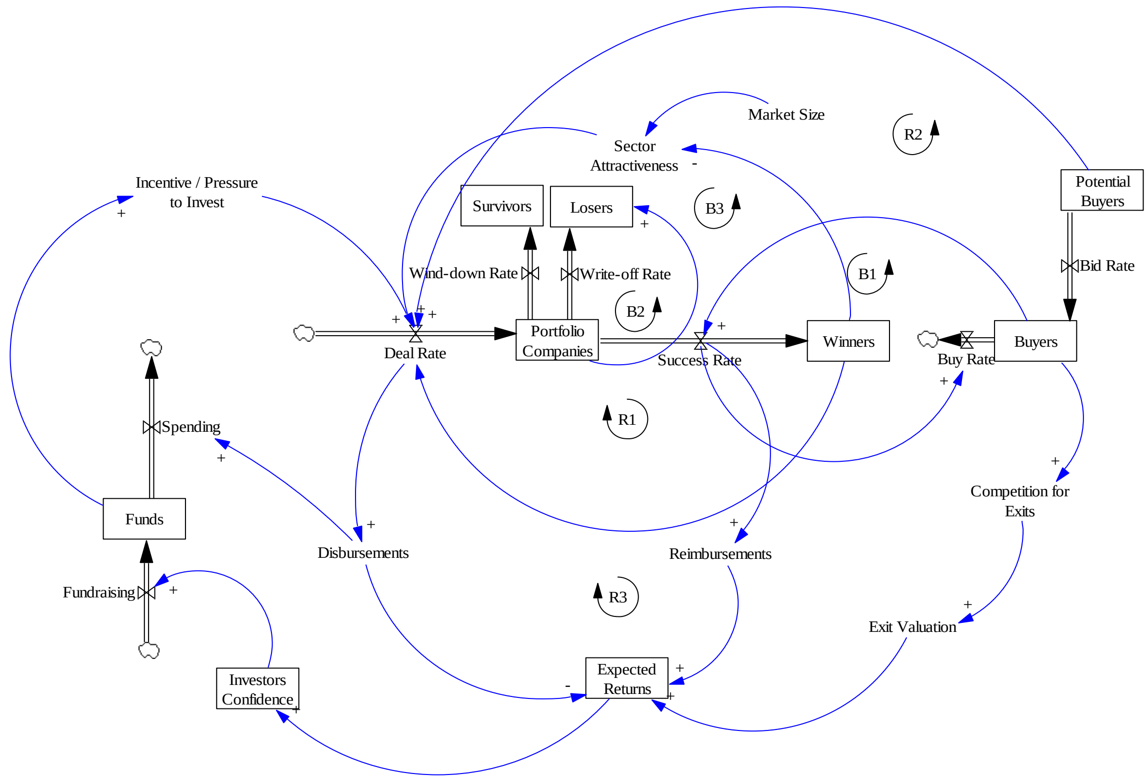

Figure 3. Dynamic Hypothesis, the SDVC model

How does the model work? The arrows indicate the causal relationships. The + signs at the arrowheads indicate that the effect is positively related to the cause: e.g. an increase in the investors' confidence causes the fundraising to rise above what it would have been (and vice versa). This loop is self-reinforcing, hence the loop polarity identifier R. It is called a positive feedback loop. The B in the center of a loop denotes balancing feedback, a negative feedback loop which is self-correcting. All systems, no matter how complex, consist of networks of positive and negative feedbacks, and all dynamics arise from the interaction of these loops with one another. Along with feedback, the other central concept of dynamic systems theory is stocks-and-flows. Stocks are accumulations. They characterize the state of the system and generate the information upon which decisions and actions are based. Stocks give systems inertia, provide them with memory and create delays by accumulating the difference between the inflow to a process and its outflow. Stocks are represented by rectangles (suggesting a container holding the contents of the stock). Stocks are altered by inflows and outflows: Funds are increased by fundraising and decreased by spending. Inflows are represented by a pipe (arrow) pointing into (adding to) the stock. Outflows are represented by pipes pointing out of (subtracting from) the stock. Valves control the flows. Clouds represent the sources and sinks for the flows: A source represents the stock from which a flow originating outside the boundary of the model arises; sinks represent the stocks into which flows leaving the model boundary drain. Sources and sinks are assumed to have infinite capacity and can never constrain the flows they support.

How does boom and bust emerge in the VC environment? To answer these key questions, it is helpful to discuss some different loops within the SDVC model separately.

1. *Loops R1 and R2: The deal-making loops.* The demand for Portfolio Companies depends on the existence of a 'hot market' for new products in a particular (e.g. technology) sector as market participants are interested in new, big or rapidly growing markets where they expect promising exit opportunities for the Portfolio Companies. The greater the number of Potential Buyers scouting for interesting companies in the sector, the higher the number of acquisitions of Portfolio Companies (ceteris paribus, (loop *R2*). As Portfolio Companies mature, some of them will exit as successes (Winners) while others (i.e. non-performing portfolio companies) will exit as failures (Losers, Survivors). When the number of successful exits increases (e.g. via IPO, trade sale or buyout), so does the number of new investments in the particular industry. The greater number of investments leads to a higher deal rate, consequently, to an increase of Portfolio Companies and to still further successful exits in a reinforcing loop (loop *R1*). On average, it takes quite a long time (2-5 years) for Portfolio Companies to be ready for an exit (Kaplan & Strömberg 2008).
2. *Loop R3: The fundraising loop.* On the supply side, the higher success rate boosts exit valuations of Portfolio Companies and, hence, the profitability of existing VC funds. When successful exits are increasing, returns from VC funds are expected to be higher and VCs can raise funds more easily because fundraising is positively linked to investors' confidence in VC and investors' confidence, in turn, is based on the assumption that LPs aspire after profit maximization. Higher expected returns in the sector attract new VCs, who compete to finance new start-ups and young companies, thereby driving the price of deal valuations up. The more funds are available, the higher the pressure on VCs to put that money to work. VCs relieve that pressure either by increasing the number

of deals they make, by increasing the size of their investments, or both. VCs have no shortage of funding since investors are eager to realize the high returns expected from VC funds.

3. *Loops B1, B2 and B3: The market saturation loops*. Many new investments are made, swelling the supply line of Portfolio Companies. After some time, the stock of Winners, which is increased by the success rate, reaches its carrying capacity at some point. The finite market size determines the total number of Winners that can compete profitably in the particular sector. The higher the number of Winners competing in the market sector, the less the sector is attractive to investors, resulting in a reduced VC investment activity (loop *B3*). Apart from that, there are no more Buyers to make acquisitions in the particular industry (loop *B1*). Consequently, the price of exit valuations falls, and successful exits in the sector decline or even stop, dragging down returns of VC funds. As returns in the sector diminish, so do fundraising and deal-making. Self-correcting negative loops then dominate and start governing system behavior, attempting to control for non-performing Portfolio Companies through other liquidity events (loop *B2*).

System dynamics simulation and scenario analysis

This section shows and discusses the simulation results of running the SDVC model. First, the base run of the model is described, which is used as a "benchmark" in order to compare the results of subsequent simulations. This scenario analysis in the second part includes the design and simulation of four investment strategies differing in their pace of investment. The scenarios are analyzed and compared to the "benchmark" on the basis of several criteria commonly used in the VC industry (e.g. Yepez 2004). Finally, the results obtained from the simulations of the SDVC model are discussed.

Base run

The base model is calibrated with average VC industry values (Yepez 2004 and Kaplan & Strömberg 2008), which appear to be appropriate for a Singaporean setting (Kästli 2011), and with best estimates for several key parameters (e.g. key delays). Values of other parameters, such as average exit valuation, the population of market participants, etc., are fictitious and are chosen with the sole purpose of providing a "benchmark" model of a virtual VC industry.

A summary of the key parameter values of the SDVC model is shown in Figure 5.

- nm) add up to a number which corresponds to half of the highest observed value (10 firms)
- High long-term (i.e., more than 5 years) returns (90%) for the industry as a whole

Ad 2) *Sector Speculators* – Bottom line: Faster is not better

- Collapse of the system: the fastest rise and fall in investment and liquidity activities; this scenario produces the highest investment peak (as measured by the number of portfolio companies), a number which is more than twice as high as the one in the benchmark
- Short and sharp rise and fall for both pre-money and exit valuations
- Break-even by year 1, which corresponds to the least amount of time, one year ahead of the benchmark
- Successful exits reach the optimum level in year 3
- Short-term returns peak at 85% in year 2, but still lower than the benchmark
- Low long-term returns (12%) for the industry as a whole

Ad 3) *Company Creators* – Bottom line: Great for few, terrible for most

- System collapse: peaks of investment and liquidation activity are both lower and more delayed compared to the previous extreme-case scenario (Sector Speculators)
- Highest peaks in pre-money valuations
- Second shortest rise-and-decline trend in exit valuations
- Break-even by month 14
- Successful exits reach the optimum level in year 4
- Highest peak of short-term returns with returns in excess of 130% in year 3
- Lowest long-term returns (0%) for the industry as a whole

Ad 4) *Diversified Investors* – Bottom line: Lucky strike

- No collapse of the system: deal-making and liquidity activities remain at low levels
- Pre-money valuations develop most poorly
- High and ongoing trend in exit valuations
- Break-even by year 3, one year later than in the benchmark
- Successful exits add up to a number which corresponds to 60% of the optimum value
- Short-term returns are slightly superior to those in the Focused Investors scenario
- High long-term returns (90%), similar to Focused Investors scenario

These observations can be summarized as follows:

Table 2. Summary of the results for scenarios with different investment horizon

	Portfolio Companies	Exit Distribution			Returns		
		Winners	Losers	Survivors	Break-even	Short-term	Long-term
Base							
Peak value	9 firms	23%	50%	27%	–	100%	30%
Peak time (month)	80	72	108	108	24	60	120
Focused Investors							
Peak value	2 firms	22%	52%	26%	–	10%	90%
Peak time (month)	2	240	240	240	48	60	240
Sector Speculators							
Peak value	20 firms	20%	53%	27%	–	85%	15%
Peak time (month)	30	30	72	72	12	24	120 (84)
Company Creators							
Peak value	15 firms	20%	53%	27%	–	125%	0%
Peak time (month)	48	48	108	108	14	36	–
Diversified Investors							
Peak value	3 firms	24%	52%	24%	–	35%	90%
Peak time (month)	6	240	240	240	36	60	120 (108)[18]

Discussion

The overall simulation results suggest that the impact of investment strategies with different investment horizons on the performance and the stability of the VC industry is twofold. First, the pace of investment may exacerbate or attenuate the boom-and-bust dynamics of VC investment. Second, it may influence the short and long-term returns performance of the overall VC industry.

The most salient findings include:

- Considering aggressive investment strategies (Sector Speculators and Company Creators) is sufficient to explain how and why the boom-and-bust phenomenon is produced endogenously. The reason for this is found in strong positive feedback between the pace at which companies are exited successfully and the pace at which new deals are made. The pool of Winners has limited capacity set by the finite number of buyers of portfolio companies.
- *Faster is not always better*: Although aggressive exit strategies are beneficial for some few VCs achieving high returns in the short run, long-term VC industry performance is poor and lower compared to the benchmark.
- Spending more does not necessarily imply investing smarter. Aggressive investors spend and receive the most money on absolute values (see charts on Commitments and Proceeds in the Appendix). However, they do not have sustainable success.
- Valuations, both pre-money and exit, rise and decline sharply and quickly due to the high competition produced by aggressive investment strategies.
- Company Creators cause the highest rise and fall in pre-money values. This result appears to be counter-intuitive since these investors do not generate the highest peak in investment activity (e.g. see number of Portfolio Companies). If a closer look into the stock-and-flow structure of the VC system is taken, it can be shown that while they take longer to make a deal, the accumulation process of 'VCs looking for a deal' is such that it causes valuation prices to increase more than in the other scenarios.
- *Passive* investment strategies tend to maintain the VC system in dynamic equilibrium; however,
- *Slower is not good either:* Passive exit strategies take too long to achieve desired returns.

Consistent with theoretical arguments developed in Kindleberger (1978), Lerner (2002), Allen & Gale (2007) etc. in the realm of boom-and-bust cycles and VC boom-and-bust, respectively, it was argued that this phenomenon is driven by the unbalance in investors' supply of capital and actual demand and that this phenomenon is generated by positive and negative feedback processes. Building on the approaches by Paich & Sterman (1993), Oliva et al. (2003) and Yepez (2004), in particular, this paper offered several novel contributions to the academic literature and management research by identifying and tackling a large research gap on the *dynamics* of VC investment strategies during times of boom and bust.

Despite the amount of research done on VC decision-making (e.g. Blair 2008), very little is known about the *dynamic* decision processes VCs execute in the real world. The importance of dynamic decision processes lies in recognizing that investment decisions in VC take place in complex, rapidly changing, and highly competitive markets where growth and returns are expected to be significantly higher. The fact that a new venture passes the evaluation of a VC firm does not mean that the VC firm will make the deal. There are mutual interactions between the decision process and the resource environment of the VC firm that directly affect its performance.

Moreover, the present study is the first to i) identify key variables, feedbacks, time delays and behavioral motivations within the VC investment process, ii) to put these components in a system dynamics model of investment strategies and, iii), to propose different scenarios of the pace of VC investment that help us better understand the sources of the system behavior.

Finally, the results of the computer simulations of the system dynamics model suggest that aggressive investment strategies might not be successful in the long run ("Faster is not always better") which is also reflected to some degree in the broader literature on private equity firms' business model where a trend towards longer-term strategies and longer time horizons has been observed (cf. e.g. Gottschalg 2007).

As Kästli (2011) highlights, contributions to the understanding of the investment process and investment strategy of VC investments in the Southeast Asian and Singaporean context are needed. Extensive research has been conducted on private equity in general and on VC returns, in particular, from a North American and Western European perspective; however, studies of other geographical markets and contexts are limited.

Asia has been the fastest growing economic region for the last 15 years (Credit Suisse 2013) and is expected to remain so in the years to come (Thomann 2010). But despite the growing impact of VC in Southeast Asia, academic research on VC in this region has not kept pace with the rapid changes in the market (Lerner & Gurung 2008). Today, it is still not fully clear whether governance, regulatory systems, operational infrastructure and other important variables specific for Singapore and its VC industry create obstacles or opportunities for VC investments in the markets (Lerner et al. 2009). In particular, the importance of VC both as an investment vehicle and as a catalyst for economic growth (Bruton et al. 2004, Gurung & Lerner 2009, Achleitner & Klöckner, 2005) and its potential for future growth (Kaplan 1989, A.T. Kearney 2012) underlines the need for an academic assessment and a fuller understanding of VC in the Southeast Asian context, requiring fundamental investigation in order to feed the SDVC model.

It would indeed be very instructive to apply the SDVC model to the Singaporean context mainly for two reasons. First, to adapt the SDVC model to the VC industry in Singapore would be a promising approach to address the research gaps identified by Kästli (2011) and others. Specifically, the system dynamics modeling and simulation approach would be appropriate because it could incorporate special features (i.e. variables) like the regulatory environment created by the Singaporean government (which has led to a decrease in agency costs and to a greater development of high-technology start-ups, Bruton et al. 2002) and combine them with the structure and characteristics of the more general SDVC model. This would offer a chance to challenge the universality of Western assumptions about both investment practices and investment strategies, which is a necessity for Western managers to seize opportunities, and ensure future success, both in Singapore and the rest of the world (Lasserre & Schütte 2006). And second, the simulation results gained on the basis of running the SDVC model are already very relevant for studying VC firms in Singapore. On the one hand, the phenomenon of boom-and-bust is well-known in the region (see, for example, Figure 1 or think of the 1997-98 Asian financial crisis). On the other hand, insights about the impact of the pace of investment on VC industry performance are very interesting for the Singaporean context since a change from rushing into VC deals (Varma 2010, Zhang 2002) to longer-term strategies has been observed (Kästli 2011).

Conclusion

The objective of this paper was to create and simulate a model of VC investment dynamics. The model captures how the boom-and-bust phenomenon may be generated by the economic agents' intendedly rational decisions within a competitive VC market, that leads to unintended poor performance for the industry as a whole. A computer simulation model was developed using data gained from an extensive literature review. Unfortunately, special attention could not be paid to Singaporean VC firms due to a lack of data available.

This final part of the present study is arranged in five subsections. First, the key findings are summarized. Second, answers to the research questions raised in the introduction are suggested. Third, the conclusions are drawn from the previous analysis in such a way that the contribution of this paper to the literature is identified. Fourth, the question of to what extent the analysis conducted here can be fruitfully applied to a Singaporean setting will be addressed. And finally, limitations of this research project and lines of productive future inquiries are outlined.

With regard to the modeling efforts three lessons are derived, in particular. In order to explore the causes and interrelationships underlying the rise and decline in VC, one should focus on three key feedback processes:

- On the one hand, evidence proposes that there is a strong positive feedback loop linking liquidity activities and deal-making (*R1*): The higher the number of successful exits (i.e. Winners) in a sector, the higher the number of new deals and investments in the sector.
- On the other hand, two negative feedback processes are crucial. *B1* is a balancing feedback that influences the number of successful exits in a given market sector and controls it at some stage. This can be traced back to the fact that the number of buyers of companies in the sector is limited. As the number of successful exits rises, the number of buyers of portfolio companies decreases. The other dominant negative feedback is *B2* which can be regarded as a natural control mechanism for underperforming deals that dominates the system when there are no more successful exits.
- Other feedback loops: Next steps on the modeling agenda would include tools for helping communicate the logic and expressiveness of the SDVC model. In this context, *subsystem diagrams* (Sterman 2000) should be mentioned. A subsystem diagram shows the overall architecture of a model and conveys information on the boundary and level of aggregation in the model by demonstrating the number and type of different units or elements represented. Apart from Figure 4, the following specification of a subsystem (among others) of the system visualized by the SDVC model would be an example of such a subsystem diagram that sheds some more light on the role of other feedback loops within the SDVC model.

This underlines the fact that all models, mental or formal, are wrong. All models are limited, simplified representations of the real world. They differ from reality in ways large and small, infinite in number. Therefore, good modelers seek multiple points of contact between the model and reality by drawing on many sources of data and a wide range of possibilities of modeling and model testing. See also below. Data on these special features could be collected by consulting experts for the Singaporean VC industry (i.e. in terms of interviews, workshops and discussions with entrepreneurs, VCs, institutional investors, scholars etc.). It may be argued though that such numerical data may not be available for public scrutiny, due to its confidential nature. Part of testing, of course, is comparing the simulated behavior of the model to the actual behavior of the system. However, testing involves far more than the replication of historical behavior. Every variable must correspond to a meaningful concept in the real world and models must be tested under extreme conditions, conditions that may never have been observed in the real world.

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References

Achleitner, A.K., & Klöckner, O. (2005). Employment Contribution of Private Equity and Venture Capital in Europe. EVCA Research Paper.

Allen, F., & Gale, D. (2007): Understanding Financial Crises, Oxford: Oxford University Press.

Asia Venture Capital Journal (AVCJ) (2009). Private Equity and Venture Capital Report 2009. Southeast Asia. Fourth Edition.

Bain & Company (2010). Global Private Equity Report 2010.

Barlas, Y. (1996). Formal aspects of model validity and validation in system dynamics. System dynamics review 12(3):183–210.

Blair, E.S. (2008). Venture Capitalist Decision Making and the Priming of the Subconscious Risk Construct in Entrepreneurial Business Plans. Ann Arbor, MI: ProQuest.

Bradford de Long, J., Shleifer, A., Summers, L.H., & Waldmann, R.J. (1990). Positive Feedback Investment Strategies and Destabilizing Rational Speculation. The Journal of Finance 45 (2), 379-395.

Bruton, G.D., Ahlstrom, D., & Yeh, K.S. (2004). Understanding venture capital in East Asia: The impact of institutions on the industry today and tomorrow. Journal of World Business, 39, 72-88.

Bruton, G.D., Ahlstrom, D., & Singh, K. (2002). The Impact of the Institutional Environment on the Venture Capital Industry in Singapore. Venture Capital 4, 197-218.

Credit Suisse (2013). La consommation asiatique donne Des ailes à la croissance.

Cyert, R.M., & March, J.G. (1963). A behavioral theory of the firm. Cambridge, MA: Blackwell Business.

Dash, M. (2000). Tulipomania: The Story of the World's Most Coveted Flower & the Extraordinary Passions It Aroused. New York City: Crown.

Ernst, D., & Häcker, J. (2007). Applied International Corporate Finance, München: Vahlen.

European Private Equity and Venture Capital Association (EVCA) (1998). EVCA Yearbook 1998: A Survey of Private Equity & Venture Capital in Europe, Zaventem, Belgium, EVCA.

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

Forrester, J.W. (1991). System dynamics and the lessons of 35 years. Greene, K.B. (ed.). A Systems-Based Approach to Policymaking, New York: Springer, 199-240.

Forrester, J.W. (1958). Industrial dynamics: A major breakthrough for decision makers. Harvard Business Review, 36(4):37–66.

Fraser-Sampson, G. (2006). Private Equity. In Multi-Asset Class Investment (pp. 155-180). John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Susses, England.

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

García, D.I. (2022). Second-home buying and the housing boom and bust. Real Estate Economics, 50 (1), 33-58.

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

Gottschalg, O. (2007). Private Equity and Leveraged Buy-outs. Study. European Parliament: Policy Department. http://www.peracs.de/report/GottschalgReportEU.pdf.

Gurung, A., & Lerner, J. (2009). The Globalization of Alternative Investments Working Papers, Volume 2: The Global Economic Impact of Private Equity Report 2009, World Economic Forum, vii-ix.

Kaplan, S. N. & Strömberg, P. (2008). Leveraged Buyouts and Private Equity. Working Paper. National Bureau of Economic Research [NBER]. http://www.nber.org/ papers/w14207.

Kaplan, S.N. (1989). The Effects of Management Buyouts on Operating Performance and Value. Journal of Financial Economics 24(2), 217-254.

Karney, A.T. (2012). Creating New Jobs and Value with Private Equity. Chicago, A.T. Kearney.

Kästli, R. (2011). Private Equity in Southeast Asia: A Comparative Analysis of Private Equity Returns in the Context of the Investment Process and Investment Strategy. Bern: Stämpfli Publikationen AG.

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

Lasserre, P., & Schütte, H. (2006). Strategies for Asia Pacific. New York: Palgrave MacMillan.

Lerner, J., Sorensen M., & Strömberg, P. (2009). What Drives Private Equity Activity and Success Globally. In The Globalization of Alternative Investments Working Papers, Volume 2: The Global Economic Impact of Private Equity Report 2009, World Economic Forum, 65-98.

Lerner, J., & Gurung, A. (2008). The Globalization of Alternative Investments. Working Papers, Volume 1: The Global Economic Impact of Private Equity Report 2008, World Economic Forum, vii.

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.

Oliva, R. (2003). Model calibration as a testing strategy for system dynamics models. European Journal of Operational Research 151(3), 552–568.

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

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

Radzicki, M. (2005). Institutional economics, post Keynesian economics, and system dynamics: Three strands of a heterodox economics braid. Economics (ICAPE), 5-7.

Richardson, G. (1991). System dynamics: simulation for policy analysis from a feedback perspective. In Qualitative simulation modeling and analysis, pages 144–169. New York: Springer.

Rogers, E.M. (2003). Diffusion of innovations. New York: Free Press.

Schwaninger, M., & Grösser, S. (2008). System dynamics as model-based theory building. Systems Research and Behavioral Science 25(4), 447–465.

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

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

Smith, R., & Smith, J. (2000). Entrepreneurial Finance. New York: Wiley Text Books.

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

Sterman, J. (2002). All models are wrong: reflections on becoming a systems scientist. System Dynamics Review 18(4), 501–531.

Sterman, J. (2001). System dynamics modeling: tools for learning in a complex world. California Management Review 43(4), 8–25.

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

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

Strickland, E. (2021). The Turbulent Past and Uncertain Future of AI: Is there a way out of AI's boom-and-bust cycle?. IEEE Spectrum, 58(10), 26-31.

Thomann, A. (2010, January 18). Asia Remains the Economic Frontrunner in 2010. Credit- Suisse Online Publications. Retrieved January 27, 2010, from http://emagazine.creditsuisse. com/app/article/index.cfm?fuseaction=OpenArticle&aoid=275733&lang=EN.

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

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

Varma, S. (2010). Private Equity in Southeast Asia. Presentation at the INSEAD Campus Singapore, February 23, 2010.

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

Yepez, C. (2004). Venture Capital Investment Dynamics: Modeling the Ottawa Boom-and-Bust. Ottawa: Carleton University Press.

Zhang, T.T. (2002). Managing Risks of Private Equity Investing in China. Journal of Private Equity, Summer 2002, 40-43.