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Path Dependencies in Venture Capital Markets

by

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Abstract

This paper examines the impact of venture capitalists' reputation building and experience accumulation on the genesis of venture capital markets. Venture capitalists must accumulate experience to successfully support high-technology enterprises. They must build reputation, i.e., a track record for successfully financing high-technology enterprises, in order to raise new funds from outside investors that have little information about the profitability of venture capital investments. Simulations are used to solve the model. The simulation results demonstrate that reputation building and experience accumulation lead to path dependencies: if venture capitalists lack experience, successive waves of unsuccessful venture-capital-backed enterprises undermine the genesis of venture capital markets.

Keywords: Reputation building, experience accumulation, dynamic efficiency, path dependencies, venture capital

JEL classification: G24, O16, O41

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1 Introduction

Several empirical studies indicate that venture capitalists need experience to select, monitor and support high-technology enterprises successfully, and that they need reputation in order to raise funds from outside investors. For example, Baker and Gompers (1999) find evidence that the presence of experienced venture capitalists reduces the fraction of insiders on the board. Reducing the fraction of insiders can be interpreted as lowering the power of CEOs who are interested in a high fraction of insiders on the board in order to establish business policies that are beneficial for them. The empirical analysis by Lerner (1994) suggests that experienced venture capitalists are more proficient in timing initial public offerings of the high-technology enterprises than their less experienced counterparts. Moreover, as the study by Gompers (1996) indicates, venture capitalists take care to signal their experience to the market in order to build up reputation: young venture capitalists take their portfolio firms public earlier than older venture capitalists do. The benefit of taking their portfolio firms public earlier, i.e., signalling their experience to outside investors, seems to exceed the costs of doing this, i.e., the greater underpricing of the shares.

The purpose of this paper is to investigate whether venture capitalists' experience accumulation and reputation building can lead to path dependencies in venture capital markets. The impact of venture capitalists' experience accumulation and reputation building on the development of venture capital investments is analysed in a model in which venture capitalists can affect positively the profitability of high-technology enterprises and in which venture capitalists have to raise money from outside investors. These outside investors initially have little information about the profitability of venture capital investments. Because of this asymmetric information, outside investors base their portfolio selection decision on past realisations of returns on venture capital investments and alternative investment opportunities. In addition, they base their portfolio selection decision on venture capitalists' reputation. In order to analyse the impact of reputation building and experience accumulation on the development of venture capital investments, the model will be analysed by means of simulations.

With simulations, trajectories of innovating economies can be determined.[1] Trajectories result from the uncertainty of the innovation process combined with past events that affect the behaviour of agents, i.e., venture capitalists, outside investors and innovators. Innovators have to make discrete choices when introducing a new product or a new process innovation. The venture capitalists also make discrete choices when deciding about investments. However, most important is that the uncertainty of the innovation process is partly a discrete choice process: the technical realization of a high-technology product can either be successful or unsuccessful. Because of this, economic states at a certain point in time can be explained by the trajectories of the past. Thus, different trajectories lead to different economic states and the events in each economic state will affect the trajectory in the future.

The model used to analyse the impact of reputation building and experience accumulation on the development of venture capital markets takes into account some of the systematic interdependencies among outside investors, venture capitalists, banks, innovators, and consumers. Recent literature analysing venture capital markets has also considered some of the systematic interdependencies among the parties involved. For example, Keuschnigg and Nielsen (2001) analyse the relation between general taxes, entrepreneurial investment and venture capital finance within a general equilibrium model. Their model results show that a tax on capital incomes reduces the number of entrepreneurs in equilibrium, while it increases the venture capitalists' incentives to advise the management teams. A tax on wage income causes the opposite effects. Kanniainen and Keuschnigg (2001) analyse a situation in which the demand for venture capital through many high-technology entrepreneurs is high, while the supply of venture capital is low because of a lack in experienced venture capitalists that offer advice. In this situation, venture capitalists demand high returns and have incentives to include many enterprises in their portfolios. With a comparative static analysis, Keuschnigg (2002) examines the effects of several exogenous shocks. A permanent increase in the managerial

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1 For a comprehensive discussion of the simulation method see Gilbert and Troitzsch (1999).

productivity of venture capitalists, for example, magnifies the number of successful innovations in the long-run. However, the literature so far has not addressed the impact of reputation building and experience accumulation on the development of venture capital investments.

The simulation results presented in this paper demonstrate that if the venture capitalists have not yet accumulated experience and if they have not yet built reputation, successive waves of unsuccessful venture-capital-backed enterprises can undermine the genesis of venture capital markets that would ultimately improve welfare. In the case of inexperienced venture capitalists, the probability to realize successive waves of unsuccessful venture-capital-backed enterprises is comparatively high because the venture capitalists lack experience to select the most promising entrepreneurs. If a venture capital market is struck by successive waves of unsuccessful venture-capital-backed enterprises, the venture capitalists without reputation cannot raise new funds from outside investors. And, if inexperienced venture capitalists cannot raise new funds, they cannot accumulate experience necessary to add value to high-technology enterprises. By contrast, if a venture capital market is not struck by successive waves of unsuccessful venture-capital-backed enterprises, venture capitalists can accumulate experience efficiently.

This paper is organized as follows. In the second, third, and fourth section, I describe the basic model, venture capitalists' reputation building, and experience accumulation, respectively. In the fifth section, I present the development of the average venture capital investments of a large number of simulation runs, while in the sixth section, I examine factors causing different developments in venture capital activity. Section seven summarizes the main findings of this paper.

2 Overview of the Basic Model

The basic model comprises two scenarios.[2] In the first scenario, only products are demanded and supplied whose development is risk-less. The development of these *traditional* products can be financed by bank credits. In this scenario, there is no demand for venture capital. In the second scenario, which is depicted in Figure 1, the consumers demand high-technology products in addition to the traditional products (for a detailed description see Schertler 2002). The development of high-technology products is risky. Venture capitalists can reduce these risks through management support and, thus, increase the expected profits of high-technology product developments. In the second scenario, venture capitalists have already accumulated experience to successfully support high-technology enterprises and have already built reputation to raise new funds from outside investors.

In order to produce a traditional or high-technology product, an entrepreneur must make a start-up investment for the development of the respective product. This start-up investment is used for research and development activities if a high-technology product should be developed, and for organizing the business if a traditional product is developed. While the development of traditional products is certain, i.e., the investment results in the development of a traditional product, the development of a high-technology product is uncertain. Thus, in this case, the start-up investment can be lost. The entrepreneur has to raise capital in the financial market because she does not have the means to finance the start-up investment herself. After successfully establishing the enterprise, both traditional and high-technology products are produced using only labour at constant marginal costs. In both scenarios, a homogeneous basic product is

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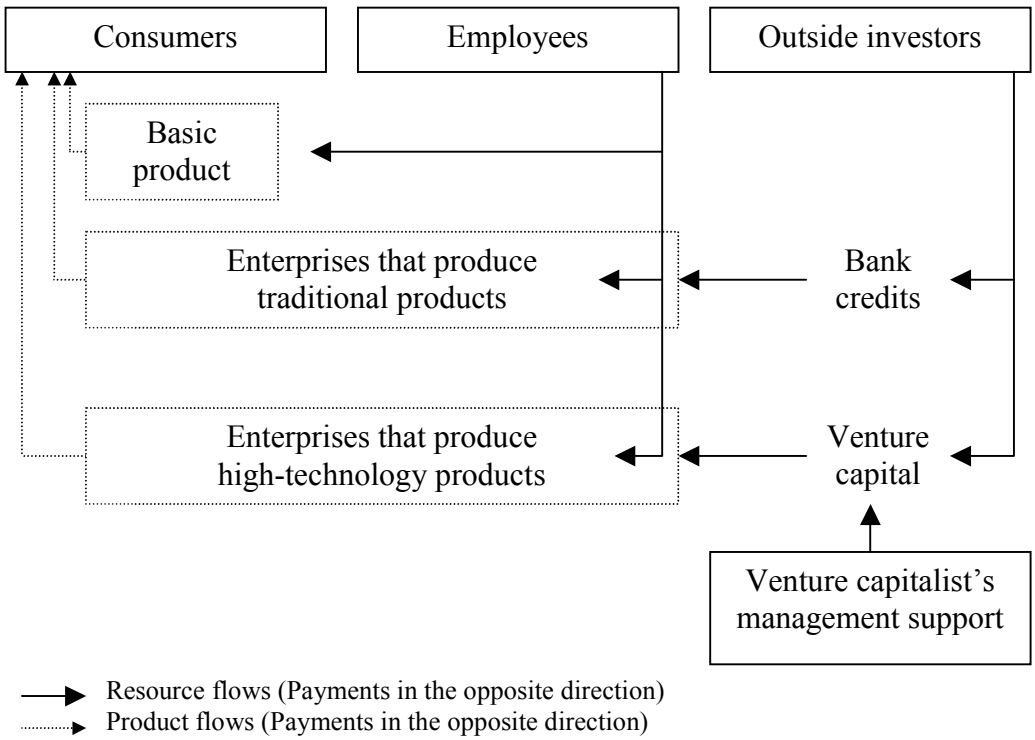
[2] Recent literature analysing generally the development of financial markets also uses this approach. For example, Bencivenga and Smith (1998) focus on the transition from the equilibrium without intermediation to the equilibrium with intermediation in which the services of intermediation are costly. Boyd and Smith (1996, 1998) examine the transition from the equilibrium with banks to the equilibrium with bank and equity markets, while Cooley and Smith (1998) examine the transition between equilibrium without financial markets to the equilibrium in which agents are specialized either as savers or capital investors.

also produced using only labour input to determine the wage rate in the economy.

Figure 1: Overview of the model



The probability of a successful development of high-technology products, which is determined by a random variable realized only after financing decisions have been taken and the start-up investment has been made, depends on venture capitalists' active involvement. Venture capitalists influence the probability of a successful development because they have a comparative advantage in financing high-technology products. This comparative advantage is based on the venture capitalists' stage- and technology-specific knowledge and experience that they need to support the management teams of the high-technology enterprises.

Traditional and high-technology products are supplied under monopolistic competition. In the steady states, free entry leads to zero profits in the market for traditional products and high-technology products: traditional and high-technology products are sold at average costs. The zero-profit conditions are used to determine the number of traditional and high-technology enterprises in the steady state. The number of traditional

enterprises determines the volume of bank credits, while the number of high-technology enterprises determines the maximum volume of venture capital in the steady state.

In each period, the individuals, who own the resources in the economy, maximize their consumption utility that is given by a love of variety function. In the first scenario, the consumption utility function contains only a basic homogeneous product and an aggregate of traditional products. In the second scenario, it contains the basic homogeneous product, an aggregate of traditional products as well as an aggregate of high-technology products. The individuals maximize their consumption utility under the restriction of their budget constraint, i.e., in the optimum their income is equal to their consumption expenditures. In the first scenario, the income is given by wage income because I assume that the risk-less rate of interest is equal to zero. In the second scenario, the income is given by the wage income and capital income because individuals demand, as risk-averse outside investors, a risk premium for capital invested in high-technology enterprises. The consumption expenditures are given by the sum of product quantities multiplied by the respective product prices.

In the steady states of both scenarios, the individuals' income is constant and the saving rate is equal to zero. The story behind this is as follows. The start-up investments are totally sunk after they have been invested, and each enterprise is active for only one period. The enterprises do not have to pay interest but they have to repay the start-up investment, and enterprises producing high-technology products additionally have to pay a risk premium. The risk premium is part of the income and is thus consumed, while the start-up investments are repaid to the risk-averse outside investors. In the next period, the outside investors offer this capital to the next generation of entrepreneurs for start-up investments. Therefore, in the steady states of both scenarios, the individuals' income is constant, and the saving rate of the economy is equal to zero.

Between the steady states of the first and second scenario, venture capitalists have to build reputation to raise new funds from outside investors, and they have to accumulate experience to successfully select, monitor and support high-technology enterprises. Venture capitalists'

reputation building and experience accumulation are to be described in the next sections.

3 Asymmetric Information between Outside Investors and Venture Capitalists

The outside investors can observe only the average return on all venture-capital-backed high-technology enterprises in a particular period but not the return of single investments. Moreover, they are not informed about particular characteristics of venture capitalists: they neither know the venture capitalists' experience in supporting the management teams nor can they observe the behaviour of venture capitalists after they have invested their capital in venture capital funds. Thus, there is an asymmetric distribution of information between the venture capitalists and the outside investors. Therefore, the outside investors base their portfolio selection decisions on the past observations of average returns on venture capital investments.

In each period, the outside investors invest their portfolio capital in bank assets and in venture capital funds. The volume of the portfolio capital is identical to the volume of the capital stock so that there is sufficient capital to finance the steady state number of traditional enterprises and high-technology entrepreneurs. Bank assets are invested only in traditional enterprises and are therefore risk-less. The return on bank assets is equal to zero because the interest rate is set equal to zero. Venture capital funds are invested only as start-up investments in high-technology entrepreneurs and are therefore risky. The share of the portfolio capital which the outside investors supply to venture capital funds in a particular period T depends on the degree of their risk aversion, the venture capitalists' reputation, and on the first two moments of the unknown distribution of the returns on venture capital investments. The two moments of the unknown distribution are calculated from past observations of average returns on venture capital investments. Specifically, I assume that the share of the portfolio capital supplied to venture capital funds is given by:

$$[1] \quad v_S^*(T) = \begin{cases} 0 & \text{if } \hat{r}_V(T) \le 0 \\ \dfrac{\Delta(T)\hat{r}_V(T)}{\xi\left(1+\hat{\sigma}_V^2(T)\right)} & \text{if } 0 < \hat{r}_V(T) < \dfrac{\xi\left(1+\hat{\sigma}_V^2(T)\right)}{\Delta(T)} \\ 1 & \text{else} \end{cases},$$

where

a hat denotes expected values,

ξ with $\xi > 0$ denotes the risk-utility parameter,

r_V denotes the return on venture capital investments,

σ_V denotes the standard deviation of the returns on venture capital investments, and

Δ with $0 < \Delta \le 1$ denotes the venture capitalists' reputation.

Note that the share of the portfolio capital supplied to venture capital funds given in equation [1] does not result from an optimisation calculus of the outside investors. However, the functional form of the share of the portfolio capital supplied to venture capital funds has some similarity to the one that results from a squared risk-utility function (for a discussion of portfolio selection approaches, and risk-utility functions see, for example, Ingersoll (1987)). The reason for assuming this specification given in equation [1] is as follows. For the simulation model, the share of the portfolio capital supplied to venture capital funds must increase with the expected average return on venture capital investments; it must decrease with the risk aversion of the outside investors, and the variance of the returns on venture capital investments. Moreover, in the steady state of the second scenario, the relation between the share of the portfolio capital supplied to venture capital funds and the risk premium must be positive: the higher the risk premium is, the higher the share of the portfolio capital supplied to venture capital funds must be.

If the outside investors would base their portfolio decision on a squared risk-utility function, an increase in the expected return on venture capital investments would not necessarily lead to a higher share of the portfolio capital supplied to venture capital funds. In addition, in the steady state, in

which the returns on venture capital investments are constant and the variance of the returns is (theoretically) equal to zero, the relation between the risk premium and the share of the portfolio capital supplied to venture capital funds is negative. If the outside investors would base their portfolio decision on an exponential risk-utility function, I could not determine the steady state relation between the risk premium and the share of the portfolio capital supplied to venture capital funds. This relation is, however, necessary to specify the risk premium that equalizes the venture capital demand and supply in the steady state of the second scenario.

It should also be noted that, even if the variance of the returns is equal to zero, the outside investors do not necessarily invest their whole portfolio capital in venture capital funds because of the specification of the share of the portfolio capital supplied to venture capital funds given in equation [1]. Only if $\hat{r}_V(T) \geq \xi / \Delta(T)$, the outside investors invest their whole portfolio capital in venture capital funds, if the variance of the returns is equal to zero. However, for the simulations, this extreme case is not so important because the variance of the returns on venture capital investments will never be equal to zero; the variance will become even in an extreme case only very small and not zero.

In each period, in which the venture capitalists are comparatively successful at financing high-technology entrepreneurs they increase their reputation until they reach the maximum level of reputation, which I fix to unity. In particular, I assume that the venture capitalists' reputation increases by the amount τ if the realized rate of success of the venture-capital-backed high-technology enterprises $\hat{\psi}_i^{VC}$ is at least as large as the exogenously given rate of success ψ_i^{VC}. Thus, the reputation of the venture capitalists in a particular period *T* results from:

$$[2] \quad \Delta(T) = \begin{cases} \Delta(T-1) & \text{if } \Delta(T-1) < 1 \text{ and } \hat{\psi}_i^{VC}(T) < \psi_i^{VC} \\ \Delta(T-1) + \tau & \text{if } \Delta(T-1) < 1 \text{ and } \hat{\psi}_i^{VC}(T) \geq \psi_i^{VC} \\ 1 & \text{else} \end{cases},$$

with $\Delta(0) > 0$.

Note that the venture capitalists' reputation does not decrease if the venture-capital-backed high-technology entrepreneurs realize an extraordinary high rate of failure.

Since the outside investors cannot observe the profitability of high-technology enterprises, they base their portfolio decision in the period T on past observations of average returns on venture capital investments. In the period T, they expect the return on venture capital investments and the variance of these returns to be

$$\hat{r}_V(T) = \frac{1}{T - t_0 - 1} \sum_{t=t_0}^{T-1} r_V(t) \text{ and } \hat{\sigma}_V^2(T) = \frac{1}{T - t_0 - 1} \sum_{t=t_0}^{T-1} \left(r_V(t) - \sum_{t=t_0}^{T-1} r_V(t) \right)^2 .$$

The average return on venture capital investments in a particular period $T-1$ results from the difference between the repayment of the successful high-technology enterprises and the venture capital invested in high-technology entrepreneurs, all divided by the venture capital invested in high-technology entrepreneurs. The realized return in a particular period $T-1$ is therefore given by:

$$[3] \quad r_V(T-1) = \frac{\left(I_i + P(T-1)\right) N_i(T-1) / \psi_i^{VC} - I_i N_i(T-1) / \psi_i^{VC}}{I_i N_i(T-1) / \psi_i^{VC}} = \frac{P(T-1)}{I_i} .$$

Thus, the return on venture capital investments increases with the risk premium of the outside investors and decreases with the volume of the start-up investment.

Venture capitalists use the risk premium to encourage the outside investors to invest their portfolio capital in venture capital funds. To put it differently, venture capitalists try to balance the share of the capital stock demanded for venture capital investments and the share of the portfolio capital supplied for venture capital investments by using the risk premium.

Which risk premium do venture capitalists offer? On the transition path between the steady state in the first scenario and the steady state in the second scenario, the venture capitalists offer a higher risk premium to encourage the outside investors to supply capital to venture capital funds because they have not yet built reputation. To put it differently, venture

capitalists who have not yet built reputation must pay a higher risk premium to receive a particular share of the portfolio capital than venture capitalists who have already built reputation. In the steady state of the second scenario, in which the venture capitalists have already built reputation, i.e., $\Delta = 1$, the risk premium must only compensate for the risk aversion of the outside investors. If the venture capitalists have built reputation, the risk premium is constant (for a given venture capital demand) since this risk aversion is constant over time. A constant risk premium leads to constant returns on venture capital investments and to a variance of the returns that is equal to zero.

With constant returns on venture capital investments and a variance of the returns equal to zero, one can re-write equation [1] and get for the share of the portfolio capital supplied to venture capital funds in the steady state of the second scenario:

[4] $v_S^* = \frac{P}{\xi I_i}$, with $0 < v_S^* < 1$.

The venture capitalists compensate an increase in the risk aversion of the outside investors with a higher risk premium in order to receive a fixed share of the portfolio capital in the steady state of the second scenario.

On the transition path between the steady states of the first and second scenario, the venture capital demand by the venture capitalists does not have to be equal to the venture capital supply by the outside investors because of the asymmetric distribution of information and the venture capitalists' reputation building. However, in the steady state of the second scenario, I assume that the venture capital supply is equal to the venture capital demand. Thus, the risk premium which compensates the risk-averse outside investors must be appropriate for the degree of risk aversion of the outside investors so that the venture capital supply and the venture capital demand is equalized.

In order to determine the relationship between the risk premium and the degree of risk aversion of the outside investors in the steady state of the second scenario, I set the share of the capital stock demanded by the venture capitalists v_d^* given in equation [A8] equal to the share of the

portfolio capital which is supplied to venture capital funds v_S^* given in equation [4].

Solving this for the risk premium gives:

[5] $$P = -\frac{A_3}{2} + \left[\left(\frac{A_3}{2}\right)^2 + \frac{\xi I_i^2 (1-\rho_i)}{(1-\rho_t)}\right]^{\frac{1}{2}}, \text{ with}$$

$$A_3 = I_i + C + \frac{I_i(1-\rho_i)}{(1-\rho_t)}.$$

Thus, in the steady state of the second scenario, the risk premium balancing the venture capital supply and demand only depends on the exogenous parameters of the model.

But what about the risk premium if the venture capitalists build reputation, i.e., if the venture capital market is on the transition path between the steady state of the first scenario and the steady state of the second scenario? Then the risk premium depends on the venture capitalists' reputation, on the past returns on venture capital investments which depend in turn on the risk premiums of past periods, and on the variance of these returns. For venture capitalists, it is impossible to calculate an adequate risk premium on the transition path, i.e., in some periods, the demand will be larger than the supply, while in other periods the supply will be larger than the demand. The reason for this is that the chosen risk premium in a particular period has two effects on the venture capital market. These effects happen, however, at different points in time. First, the risk premium directly affects the venture capital demand by high-technology entrepreneurs because the risk premium is part of the fixed costs and the higher the fixed costs, the lower ceteris paribus the demand for venture capital is. Second, the risk premium of the current period affects the portfolio decision of the outside investors in the next periods but not in the current one. Therefore, it is impossible to calculate an adequate risk premium simultaneously accounts for both effects.

However, for the simulation analysis, it is sensible to specify a risk premium that changes when the level of reputation changes because otherwise venture capitalists without reputation have no mechanism to

receive larger amounts of the portfolio capital. Therefore, I assume that the venture capitalists (who choose the risk premium) ignore the effect of the risk premium in a particular period on the venture capital supply in the successive periods. Then, the risk premium in a particular period T can be calculated as:

$$[6] \qquad P(T) = -\frac{A_3}{2} + \left[\left(\frac{A_3}{2} \right)^2 + \frac{\xi I_i^2 (1 - \rho_i)}{\Delta(T)(1 - \rho_t)} \right]^{\frac{1}{2}} \text{ for } \Delta < 1,$$

Thus, the higher the level of venture capitalists' reputation is, the lower the risk premium will be.

4 Experience and Success Probability

Venture capitalists accumulate the experience necessary to make high-risk investments profitable during their activities as active financial intermediaries. Certainly, they typically start their career with some basic experience because they have often founded their own high-technology enterprises and they have often also experience in selling enterprises successfully at a stock market. With their experience, venture capitalists can early recognize on crisis situations in the enterprises they have chosen to finance. Thus, the management support of experienced venture capitalists adds more value than the support of inexperienced venture capitalists. Moreover, venture capitalists use their experience to select new enterprises. The more experience venture capitalists have accumulated, the better business plans and business ideas can be evaluated. Thus, experienced venture capitalists select ceteris paribus enterprises that are more successful than the ones selected by their inexperienced counterparts. Venture capitalists' experience can be interpreted as a mechanism with which they can reduce the uncertainty of the innovation process.

In order to capture the venture capitalists' experience accumulation in the model, I assume that the more enterprises the venture capitalists have financed successfully, the higher their experience is. Suppose that the experience in period T is given by:

$$[7] \quad H(T) = \begin{cases} H(0) + \sum_{t=1}^{T-1} N_i(t) \Big/ \varpi N_i^* & if\ H(0) + \sum_{t=1}^{T-1} N_i(t) < \varpi N_i^* \\ 1 & else \end{cases},$$

where

ϖ with $\varpi > 1$ denotes a shift parameter which determines the speed of the experience accumulation,

$N_i(t)$ denotes the number of successful high-technology entrepreneurs in period *t*,

N_i^* denotes the steady state number of high-technology enterprises, and

$H(0)$ with $H(0) > 0$ denotes the basic experience of venture capitalists.

Since $\varpi > 1$, venture capitalists need some periods to accumulate the experience to support high-technology enterprises successfully. Therefore, an increase in the capital provided to venture capital funds does not necessarily lead to an increase in the speed of experience accumulation. The intuition behind this is that each single venture capitalist has a maximum level of experience that he can accumulate in a particular period.

As in the basic model, I assume that the venture capitalists affect the probability of venture-capital-backed high-technology entrepreneurs to be successful. But the size of this effect depends now on the venture capitalists' experience. The probability of a high-technology entrepreneur to be successful in period *T* is given by:

$$[8] \quad \psi_i^{VC}(T) = \begin{cases} H(T)\psi_i^{VC} & if\ H(T) < 1 \\ \psi_i^{VC} & if\ H(T) = 1 \end{cases},$$

where,

ψ_i^{VC} without the period index denotes the exogenously given probability of a high-technology entrepreneur to be successful if the venture capitalists have already accumulated the necessary experience to finance high-technology enterprises successfully.

For a venture capital market to develop, the starting value of the venture capitalists' experience must exceed a critical level. This critical level is determined implicitly by a condition that states that a venture capital market will emerge only if the value-added by venture capitalists' management support is large compared to the costs of management support (equation [16] in Schertler (2002)). Replacing the probability of high-technology entrepreneurs to be successful ψ_i^{VC} by the starting value of the venture capitalists' experience $H(0)$ multiplied by the probability to be successful ψ_i^{VC} leads to the following critical starting value for the venture capitalists' experience:

$$[9] \quad H(0) > \frac{(I_i + P + C)\psi_i}{(I_i + P)\psi_i^{VC}}.$$

Thus, if the venture capitalists do not have sufficient basic experience, a venture capital market in which financial means are offered in combination with management support would not develop.

The demand for venture capital does not change if only the experience accumulation process of the venture capitalists is taken into account. The reason for this is that the high-technology entrepreneurs' probability to be successful ψ_i^{VC} that depends on the venture capitalists' experience affects the number of high-technology enterprises producing high-technology products but not the number of high-technology entrepreneurs that try to develop high-technology products. Thus, if I do not consider reputation building, the venture capital demand on the transition path is equal to the demand in the steady state. However, if the venture capitalists have not built sufficient reputation, the venture capital demand is lower on the transition path than in the steady state because of the higher risk premium on the transition path.

While the experience accumulation of the venture capitalists does not affect the venture capital demand, it does affect the number of high-technology enterprises because this number depends on the probability to be successful and, thus, on the experience of the venture capitalists. The reason for this is that the probability of the high-technology entrepreneurs to be successful affects the repayment that the venture capitalists demand from the high-technology enterprises: the higher the probability of the high-technology

entrepreneurs to be successful is, the lower the demanded repayment is. This repayment is a part of the fixed costs of the high-technology enterprises, and the steady state number of enterprises increases if the fixed costs decrease. Thus, the higher the experience of the venture capitalists becomes, the closer the number of high-technology enterprises on the transition path to the steady state number is.

The number of periods that the venture capitalists need to reach the maximum level of experience depends on the shift parameter ϖ that determines the speed of the experience accumulation. The higher this shift parameter is, the more periods the venture capitalists need to accumulate the experience necessary to finance high-technology enterprises successfully. And the more periods the venture capitalists need to accumulate experience, the more periods the simulation runs will need to reach the steady state number of high-technology enterprises.

5 Simulation of Venture Capital Investments

The reputation building and experience accumulation of the venture capitalists have a substantial impact on the level of venture capital activity. Simulation runs[3] that started with identical initial parameters show significant different levels of venture capital investments after some periods of time. Each graph in Figure 2 depicts the development of the venture capital investments for the average and the upper and lower bound using a large number of simulation runs. The average is defined as the average venture capital investments of all simulation runs in a particular period. The upper bound is defined as the average plus the standard deviation of the venture capital investments in a particular period, and the lower bound is defined as the average minus this standard deviation. The graphs in Figure 2 differ because of different initial parameters. In particular, I vary the value of the initial reputation, the speed of reputation building, the probability of high-technology entrepreneurs to be successful,

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3 A description of the simulation procedure is in appendix.

the time horizon of the outside investors, and the past returns on venture capital investments.[4]

The difference between the graphs in column (a) and in column (b) of Figure 2 results from various past returns on venture capital investments that must be given in order to start the simulations. In column (a), the venture capital supply in the first period is comparatively low because the chosen values of past returns on venture capital investments leads to an expected return of $\hat{r}_V(1) = 10.6$ with a variance of $\hat{\sigma}_V^2(1) = 80.14$ which results in a share of the portfolio capital supplied to venture capital funds that is much lower than one per cent. In column (b), by contrast, the venture capital supply in the first period is comparatively high because the values of past returns on venture capital investments have an expected return of $\hat{r}_V(1) = 10.0$ with a variance of only $\hat{\sigma}_V^2(1) = 0.0067$. For these past returns, the outside investors supply more than seven per cent of the portfolio capital to venture capital funds if $\Delta(0) = 0.15$.

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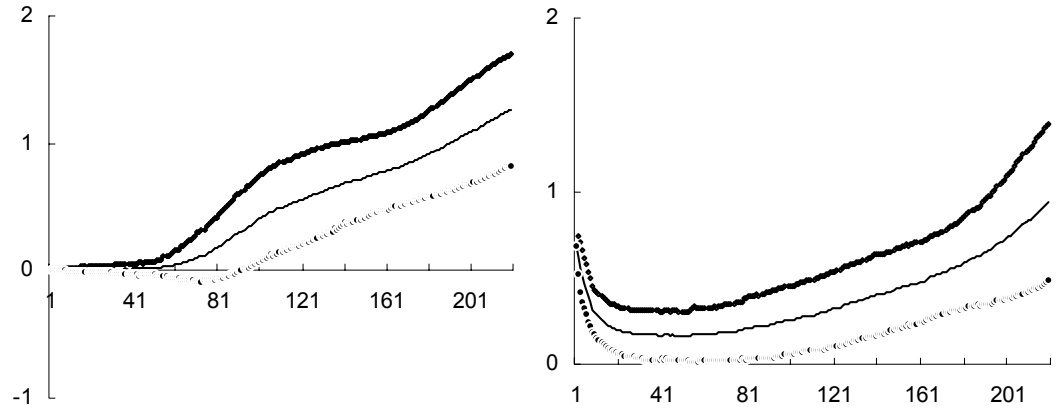
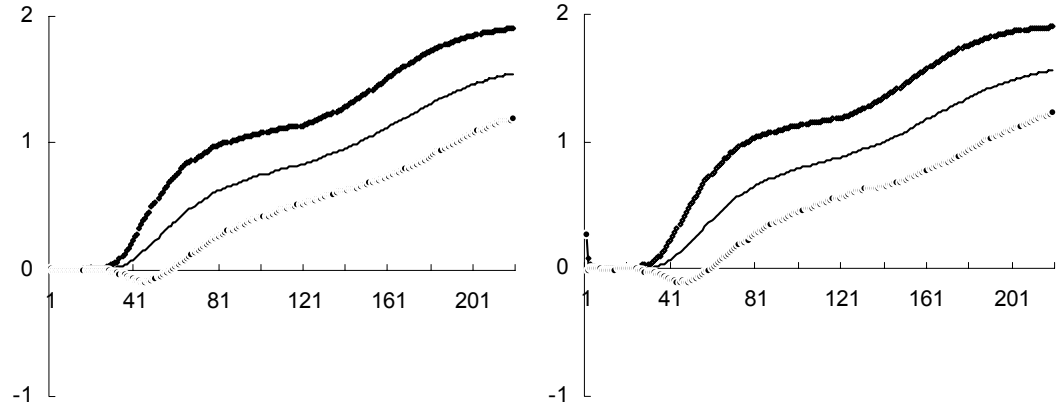
4 Most of the other exogenous parameters of the model affect the size of the venture capital market so that variations of these parameters are not presented here. Increasing the number of individuals or the share of the income spent of aggregated products, decreasing the start-up investment of innovative enterprises, the risk-aversion of the outside investors, or the differentiation parameter of innovative products increases the size of the venture capital markets. No impact on the size of the venture capital market has the differentiation parameter of traditional products and the start-up investment of traditional enterprises.

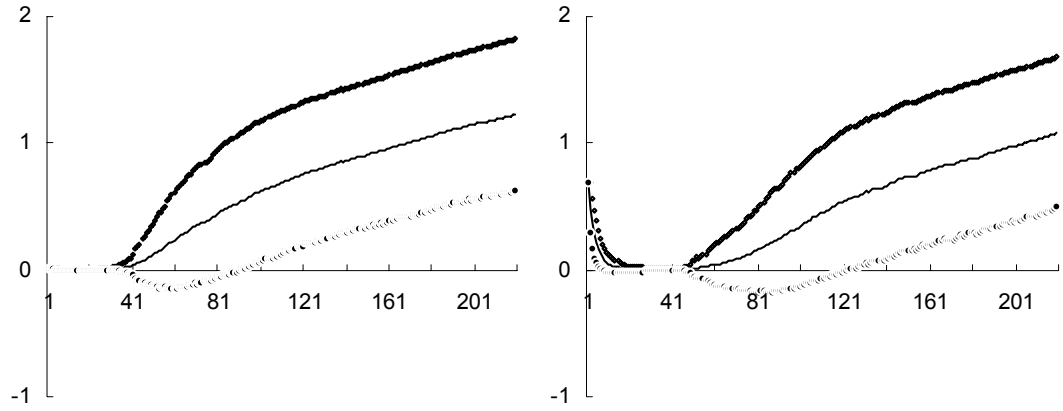
Figure 2: Venture capital investments (in 1,000) on the transition path



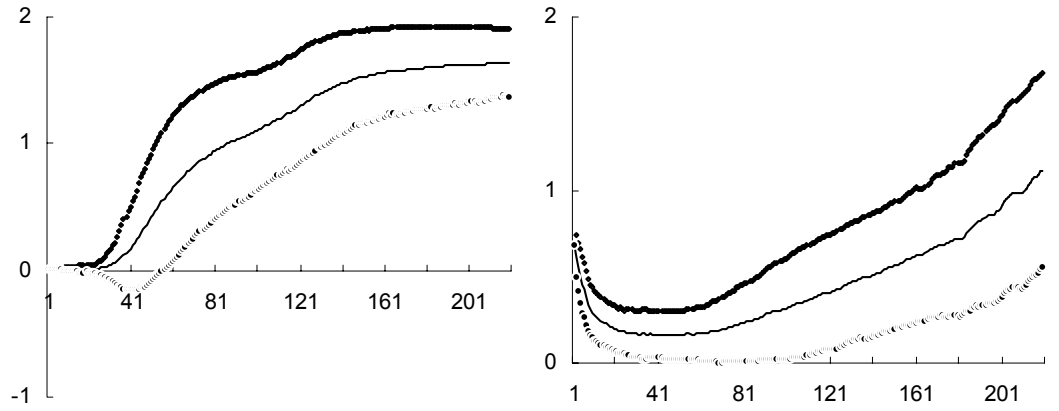
BASELINE: $\psi_i^{VC} = 0.6,\ H(0) = 0.15,\ \Delta(0) = 0.15,\ \varpi = 25,\ \tau = 0.04,\ T - t_0 = 8.$



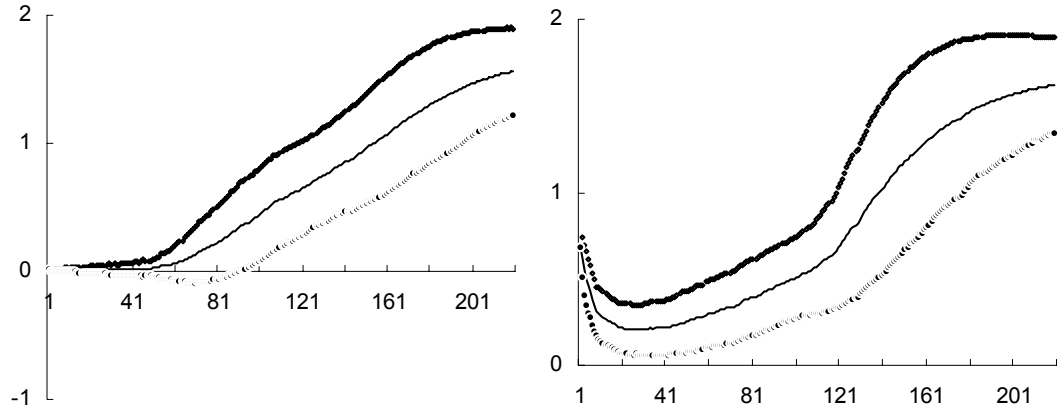
REPUTATION: $\psi_i^{VC} = 0.6,\ H(0) = 0.15,\ \Delta(0) = 0.05,\ \varpi = 25,\ \tau = 0.04,\ T - t_0 = 8.$



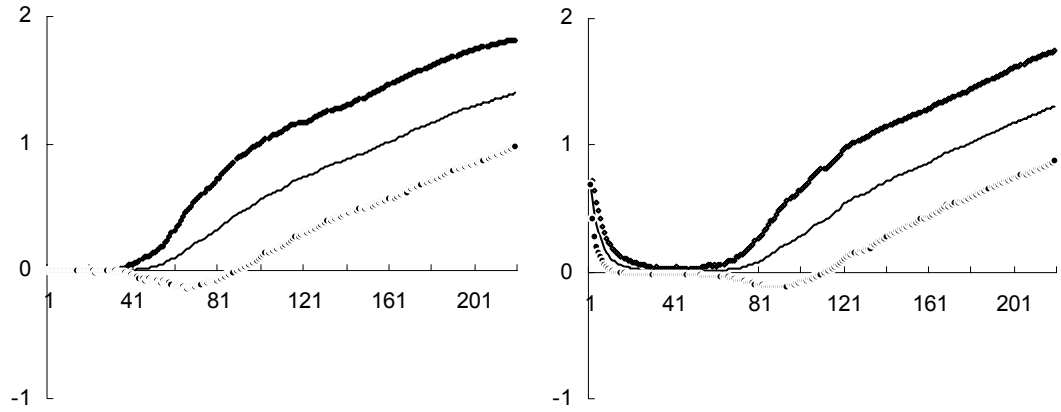
EXPERIENCE: $\psi_i^{VC} = 0.6,\ H(0) = 0.05,\ \Delta(0) = 0.15,\ \varpi = 25,\ \tau = 0.04,\ T - t_0 = 8.$



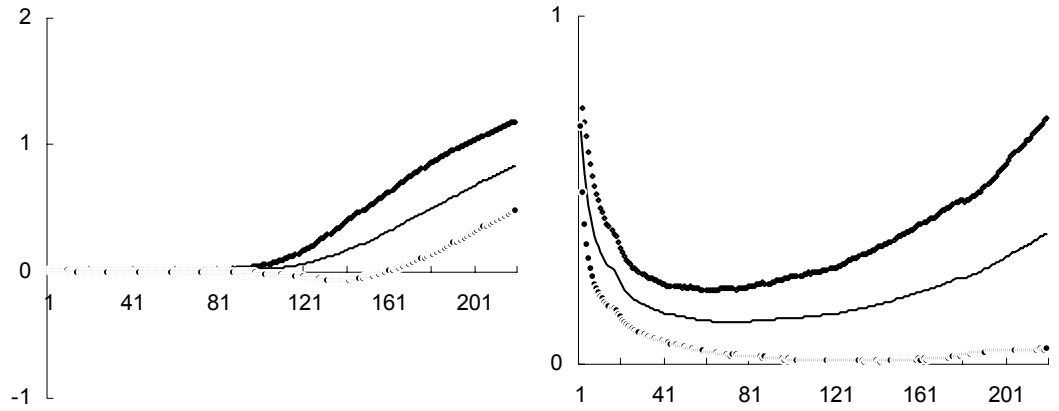
SPEED OF REPUTATION BUILDING: $\psi_i^{VC} = 0.6$, $H(0) = 0.15$, $\Delta(0) = 0.15$, $\varpi = 25$, $\tau = 0.4$, $T - t_0 = 8$.



SPEED OF EXPERIENCE ACCUMULATION: $\psi_i^{VC} = 0.6$, $H(0) = 0.15$, $\Delta(0) = 0.15$, $\varpi = 15$, $\tau = 0.04$, $T - t_0 = 8$.



SUCCESS PROBABILITY: $\psi_i^{VC} = 0.3$, $H(0) = 0.15$, $\Delta(0) = 0.15$, $\varpi = 25$, $\tau = 0.04$, $T - t_0 = 8$.



TIME HORIZON OF OUTSIDE INVESTORS: $\psi_i^{VC} = 0.6$, $H(0) = 0.15$, $\Delta(0) = 0.15$, $\varpi = 25$, $\tau = 0.04$, $T - t_0 = 20$.

(a) (b)

—— average ◇ upper bound • lower bound

Note: Average denotes the average venture capital investments of 500 simulation runs in a particular period. Upper bound denotes the average plus one standard deviation of the venture capital investments in a particular period, and lower bound denotes the average minus one standard deviation. Additionally the following parameters have been used: $\rho_t = \rho_i = \beta_B = \beta_T = 0.5$, $I_i = I_t = C = 1$, $L = 50{,}000$, $\xi = 20$. In (a) the past returns on venture capital investments are $r_V(-2) = 0$, $r_V(-1) = 21.9$, $r_V(0) = 10.0$, while in (b) these values are $r_V(-2) = 10.1$, $r_V(-1) = 9.9$, $r_V(0) = 10.0$.

Lowering the basic reputation of the venture capitalists as it is done in the *REPUTATION* simulation seems to have an abnormal effect on the average level of venture capital investments compared to the *BASELINE* simulation: the reduction in the basic reputation leads to a higher average level of venture capital investments on the transition path. The mechanism behind this works as follows. In the *REPUTATION* simulation, the venture capitalists build their reputation faster than their counterparts in the *BASELINE* simulation. Remember that venture capitalists build reputation if the realized success rate exceeds the exogenously given success rate of the steady state. Thus, if inexperienced venture capitalists finance a large number of high-technology enterprises, the probability to build reputation

is equal to zero because the low level of experience leads to a low expected and a low realized probability to be successful. However, if they finance only one high-technology enterprise, the probability to build reputation is larger than zero because this enterprise can be either successful or unsuccessful resulting in a realized success rate that is either equal to one or equal to zero. And this is what happens in the *REPUTATION* simulation: in the first 20 periods, the venture capital supply is comparatively low so that the venture capitalists can finance only few high-technology entrepreneurs. In this simulation, the venture capitalists build reputation even if they have not yet accumulated the experience necessary to finance high-technology enterprises successfully.

The reduction in the basic reputation causes still another interesting effect compared to the *BASELINE* simulation. While in the *BASELINE* simulation, the number of simulation runs is comparatively low in which the outside investors do no longer supply capital to venture capital funds after some periods, the respective number in the *REPUTATION* simulation is about nine times as high as in the *BASELINE* simulation. Thus, a lower value of the venture capitalists' basic reputation does not improve welfare as suggested by the higher average level of venture capital investments.

A decrease in the basic experience of the venture capitalists depicted in the *EXPERIENCE* simulation reduces the average level of the venture capital investments, increases the time that the simulation runs need to reach the steady state level of the venture capital investments, and increases the volatility of venture capital investments on the transition path. However, the effects are comparatively small. While in the *BASELINE* simulation, the average level of venture capital investments is about 1,263 currency units in period 220, the respective value in the *EXPERIENCE* simulation is 1,223 currency units. The difference with respect to the standard deviation is more substantial: the *BASELINE* simulation has a standard deviation of about 434 in period 220, while the *EXPERIENCE* simulation has a standard deviation of about 595 in the respective period.

An increase in the speed of reputation building or in the speed of experience accumulation has a positive impact on the development of venture capital markets because the steady state level of venture capital investments is reached in shorter time. In comparison to the *BASELINE*

simulation, the *SPEED OF EXPERIENCE ACCUMULATION* simulation has a higher average level of venture capital investments in all periods except some few periods at the beginning of the simulation. An increase in the speed of experience accumulation affects the standard deviation positively. However, after period 200, the standard deviation in the *BASELINE* simulation is higher than in the *SPEED OF EXPERIENCE ACCUMULATION* simulation. An increase in the speed of reputation building depicted in the *SPEED OF REPUTATION BUILDING* simulation has similar effects than an increase in the speed of experience accumulation.

Reducing the success probability from 60 per cent in the *BASELINE* simulation to 30 per cent in the *SUCCESS PROBABILITY* simulation has only little effects on the development of the average level of venture capital investments and on the standard deviation in the simulation presented in column (a). However, the impact is much larger in the simulation presented in column (b) in which the past returns on venture capital investments lead to a high share of the portfolio capital that is supplied to venture capital funds.

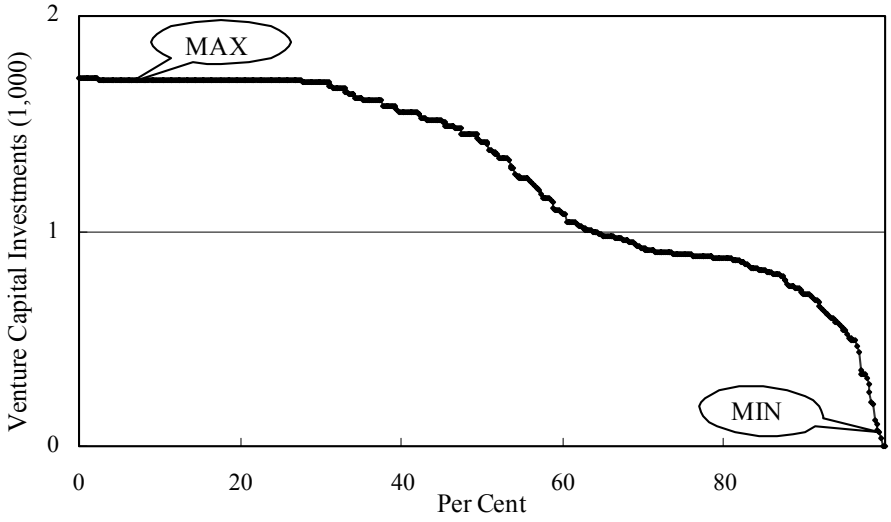
The *TIME HORIZON OF OUTSIDE INVESTORS* simulation shows the effect of an increase in the number of periods that the outside investors consider in their portfolio decision. In comparison to the *BASELINE* simulation, this simulation has a lower average level of venture capital investments on the transition path and the simulation runs need a longer time to reach the optimal allocation of capital in the steady state. Thus, if the outside investors review many periods of the venture capital markets' history, the venture capital investments grow at a lower rate. It is the higher variance of the returns on venture capital investments which mainly causes this result: high volatility of the returns in the initial stage of a venture capital market keep the market away from growing.

6 Interpretation of the Simulation Results: The Importance of Path Dependencies

The standard deviations of the simulations indicate significant differences between the runs of a single simulation with respect to the development of venture capital investments. In the following, I will present therefore two

simulation runs selected out of the *BASELINE* simulation. The simulation run MIN denotes a run in which the steady state allocation of capital is not reached even after 220 periods, while the simulation run MAX denotes a run in which the optimal allocation of capital is realized after period 161.

Figure 3: Probability distribution of venture capital investments



Note: The graph shows the percentage of simulation runs of the *BASELINE* simulation that reached particular levels of venture capital investments in period 220. MIN denotes the simulation run with a comparatively low level of venture capital investments, and MAX denotes the run that has already reached the steady state level of venture capital investments. For parameter values used see Figure 2.

Figure 3 depicts that the simulation run MIN has a very low level of venture capital investments in period 220, while the simulation run MAX has already reached the steady state level of venture capital investments. Moreover, Figure 3 depicts how likely it is to reach different levels of venture capital investments. The probability to reach the steady state level of venture capital investments in the period 220, which is equal to 1,700 currency units, is about 30 per cent. By contrast, the probability to reach a venture capital investment level of about 100 currency units (the venture capital investments in the MIN run are 40 currency units) is below one per cent.

The differences between the simulation runs MIN and MAX are caused by differences in the venture capital supply and demand conditions. The simulation run MAX has low levels of venture capital investments in the

first 41 periods, while the run MIN has higher levels of investments in this time. Around the period 50, the levels of venture capital investments start to increase in both simulation runs. However, in the run MAX the venture capital investments increase up to 1,000 currency units and stay there for about 60 periods, while in the run MIN the venture capital investments drop down to a low level after some periods. Interestingly, the run MIN shows several ups and downs during the observation period without increasing the average level of venture capital investments substantially.

In order to discuss the differences between these two simulation runs, I divide the observation period in three development stages. The distinction of the three stages is based on the simulation run MAX. In the first stage, called the initial stage, the realized failure rates have high levels and are very volatile. This stage is from the beginning of the simulation to period 58. The second stage, called the expansion stage, is characterized by dropping realized failure rates. It comprises the periods 59 to 141. In the third stage, called the mature stage, the realized failure rates are constant at a low level.

The interaction of the venture capitalists' experience accumulation and the reputation building causes the differences between the two simulation runs. If the venture capitalists build some reputation in the initial stage, the outside investors increase the venture capital supply. If the venture capital supply increases, the venture capitalists can finance more high-technology entrepreneurs. If venture capitalists finance more high-technology entrepreneurs, the number of high-technology enterprises increases as well and, thus, venture capitalists accumulate experience at a higher rate. Note, that an increase in the number of high-technology entrepreneurs financed does lead to an increase in the number of high-technology enterprises only if the venture capital demand exceeds the venture capital supply.

What are the effects at work in the initial stage in particular? In the simulation run MAX, the realized failure rates, which are the driving force in the model, vary between zero and 100 per cent, while in the simulation run MIN they vary only between 75 and 95 per cent. In the simulation run MAX, the venture capitalists can build some reputation because they are extraordinarily successful in several periods, i.e., the realized success rates exceed the exogenously given probability of high-technology enterprises to

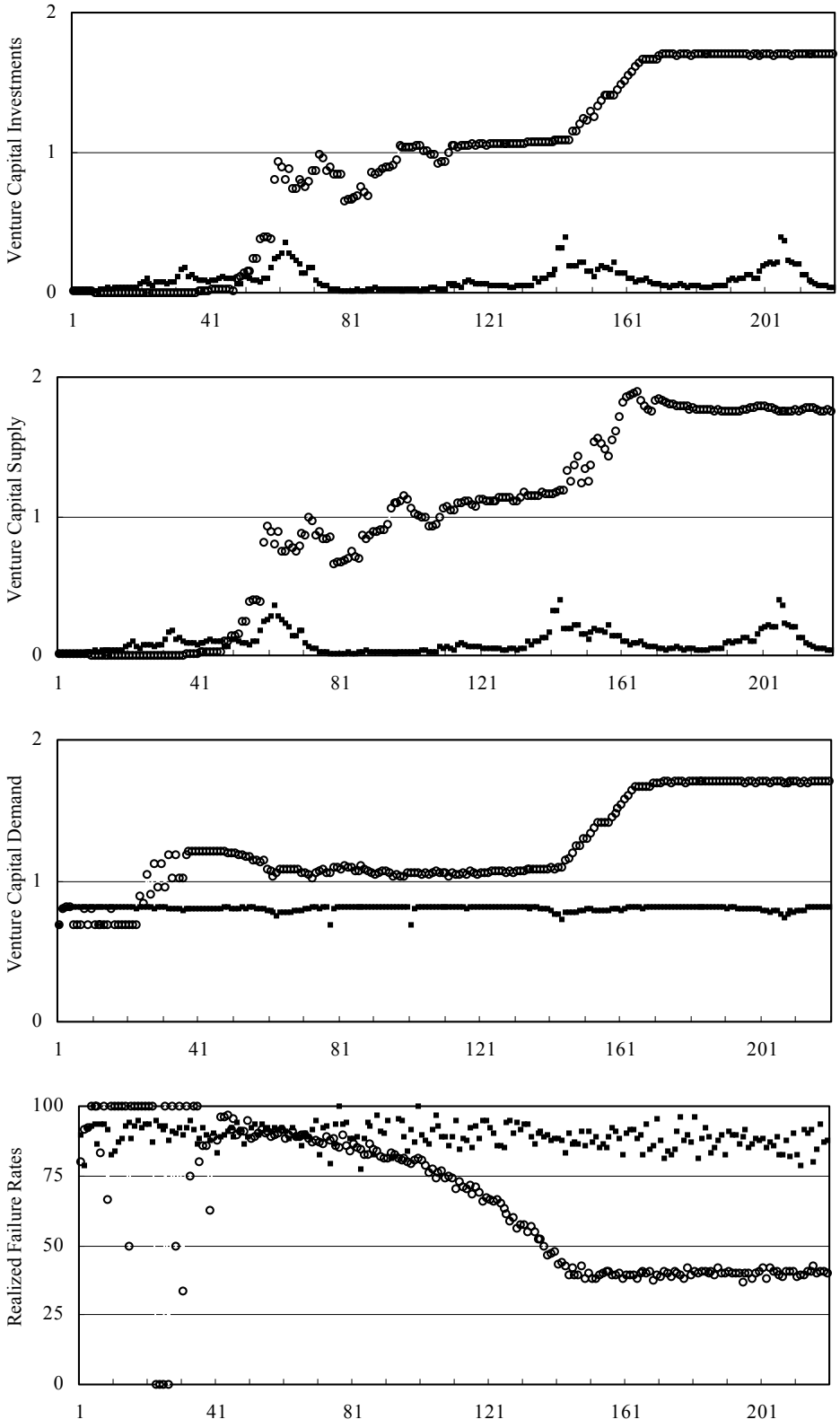
be successful. An increase in reputation has ceteris paribus a positive impact on the venture capital supply by the outside investors. In the simulation run MIN by contrast, the venture capitalists do not build reputation because their realized failure rates are too high in all periods.

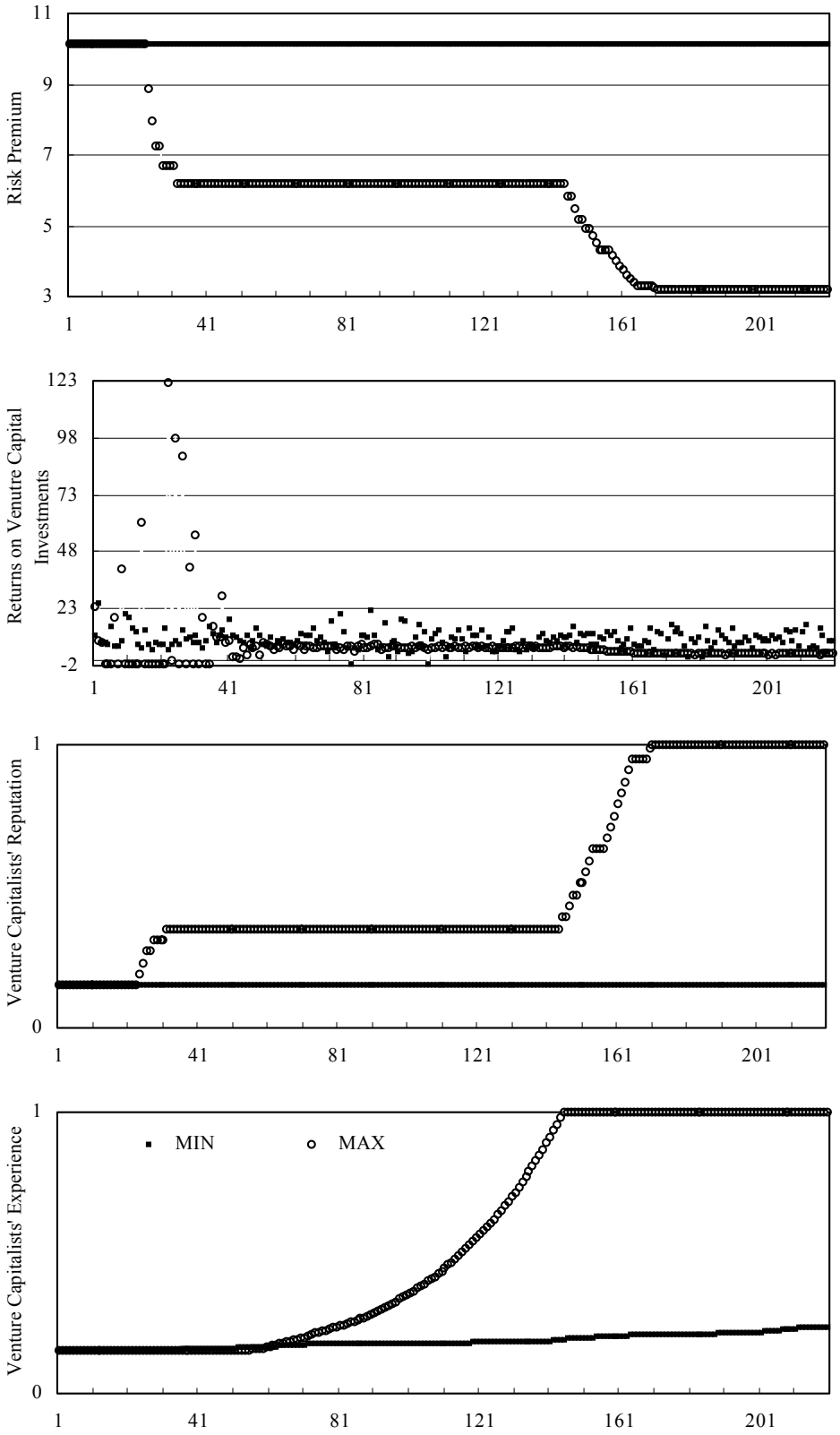
In the simulation run MAX, the increase in the reputation lowers the risk premium for the outside investors, while in the run MIN the risk premium does not change because the reputation does not change. In the initial stage of the simulation run MAX, the reduction in the risk premium increases the demand for venture capital because the risk premium is a integral part of the fixed costs of the high-technology enterprises, and decreasing fixed costs increases the number of high-technology entrepreneurs demanding venture capital. However, in the initial stage, the venture capital demand exceeds the venture capital supply in both simulation runs.

What are the effects at work in the expansion stage in particular? In the simulation run MAX, the realized failure rates vary only slightly in the first few periods of the expansion stage. This, in combination with the lower risk premium, encourages the outside investors to increase the venture capital supply because the lower returns on venture capital investments are overcompensated by a lower volatility in the returns. There is a similar effect in the simulation run MIN. However, this effect is much smaller and not persistent as in the simulation run MAX. In the simulation run MAX, the venture capital supply stays at a comparatively high level, while in the simulation run MIN it drops after some periods because the volatility of the realized failure rates increases again.

After the simulation run MAX reaches the expansion stage, the risk premium equalizes the venture capital demand and supply in many periods. Moreover, the difference between venture capital supply and demand is compared to the level of venture capital investments small. Thus, although the venture capitalists are not fully informed about the decision rule of the outside investors with respect to the share of the portfolio capital invested in venture capital funds (see equation [6]), they are capable to raise sufficient funds for a given venture capital demand.

Figure 4: Differences between the simulation runs MIN and MAX





Note: see Figure 3.

In the simulation run MAX, the high supply of venture capital allows the venture capitalists to finance a large number of high-technology entrepreneurs. Financing a large number of high-technology entrepreneurs leads to a large number of high-technology enterprises and this increases the venture capitalists' experience. Higher experience of the venture capitalists leads to lower realized failure rates, which in turn increase the venture capital supply so that venture capitalists can finance a larger number of high-technology entrepreneurs.

What are the effects at work in the mature stage in particular? The effects in the simulation run MIN do not differ from those in the expansion stage, while the simulation run MAX experiences the last changes on the way to reach the optimal allocation of capital in the steady state. In the simulation run MAX, the venture capitalists start again to build reputation for successfully financing high-technology entrepreneurs after they have accumulated sufficient experience. Each increase in the reputation leads ceteris paribus to an increase in the venture capital supply. Moreover, each increase in the reputation leads to a decrease in the risk premium that affects only scarcely the returns on venture capital and, thus, the supply of venture capital. However, the decrease in the risk premium affects significantly the demand of venture capital.

In the simulation run MIN, the venture capital demand exceeds persistently the venture capital supply in the expansion as well as in the mature stage. The reason for this is that the venture capitalists ignore the effect of the volatility of the returns on venture capital investments on the share of the portfolio capital supplied to venture capital funds. Due to the highly volatile realized failure rates, the returns on venture capital investments are also highly volatile leading to a small share of the portfolio capital which the outside investors supply to venture capital funds. This in turn leads to low investments in high-technology entrepreneurs so that venture capitalists accumulate very slowly the experience necessary to finance high-technology entrepreneurs successfully. However, there is no reason to believe that the simulation run MIN will not reach the steady state level of venture capital investments. It will only need a very long time.

An alternative specification of the risk premium given in equation [6] may partly solve the persistent divergence of the venture capital supply and

demand in the simulation run MIN. Promising seems the idea to model a learning process of venture capitalists: how do venture capitalists recognize that their offered returns are too low for given investment risks, and how they can encourage the outside investors to increase the share of their portfolio capital supplied to venture capital funds.

However, it is most important to note that the simulation runs demonstrate how the trajectories of an innovating economy differ even if the initial conditions are identical. In the simulation run MAX, the specified risk premium leads to an equalization of the venture capital demand and supply after some periods, while in the simulation run MIN it undermines the development of a venture capital market that would ultimately improve welfare. The differences in the trajectories, which are substantial, result from venture capitalists' accumulation of experience and their building of reputation, the uncertainty of the innovation process, the asymmetric distribution of information between the parties that are involved in venture capital markets (such as the outside investors and the venture capitalists), and the past events that determines the behaviour of these agents. These interactions taking place on venture capital markets offer one explanation why venture capital activity differs substantially between countries.

7 Concluding Remarks

This paper has examined the effects of venture capitalists' reputation building and experience accumulation on the development of venture capital investments. Venture capitalists have to build reputation, i.e., a track record for successfully financing high-technology enterprises, because they have to raise funds from outside investors that initially have little information about the profitability of venture capital investments. Moreover, venture capitalists have to accumulate stage- and technology-specific experience in order to add value to high-technology enterprises.

The simulation model that has been used to analyse the development of venture capital investments captures the main agents of these markets: venture capitalists, outside investors, and entrepreneurs. Venture capitalists invest management support in addition to financial means in enterprises developing high-technology products. Through their management support, venture capitalists increase the probability of the high-technology

entrepreneurs to be successful and, thus, the profitability of the high-technology enterprises. Venture capitalists do not invest their own financial resources; they have to raise funds from outside investors. The outside investors initially have little information about the profitability of venture capital investments. Therefore, they base their portfolio decision on past observations of returns on venture capital and bank assets that contain information about the future profitability of venture capital investments.

In order to examine the genesis of venture capital markets, two scenarios of the model have been constructed. In the first scenario, consumers demand only traditional products that can be developed without risk. Thus, in this scenario, a venture capital market would never develop because the venture capital demand is insufficient since there are no high-technology entrepreneurs demanding venture capital. In the second scenario, the consumers demand high-technology products in addition to traditional products. The development of high-technology products is risky. Each high-technology entrepreneur develops only one high-technology product and demands venture capital because the venture capitalists' management support increases the probability of high-technology entrepreneurs to be successful. In the steady state of the second scenario, the venture capitalists have already accumulated experience and they have already built reputation.

The transition of the economy between the steady states of the two scenarios has been analysed by means of simulations. The simulation results have suggested that the development of venture capital markets that started with identical initial conditions can lead to different trajectories. Thus, reputation building and experience accumulation in combination with the uncertainty of the innovation process leads to path dependencies in venture capital activity.

In particular, if the outside investors base their portfolio decision on past realizations of returns on venture capital investments and if venture capitalists have not yet built reputation, venture capital investments depend considerably on the success of past venture-capital-backed enterprises. Successive waves of unsuccessful venture-capital-backed enterprises hamper venture capitalists' experience accumulation substantially. This is because venture capitalists are incapable of raising new funds from outside

investors. If, however, the venture-capital-backed enterprises are all successful in successive periods, the outside investors believe in the venture capital idea, and they supply a larger share of their portfolio capital to venture capital funds. Since more capital is available, venture capitalists can finance a larger number of high-technology entrepreneurs. If venture capitalists finance a larger number of high-technology entrepreneurs, they accumulate experience at higher rates so that future generations of high-technology entrepreneurs can start their enterprises with a higher probability to be successful. In addition, venture capitalists' accumulated experience reduces the price of venture capital for the high-technology entrepreneurs so that the venture capital demand increases.

This paper offers a further explanation for the differences in venture capital activity that are substantial across countries. While the recent literature explains differences in venture capital activity through differences in financial systems (Black and Gilson 1998) and innovation systems (Becker and Hellmann 2000) of the economies, in this paper it has been shown that the levels of venture capital investments can differ even if the economies have identical initial conditions. These differences are the result of the interaction of the uncertainty of the innovation process, the discrete choices made in the innovation process, venture capitalists' experience accumulation and reputation building, and the asymmetric distribution of information among the agents acting on venture capital markets.

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Appendix

Description of the model

In the second scenario, a representative individual maximizes the following consumption utility that consists of a basic homogeneous product X_B, an aggregate of traditional products X_{nt} and an aggregate of high-technology products X_{mi}

[A1] $U = X_B^{\beta_B}\left(\sum_m X_{mi}^{\rho_i}\right)^{\frac{\beta_T}{\rho_i}}\left(\sum_n X_{nt}^{\rho_t}\right)^{\frac{\beta_T}{\rho_t}}$, under the budget constraint

[A2] $X_B + \sum_m p_{mi}\, X_{mi} + \sum_n p_{nt}\, X_{nt} = Y$, where

β_s with $s \in \{B,T\}$ and $0 < \beta_s < 1$ denotes the income shares of the basic product and the aggregate of traditional and innovative products,

ρ_j with $0 < \rho_j < 1 \quad j \in \{i,t\}$ denotes the degree of differentiation in the monopolistic market,

$p_{.j}$ denotes the price of a particular traditional or high-technology product,

$i\,(t)$ denotes the index of high-technology (traditional) products,

Y denotes the income of the individuals. Because each individual supplies one unit of labour inelastically, the income is given by the wage rate w multiplied by the number of individuals L plus the risk premium per financed high-technology entrepreneur P multiplied by the number of high-technology entrepreneurs $Y = wL + N_{Fi}^{*}P$.

The venture capital market is competitive. The venture capitalist's management support increases the probability of a successful development of the entrepreneur's innovative product to $\psi_i^{VC} > \psi_i$. For their active involvement in high-technology enterprises, venture capitalists demand $R^{VC} = (I_i + P + C)/\psi_i^{VC}$ where C denotes the management costs of the venture capitalists, and I_i denotes the start-up investment of an entrepreneur.

An entrepreneur who wants to start her own traditional or high-technology enterprise, i.e., an enterprise that produces a traditional or high-technology product, maximizes her expected profit by setting the price of its product and takes the Marshallian demand function resulting from the consumption maximization as given. An entrepreneur maximize the following expected profit:

[A3] $\hat{\pi}_{\bar{m}i} = \psi_i^{VC}\left(p_{\bar{m}i} - \ddot{w}\right)X_{\bar{m}i} - \psi_i^{VC}R^{VC}$.

Inserting the optimal product price, which is identical for all high-technology products, I can write the expected profit of the high-technology entrepreneurs as a function of the number of high-technology enterprises N_i. Setting the expected profit equal to zero determines the number of high-technology enterprises in the steady state that is given by:

[A4] $N_i^* = \dfrac{\psi_i^{VC}(1-\rho_i)L}{(I_i + P + C)\beta - (1-\rho_i)P}$, with $\beta = \beta_B\left[\dfrac{1}{\beta_T} + \dfrac{2}{\beta_B}\right]$ and $N_{Fi}^* = N_i^* / \psi_i^{VC}$.

The wage rate is equal to one because the basic homogeneous product is produced using solely labour and the price of the basic homogeneous product is set equal to one.

Free entry in the market for traditional products leads to the following steady state number of traditional enterprises:

[A5] $N_t^* = \dfrac{(1-\rho_t)\left(L + N_i^* P / \psi_i^{VC}\right)}{\beta I_t}$.

The venture capital demand results from the number of venture-capital-backed high-technology entrepreneurs multiplied by the start-up investment:

[A6] $V_d^* = N_{Fi}^* I_i = \dfrac{N_i^* I_i}{\psi_i^{VC}} = \dfrac{I_i L(1-\rho_i)}{(I_i + P + C)\beta - P(1-\rho_i)}$.

In the steady state, the capital stock, which is necessary to finance the optimal number of traditional and high-technology enterprises, results from

$K^* = N_t^* I_t + N_i^* I_i / \psi_i^{VC}$. Inserting the optimal number of high-technology and traditional enterprises gives:

$$[A7]\ K^* = \frac{(1-\rho_t)L}{\beta} + \frac{(1-\rho_i)L((1-\rho_t)/\beta\ P + I_i)}{(I_i + P + C)\beta - (1-\rho_i)P}.$$

Dividing the venture capital demand by the capital stock of the economy in the steady state gives the share of venture capital:

$$[A8]\ v_d^* = \frac{N_i^* I_i / \psi_i^{VC}}{N_t^* I_t + N_i^* I_i / \psi_i^{VC}} = \frac{\dfrac{I_i(1-\rho_i)}{(I_i + P + C)\beta - P(1-\rho_i)}}{\dfrac{(1-\rho_t)}{\beta} + \dfrac{(1-\rho_i)(P(1-\rho_t)/\beta + I_i)}{(I_i + P + C)\beta - P(1-\rho_i)}}.$$

Description of the simulation procedure

In order to start the simulations, several parameters have to be given. I distinguish between initial values and parameters that do not vary throughout the simulations.

Initial values must be given for the reputation of the venture capitalists $\Delta(0)$, their experience $H(0)$, the past returns on venture capital investments, such as $r_V(-2)$, $r_V(-1)$, $r_V(0)$, and the income of the individuals $Y(0)$. The following parameters do not vary throughout the simulations: ρ_j, β_S, I_j, C, L, ξ, ψ_i^{VC}, τ, $T - t_0$, ϖ.

After fixing the initial values and parameters of the model, the program calculates the steady state capital stock given in equation [A7] that is identical with the portfolio capital, and the steady state number of high-technology enterprises given in equation [A4].

Thereafter, the simulation procedure can be started. Most of the equations used for the simulation are presented above. However, there are some differences between the equations presented above and the ones used in the simulations. These differences will be discussed below in detail.

In a particular period *T*, the program does the following steps:

First step: Calculation of the share of the portfolio capital supplied to venture capital funds using equation [1]. The supply of venture capital

results from the portfolio capital multiplied by the share supplied to venture capital funds.

Second step: Calculation of the number of traditional enterprises and high-technology entrepreneurs that should be financed. If the venture capital supply (demand) exceeds the demand (supply), the supply (demand) determines the number high-technology entrepreneurs that are financed.

> Calculation of the venture capital demand: First, the risk premium adequate for the current reputation is calculated (equation [6]). Thereafter, the number of high-technology entrepreneurs is calculated that drives the expected profits of high-technology enterprises equal to zero using the following formula:

$$N_{Fi}(T) = \frac{(1-\rho_i)Y(T-1)}{(I_i + P(T) + C)\beta}.$$

> Thus, instead of using the current income of the individuals that depends on the number of successfully started high-technology entrepreneurs, I use the income of the respective last period in order to minimize problems of negative profits of high-technology enterprises.

Third step: A random variable determines how many of the venture-capital-backed high-technology entrepreneurs are successfully using the current probability to be successful given by equation [8].

Fourth step: Calculation of the return on venture capital investments using the following formula:

$$r_V(T) = \frac{(I_i + P(T))N_i(T)/\psi_i^{VC} - I_i N_{Fi}(T)}{I_i N_{Fi}(T)}.$$

> This formula differs from the one presented in the equation [3] in the following way. In equation [3], the return on venture capital investments is calculated using expected values of the number of high-technology enterprises and entrepreneurs, while in the simulations the realized numbers of high-technology enterprises and entrepreneurs are used.

Fifth step: Calculation of venture capitalists' experience given in equation [7], calculation of venture capitalists' reputation given in equation [2], both for the next period.

Sixth step: Calculation of the enterprises' profits using the following formulas:

$$\pi_i(T) = \frac{(1-\rho_i)Y(T-1)}{\beta N_i(T)} - \frac{I_i + P(T) + C}{\psi_i^{VC}(T)} \text{ and } \pi_t(T) = \frac{(1-\rho_t)Y(T-1)}{\beta N_t(T)} - I_t .$$

Seventh step: Calculation of the individuals' income using the following formula:

If $r_V(T) > 0$ then $\quad Y(T) = L + N_i(T)(P(T) + \pi_i(T)) + N_t(T)\pi_t(T)$

If $r_V(T) \le 0$ then
$$Y(T) = L + N_i(T)\left(\frac{P(T)}{\psi_i^{VC}(T)} + \pi_i(T)\right) + N_t(T)\pi_t(T) - \left(I_i N_{Fi}(T) - \frac{I_i + P(T)}{\psi_i^{VC}(T)} N_i(T)\right)$$

End of the particular period *T*. If another period is required, the program starts again with the first step.