VENTURE CYCLES: THEORY AND EVIDENCE

THOMAS GEHRIG
RUNE STENBACKA

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Abstract

We demonstrate how endogenous information acquisition in venture capital markets creates investment cycles when competing financiers undertake their screening decisions in an uncoordinated way, thereby highlighting the role of intertemporal screening externalities induced by competition among venture capitalists as a structural source of instability. We show that uncoordinated screening behavior of competing financiers is an independent source of fluctuations inducing venture investment cycles. We also empirically document the existence of cyclical features in a number of industries such as biotechnology, electronics, financial services, healthcare, medical services and consumer products.

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Thomas Gehrig
Institute for Economic Development Research
University of Freiburg
79085 Freiburg
Germany
thomas.gehrig@vwl-freiburg.de

Rune Stenbacka
Swedish School of Economics
P.O.Box 479
00101 Helsinki
Finland

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I. Introduction

The ability of financial markets to identify and finance innovative firms is widely attributed to have substantially contributed to the impressive performance of the US-economy and its technological leadership in recent decades. Especially venture capital firms have performed a central function in the selection process (see Hellmann, 2000). Modern technology leaders such as Amazon, Apple, Cisco, e-Bay, Genentech, Intel, Microsoft and Sun Microsystems did all initially start up with venture capital support.[1]

In contrast bank-dominated financial systems seem to have been less successful in funding innovative firms. European governments, for example, and even the European Commission identify a need for public intervention to bolster venture capital in order to boost sluggish growth and reduce unemployment.[2] And indeed, venture financing in Europe has "taken off" only after the so-called "new markets" were created as special technology segments of the various European stock exchanges (see Bottazzi and Da Rin, 2002). Those segments are particularly relevnt for new and sufficiently matured innovative firms.

Given the differential comparative performance of the various financial systems in regard to innovation much of the literature concentrates on issues of the optimal design and contracting in venture financing (for surveys see e.g. Gompers, Lerner, 1999 and Kaplan, Strömberg, 2000) in order to explain long run performance. Surprisingly,

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1 Bottazzi and Da Rin (2002) also mention Federal Express and Starbucks as more traditional companies that received venture capital support during the start-up phases.

2 Along this line the European Commission Report of 1998 explicitly firms under the title: „Risk Capital: A Key to Job Creation in the European Union".

the role of project selection has largely been neglected.[3] Costly project selection is the central theme of our present contribution and it is key to understand short run patterns of venture capital investments.

The cyclical nature of venture capital investments seem to be common wisdom among industry experts. It has largely been asserted, but it is nevertheless rarely documented. In this sense one of the founding fathers in the industry, W. Sahlmann, is quoted as: “Cycles are inevitable but not necessarily bad, provided that the players anticipate them and respond accordingly. ... As more and more capital chases a limited set of solid opportunities, it inevitably leads to what our forebears called a 'Tragedy of Commons'--too many cows feeding on the same pasture. When it does happen, I suspect we will be shocked, even though the inevitability of such cycles is clear." (cited in Jacobs, 1999). This is precisely the feature of venture markets we address in our contribution.

We argue that the screening activity of competing venture capitalists necessarily generates pool-worsening externalities for the whole venture financing industry. By cherry picking the best innovators in a narrowly specified market segment venture financiers leave an adversely selected pool for further funding by competitors at a later time period. Thus after periods of intensive screening the returns to screening will necessarily be reduced in the following period(s). Thus the screening externality reduces screening incentives for the whole industry until the pool of applicants has sufficiently improved again through a process of entry by new innovators. Ultimately the pool improvement triggers positive screening incentives in some later period leading the

[3] This is all the more surprising since based on their empirical work Kaplan and Strömberg (2001, 2002) explicitly call for theoretical work that incorporates “investor costs of evaluating potential investments” (Kaplan and Strömberg, 2001, p. 248).

industry into cycling between states of high and low screening activities**.** In a world with heavy discounting of high-tech projects the delays caused by cycles will necessarily impose significant welfare losses on the economy.

In our theory screening cycles emerge endogenously and by necessity, as long as they arise. They result from uncoordinated search for the best projects. In a more coordinated setting, i.e. in a cartel or under information sharing, endogenous cycles cannot occur. In contrast to prominent theories of financial fluctuations our theory does not require the existence of exogenous stochastic shocks (e.g. Kiyotaki and Moore, 1997). Our theory is not about amplifications of exogenous shocks but about the endogenous emergence of cycles. It is also worth emphasizing that these venture cycles should not be confused with Gomper's and Lerner's "venture capital cycles" (Gompers and Lerner, 1999), which track the life cycles of venture projects and not the cyclicality of industry conduct per se.

On the basis of our theory we predict that in a competitive world with a stationary inflow of new ideas the number of projects funded would typically exhibit negative serial correlation over time. Indeed this is a feature of certain prominent segments of the U.S. venture capital market. While on an aggregate level it is difficult to identify higher frequency cycles we document cycles of the length of only few quarters for numerous high-tech sectors for the period of 1995.1-2002.2. These cycles seem particularly prevalent in biotechnology, electronics, financial services, healthcare and medical services and consumer products. Moreover, and interestingly, in a number of prominent high technology segments the numbers of venture financing deals do not seem to be directly affected by the stock market bubble in 1998-2000.[4]

Our empirical finding complements scant earlier evidence. E.g. based on annual data Lerner et al. (2000) find low frequency cycles in the U.S. biotechnological industry between 1978-1995. Likewise Gompers and Lerner (1999, Fig. 1.1) find weak evidence of low frequency cycles for aggregate U.S. data from 1965-1996.[5]

What policy implications can we derive from our findings? Basically venture cycles imply dynamic inefficiencies, which might be considered to justify public policy intervention. We discuss the role for structural regulation, (mandatory) information sharing and screening subsidies. Since cycles are a result of uncoordinated competition among venture capitalists reducing the intensity of competition might result in large transfers from innovators to venture financiers, and thus reduce the participation of innovators. Therefore, mandatory information sharing seems a better instrument to coordinate and, possibly, intensify competition among financiers. The problem of information sharing, however, is that it invites poaching activities after a successful start-up phase, and, thus, intensifies ex-post competition after the start up. This again reduces ex-ante competition prior to the start-up. As Gehrig and Stenbacka (2002) demonstrate in the presence of switching costs, information sharing may reduce the overall competitiveness of the VC-market, which again reduces potential participation by innovators.

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[4] In those sectors even the valuations of the venture capital deals does not seem greatly affected by the stock market bubble. See section II.

[5] See also Shoar (2002, p.2 „Cycles are no News to the Venture Capital Industry“) for more recent aggregate data of the whole venture capital industry.

Public subsidies finally could generate perverse screening and financing incentives. To the extent that venture capitalists exit their investments after a successful start-up phase, they may have incentives to window dress their clients at the IPO-stage and unload them on the stock market. This argument could provide a potential explanation for the lacklustre performance of the "Neuer Markt" in Germany and its ultimate closure after only 5 years as a result of perverse subsidy related financing incentives.[6]

The paper is organized as follows. Section II provides empirical evidence about venture cycles in certain industries. Section III presents a formal model of the screening activity of venture capitalists and section IV discusses its relation to the empirical evidence. Section V discusses policy implications and Section VI concludes.

II. Time Series Evidence of Venture Capital Investments

While there is a lot of evidence about contractual structures in venture financing (e.g. Gompers and Lerner, 1999, Kaplan and Strömberg, 2000, 2002) and about the relation of venture capital support and innovative activity and growth (e.g. Kortum and Lerner, 2000, Hellmann and Puri, 2000 and Bottazzi and Da Rin, 2002) very little is known about the time series properties of venture investments.

Gompers and Lerner (1999, Fig. 1.1) provide time series evidence on annual aggregate data for the whole venture industry from 1965-1996. Lerner et al. (2000) find empirical evidence about the influence of financial cycles on contractual design and conduct in venture backed companies in the biotechnology industry. They also provide first evidence on cycles in that industry. Between 1978 and 1995 about 3 full cycles can

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[6] Note that in the early phase of a new market reputational mechanisms may not be available.

be identified (Lerner et al., 1999, figure 2). Based on a slightly longer period of aggregate observations also Shoar (2002) finds that "cycles are no news for the venture capital industry".

While generally access to data on venture capital investments is highly confidential, and generally restricted, we present first evidence based on quarterly data made public by PriceWaterhouse, VentureOne and the National Venture Capital Association (NVCA) from 1995.1-2002.2 (NVCA, 2002). These data are disaggregated into 17 sectors including the most prominent high-technology industries. The raw data provide information about total investments in each sector as well as the number of venture capital deals.

Both observations are aggregated across all stages of venture financing, i.e. seed financing, start-up financing and follow-on offerings (including expansion finance and later stage finance). Since we are mainly interested in explaining project selection detailed information about the financing stages would clearly be desirable but, at this stage, such data are not available to us. Currently such information is only available at an annual frequency (e.g. Bottazzi and Da Rin, 2002) for the years 1991-2000 and 6 industrial sectors. However, as we shall see annual data are not very revealing, since the screening cycles are really a matter of quarters or, possibly, even months.

Now let us have a look at the data. Appendix 1 presents the quarterly growth rates of financial transactions for all 17 industries. It seems fair to state that a high degree of cyclicality can be observed in virtually all industries and aggregates considered. Moreover the pattern of the cycles does not seem to be substantially affected by the stock market bubble in 2000. This picture is essentially repeated with the valuation free data on transaction numbers, which are not reported here. Hence, on the basis of aggregate data for the overall venture capital industry it appears that general stock market conditions do not seem to drive and dominate venture capital investments and venture capital cyclicality.

More information about the nature of the cyclicality in the various industries can be read from the respective power spectra in Appendix 2. Again, since those spectra are very similar for financial volumes and numbers of transactions we only report the information for financial volumes.

It appears that most spectra concentrate power on high frequencies with a low numbers of quarters per cycle, mainly between 2-5 quarters per cycle. This includes important sectors such as biotechnology, consumer products and services, financial services, health care, electronics, medical devices and equipment, and semiconductors. In all these cases lower frequencies tend to attract negligible spectral weight.

In the cases of information technology, retailing, networking and equipment, computers and peripherals and media and entertainment a significant low frequency component is present, suggesting a lack of stationarity.[7] In all these industries high frequencies of 2-5 quarters per cycle attract higher power than the low frequencies. Only in the case of the software industry the low frequency component seems to dominate all other frequencies.

In summary, both in industries with stationary and non-stationary data high frequency cycles from 2 to 5 quarters can be identified in all but one industry. Moreover, the length of the dominant cycle varies significantly across industries. This empirical phenomenon we want to identify with the term venture cycle.

What is the source of this high frequency cyclicality? In the sequel this paper attempts to provide an economic explanation of this regularity.

III. Venture Capital Financing with Costly Screening

Let us now present a theory of venture capital financing with costly screening. The theory builds on the framework of Gehrig and Stenbacka (2003). Consider a dynamic and stationary market environment. Each period a new cohort of potential innovators enters the market. For simplicity, these potential innovators are of two types: good (G) or bad (B). These potential innovators arrive without funds but possibly with project ideas that could generate positive cash-flows in the market. One unit of funding is required to fund each project. We assume that only G-type entrepreneurs can generate a positive cash-flow of R_G if they are successful, which happens with probability π. Otherwise, they earn a zero cash-flow. B-type entrepreneurs can never generate a positive cash-flow. Their only interest is to consume benefits from control, incorporated in the project returns, while in charge of a project. All entrepreneurs are impatient with discount factors $\delta_e < 1$.

These innovators have access to no other source than the venture capital industry for financing of their projects. Venture capitalists possess specific screening abilities and expertise not available to other financial intermediaries and potential competitors. Implicitly, we are only interested in markets where the funding of innovative projects is too risky for banks and other types of intermediaries.

Venture capital firms refinance at a competitive deposit market equal to the (safe) interest rate $r_0 \geq 0$. For subsequent use we let $R_0 = 1 + r_0$. The venture capitalists are also impatient with a discount factor of $\delta_F < 1$.

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[7] These industries appear to have been more affected by the stock market bubble of 1998-2002 than those

The contracts offered by venture capitalists can be viewed as standard debt contracts with a fixed repayment obligation including bankruptcy provision. Since we model cash flow uncertainty as a two-state variable, however, this characterization is general enough to also enable an interpretation of this funding in terms of equivalent equity contracts. As much of literature emphasizes, the art of venture financing includes the design of an optimal capital structure. In our framework we abstract from the design issue. Contractual form is a matter of indifference in our set-up. Therefore, in the sequel, we can concentrate on the terminology of debt contracts without affecting the generality of our claims.

Venture financiers cannot directly distinguish type-G from type-B applicants. However, they have access to a specific screening technology, which is (implicitly) available to other types of intermediaries only at (much) higher costs. We will concentrate the analysis on the case of perfect screening technologies.[8] Hence, assume for now that by spending a fixed project-specific monitoring expenditure $c>0$ the venture capitalist can determine the type of a project application with certainty. Clearly, if the financier makes use of the available screening technology it is optimal to grant credit when a project is classified as G and to denying funding when classified as B.

The venture industry operates repeatedly with an infinite horizon $t=0,1,2,\ldots$. In each period there is a constant number of $F \geq 1$ venture financiers.

Each period a mass of new potential projects enter the venture capital market. Denote the mass of entering projects in period t by η_t and the proportion of profitable (good) projects by $0 < \lambda_t < 1$. In principle, both the size of the pool of new projects as

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with stationary growth rates.

well as its composition may vary over time. Since our concern is to analyze how the conduct of banks engaged in repeated competition may generate cycles, we will be largely concerned with a stationary pool of new projects so as to actually bias the model against cycling. Hence, let $\eta_t = \eta = 1$ and $\lambda_t = \lambda$ for $t=1,2,...$.

In each period t venture capitalists face a pool of project applications consisting of new entrants and, in addition, applicants that have been rejected by some rival financier in some earlier period. The statistical properties of this pool therefore depend on whether financiers recall earlier applications and on the extent to which the venture capital industry institutes mechanisms of information sharing. We assume perfect recall on the side of the venture financiers. Hence a rejected applicant will direct future funding applications to rival financiers and leave the pool of applicants when the set of venture capitalists is exhausted. Moreover, we assume that venture financiers do not share information about earlier screening results. Accordingly, the pool of applications for a given venture capitalist consists of a random allocation of the new vintage of projects and a share of opportunistic applications of formerly rejected entrepreneurs.

Hence, venture financiers need to decide about their screening and funding activities. They can fund without screening, they can provide screened funding only, or they can remain inactive altogether. After the screening results are obtained, or when the financier decides to offer unscreened funding, the financier and the entrepreneur enter the stage of lending rate negotiations. We assume that a successful entrepreneur can always threaten to acquire a second screen from a competing venture financier at some later period. However, since this second offer is subject to delay, the current financier

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[8] In Gehrig and Stenbacka (2003) we investigate in great detail the more general and realistic screening technologies with classification errors of type I and type II.

can exert a limited degree of market power and thereby extract a positive rent even in the presence of competition.

When entrepreneurs get a second screen they can enforce a contract at marginal costs due to Bertrand competition among the two rival financiers.[9] Let $n \geq 1$ be the expected time for another screen from some rival venture capitalist. In this case the current financier can charge the rate $R = (1-\delta_e^n)R_G + \frac{R_0}{\pi}$, which implies a mark-up of $(1-\delta_e^n)R_G$ over the venture capitalist's expected cost of funding for screened finance, $\frac{R_0}{\pi}$. Thus, the mark-up is a decreasing function of the entrepreneur's discount factor, δ_e, while it is an increasing function of the delay in acquiring a second screen, n. If the venture financier faces no competition we assume that it extracts all the surplus by charging $R^m = R_G$.

In case of inactivity the new project holders can decide afresh about which venture capitalist to address. For simplicity we assume that already matched entrepreneurs stay with an inactive financier until this financier starts screening again.[10]

We proceed by first discussing the case of a single venture capitalist in subsection A). This analysis sets the stage for the case of competition in the venture capital industry in subsection B).

A) A Monopolistic Venture Capitalist

[9] In the sequel we will concentrate on pool characteristics which generate screening incentives for banks. Hence we will not be particularly interested in the case of unscreened finance, as the analysis of this case is completely straightforward with no interesting dynamics.

[10] Gehrig and Stenbacka (2003) discuss alternative rematching assumptions such as random re-matching. They find that the basic results and intuitions are robust with respect to the rematch assumption.

Let us start the analysis with the case of a monopoly financier or a cartelized industry. This case is particularly simple, since in such an environment the monopolist can always extract all the project surplus.[11] Thus the pricing of the VC-deal is straightforward and we can concentrate on the screening activity of the monopolist.

Basically, the monopolist can pursue three strategic options: (i) inactivity (no screening and no funding), (ii) screening and funding of worthwhile projects and (iii) unconditional funding without screening. While unscreened funding requires a sufficiently good pool of applicants and inactivity will occur for a sufficiently adversely selected pool, screened financing will occur for the intermediate case of a pool of applicants that is moderately adversely selected.

In fact there are critical levels $0 < \underline{\lambda} < \overline{\lambda} < 1$ of pool compositions that decompose the parameter space into three regions where the venture capitalist will pursue one of those strategies. In other words, there is a $\bar{\lambda} = \dfrac{R_0 - c}{R_0}$<1, such that for $\lambda > \overline{\lambda}$ the venture capitalist will no longer engage in costly screening. In this case his expertise is no longer relevant, and in principle, he faces competition by banks and other intermediaries that do not have access to the screening technology at the cost *c>0.* It can immediately be seen that $\dfrac{\partial \overline{\lambda}}{\partial c} = -\dfrac{1}{R_0} < 0$ which implies that an increase in the screening cost will decrease the upper threshold for screening to be optimal.

On the other if the pool is sufficiently badly composed, more precisely if $\lambda < \dfrac{c}{\pi R_G - R_0} = \underline{\lambda}$, the venture capitalist prefers to withdraw from the market all

[11] At this stage we ignore the complications that arise, when output is a joint team effort and both the entrepreneur and the financier face market power.

together. The lower threshold of the pool composition, $\underline{\lambda}$, for screening to be profitable satisfies the comparative statics properties that $\frac{\partial \underline{\lambda}}{\partial c} = \frac{1}{\pi R_G - R_0} > 0$ as well as $\frac{\partial \underline{\lambda}}{\partial R_G} = \frac{-\pi c}{(\pi R_G - R_0)^2} < 0$. Increased screening costs raise the lower bound for screening to be profitable, whereas access to potentially more attractive projects makes screened funding sustainable for pools with a lower proportion of creditworthy projects.

Since the pool of new projects is stationary over time, the monopolist venture capitalist will optimally make the same decision in each period. A venture capitalist with monopoly power will optimally engage in funding based on project-specific screening only in the intermediate range of pool characteristics with $\underline{\lambda} < \lambda < \overline{\lambda}$. Hence, overall market performance will be stationary in this case. This is our first result:

Result 1 (Monopoly)*:* *In a stationary environment the pool composition λ determines whether a monopoly financier will never fund a project, screens each period and grants funding to approved projects or always provides funding without screening in all periods. The stationary equilibrium is characterized by the stationary quality $\mu_t = \lambda$ of the pool of applications in each period with*

(i) inactivity for each t (t=1,2,...) *if* $0 \le \lambda < \underline{\lambda}$

(ii) screening with repayment rate R_G for each t *if* $\underline{\lambda} \le \lambda \le \overline{\lambda}$

(iii) funding all projects without screening at the rate R_G for each t *if* $\overline{\lambda} < \lambda \le 1$.

Proof: See Gehrig and Stenbacka (2003).

Accordingly, with a single venture capitalist or with a completely coordinated venture capital industry the funding activities are stable in a stationary environment. The monopolist financier, or the cartel, implicitly exercise perfect recall and ensure perfect communication across periods. These two assumptions eliminate all potential dynamic links. Hence, in a coordinated environment the emergence of funding cycles requires exogenous variation in the composition of the pool of new applicants across periods. A distinguishing feature of competition, however, seems to be the lack of (complete) coordination.[12] Will this lack of coordination render cycles possible or will it even generate cycles by necessity?

B) Competition in the Venture Capital Industry

In this section we focus, for simplicity, on a duopolistic venture capital industry. Uncoordinated competition generates an important intertemporal link. Namely, rejected applicants get another chance to apply for funding at other venture capital firms in the next period, and, hence, these applicants tend to reduce the quality of competitors' applicant pools. How does this inter-temporal pool-worsening effect impact on venture capitalist's screening incentives and financing rates in equilibrium?

With passive entrants each duopoly venture capitalist essentially attracts half of the profitable projects each period. Since those passive entrepreneurs stay until they are screened, they will ultimately be funded by the venture firm they initially contacted. In this scenario entrepreneurs are randomly allocated and there is virtually no competition initially.

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[12] See Bolton, Farrell, 1990.

However, venture capitalists may decide not to screen each period. To see why this happens consider a period t in which both financiers have engaged in screening. This implies that all available worthwhile projects of earlier periods get funding. Hence in period *t+1* the individual pools of each bank consist of 50 percent of new applicants plus the mass of projects that have been rejected previously. Accordingly, each venture capital fund faces a pool of a quality $\mu_{t+1} = \dfrac{\frac{\lambda \eta_{t+1}}{2}}{\frac{\eta_{t+1}}{2} + \frac{(1-\lambda)\eta_t}{2}} = \dfrac{\lambda}{2-\lambda} < \lambda$, which is lower than the quality of the newly-born generation of projects. This quality may well fall short of the critical level $\underline{\lambda}$ for profitable screening. If this happens the financier, and in fact both financiers, prefer not to screen in period *t+1*. So screening implies that each venture capitalist faces formerly rejected applicants in its pool in addition to the new applicants. Since venture capitalists do not communicate they cannot distinguish the different vintages of applicants.

If both financiers decide to remain passive in period *t+1* the pool will improve again in period *t+2* because of the inflow of a pool of new applicants with higher average quality. Hence, $\mu_{t+2} = \dfrac{\frac{\lambda \eta_{t+1}}{2} + \frac{\lambda \eta_{t+2}}{2}}{\frac{\eta_{t+1}}{2} + \frac{\eta_{t+2}}{2} + \frac{(1-\lambda)\eta_t}{2}} = \dfrac{2\lambda}{3-\lambda} > \dfrac{\lambda}{2-\lambda}$. If the pool is not yet good enough to render screening profitable in period *t+2* it will improve over time until eventually screening is profitable again.

These two counteracting forces, screening-induced pool worsening and the pool improvement after periods of inactivity, are the mechanisms that may generate persistent screening cycles.

Before we state the result, we still need to discuss lending rate setting. Note that periods of inactivity will increase the cost of delay for entrepreneurs**.** If they have to anticipate a spell of n periods of inactivity at the rival fund, the costs of delay are $\left(1-\delta_e^n\right)R_G$. An entrepreneur classified to be creditworthy can always threaten to acquire a second screen from a competing financier at some later period. If this second offer is subject to an expected delay of n periods the entrepreneur will in fact face a switching cost of $\left(1-\delta_e^n\right)R_G$. For that reason the incumbent financier can exert some market power and thereby extract some rent despite the existence of competition. In light of these switching costs a high-quality project holder would find it profitable to delay initiation of the project and switch to the rival financier if

$$R(n) = \left(1-\delta_e^n\right)R_G + \frac{R_0}{\pi} \quad < \quad R_G .$$

Consequently, competition will discipline the venture capitalists and generate the repayment obligation of

$$R(n) = \left(1-\delta_e^n\right)R_G + \frac{R_0}{\pi}$$

in equilibrium.

At this lending rate screening is profitable provided that $\lambda(\pi R(n) - R_0) - c \geq 0$, which implies a critical level of pool composition $\underline{\lambda}(n) = \dfrac{c}{\pi R(n) - R_0} = \dfrac{c}{\left(1-\delta_e^n\right)\pi\ R_G}$.

We can now state the simplest set of conditions under which competition will necessarily generate a regular 2-cycle of venture investments.

Result 2 (Competition in the Venture Capital Industry): *If* $\delta_b < 1$ *and if both* $\frac{\lambda}{2-\lambda} < \frac{c}{\left(1-\delta_e^2\right)\pi\ R_G}$ *and* $\frac{2\lambda}{3-\lambda} > \frac{c}{\left(1-\delta_e^2\right)\pi\ R_G}$*, there is a unique and symmetric equilibrium in the venture capital market with regular 2-cycles consisting of alternating phases of financing and inactivity. In active periods the funding terms are given by* $R(2) = \left(1-\delta_e^2\right)R_G + \frac{R_0}{\pi}$.

Proof: See Gehrig and Stenbacka (2003).

The cyclical nature of the equilibrium in the venture capital market is quite straightforward, given the pool-worsening effect after a screening period and the pool improvements subsequent to a period of inactivity. While this equilibrium may not be the only equilibrium of the repeated game between the venture financiers, the pool-worsening argument applies to any equilibrium in the venture market. Under the conditions of Result 2 any equilibrium will exhibit some element of cycling.

The pool-worsening effect induced by screening has been analyzed first by Broecker (1990) and subsequently by Gehrig (1998) and Kanniainen and Stenbacka (2000) within the framework of static banking models. The present paper draws out the dynamic implications of this pool-worsening effect.

Discounting by venture capitalists is also important for the emergence of cycles. By deferring screening in periods that can be clearly identified with negative profits the expected costs of screening can be reduced. In the absence of a time preference for financiers, cycles may still arise, but stationary equilibria may also emerge with constant screening in all periods. In this case banks lend at the constant interest rate of $R(1) = (1-\delta_e)R_G + \frac{R_0}{\pi} < R(2)$.

Overall the basic mechanism characterized by Results 1 and 2 delineates how uncoordinated screening by competing venture capitalists generates a dynamic externality causing substantial instability, or at least cycles, in venture investments. This instability shows up as an intertemporal agglomeration of funding activities so that phases of boosted screened funding alternate with phases of inactivity during which the venture market does channel less funds to profitable projects.

The basic finding of Result 2 is robust with respect to various generalizations in the set-up as shown by Gehrig and Stenbacka (2003). For example, different re-matching assumptions for entrepreneurs after market periods of inactivity, increasing the number of venture capital firms to F>2, different processes of rate negotiations between venture financiers and entrepreneurs or allowing imperfect screening technologies will not qualitatively annihilate the necessity of the emergence of investment cycles. Furthermore, the emergence of venture cycles is robust relative to processes of syndication among venture capital firms as long as this process does not extend to the whole industry, thereby essentially transforming the market industry into a monopoly.

Finally, it should be emphasized that we concentrate on regular 2-cycles only for pedagogical reasons. Even the simple framework adopted here does generate quite a rich set of (complex) dynamic patterns in equilibrium. The model does not necessarily predict the emergence of 2-cycles. It does predict, however, that in an otherwise constant world, venture investments as measured by the number of deals or by value are variable and not constant, and possibly cyclical in the strict sense.[13] Of course, to the extent that the inflow of projects is not stationary (or even cyclical) our theory does only predict a complex dynamic interaction between the pool dynamics and the dynamic pool-worsening externality. This interaction might very well incorporate various amplifying mechanisms.

IV. On the Relation between Data and Theory

How does the theory presented above help to understand the time series properties reported in section II? First of all it should be noted that apparently general economic conditions such as business cycles, stock prices and interest movements necessarily do affect and in some industries (e.g. in telecommunications, software, media and entertainment, retailing and distribution, IT-services – see figures 12-16) even seem to dominate the screening and investment activity of venture capitalists.[14] Even in our limited data set the strong influence of the stock market boom in 1999- 2000 on venture activity is clearly recognizable.

However, the data also reveal idiosyncratic movements and high frequency cyclicality with cycles of average length of few quarters in almost all industries. These cycles seem particularly pronounced in biotechnology, financial services and consumer products, health care and medical services, but they do seem to occur in most of the other industries as well, even where their influence is clearly dominated by the stock market boom.

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[13] For example, Gehrig and Stenbacka (2003) provide conditions on the pool characteristics for the emergence of asymmetric n-cycles.

[14] The same holds for aggregate activity in the venture capital industry.

In principle, these cycles could be completely caused by cyclical arrival of applications and new project ideas. In that case our theory would not matter at all. If on the other hand the inflow of applications were rather stationary, the documented cyclicality would appear in accordance to our theory. Unfortunately, on the basis of the available data we cannot test to what extent our theory contributes to the documented cycles. We would need to have observations not only about successful projects that ultimately did acquire funding, but also about rejected projects. Only this joint information would allow us to track pool quality over time.

Another complication for the interpretation of the data arises from the fact that our data do not distinguish between different stages of venture investments. While our theory mainly applies to seed finance and the start-up phase, the data also comprise follow-up funding and last-stage funding immediately prior to an IPO. Clearly, follow-up and last–stage financing follow positive results of earlier commitments. The cyclical features, therefore could also result from the aggregation of different stages. Unfortunately, our data are broken down with respect to the various financing stages only for the aggregate venture industry and not by industry sector.

Finally, at this stage we ignore the influence of fund raising conditions for venture capitalists. In principle, variations in general capital market conditions are measured by the refinancing cost R_0. In our theory R_0 does affect both critical values of λ, and, therefore, necessarily the screening incentives and the properties of venture cycles.

IV. Public Policy Implications

On the basis of our theory and empirical observations, and in accordance with widely held beliefs among industry experts, investment cycles represent a characteristic feature of venture financing. These cycles could be viewed as a certain kind of market failure since they entail allocative inefficiencies as they tend to delay the implementation of high-tech projects, the value of which depreciate at a high rate. Thus from a public policy perspective the question arises, what institutions and/or regulations might improve market outcomes in the venture industry. Since cycles do not occur in cartelized venture industries one might argue that regulating market structure might be a suitable remedy.

Alternatively, one might argue that cycles are the result of "too much" decentralization. Pool worsening is a social problem because of the uncoordinated information production by independent venture capitalists. Thus truly bad projects receive several chances and, possibly, several reviews. From a societal perspective this cost arises because negative information produced by one venture financier is lost for society after this type is rejected.[15] [16] It appears that information sharing agreements or information sharing institutions might be a proper policy response to this problem.

Finally, since cycles do arise because screening does not seem worthwhile in certain periods, one might argue that subsidizing screening activities of entrepreneurial activity might stimulate overall information production and reduce the social costs associated with investment cycles. We will discuss these arguments in turn.

A) Market Structure Regulation

Our theory predicts that cycles are inherently related to competition and decentralization. Therefore, one might "solve" the inefficiencies caused by investment

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[15] Obviously, positive information is not lost since those entrepreneurs will receive funding.

cycles by fostering cartelization or by monopolizing the venture capital industry. Clearly, a monopolist would screen efficiently, since he could earn the full returns on his screening activities. In our base model the monopoly market structure would indeed implement an efficient allocation.

However, monopoly in the venture capital industry appears efficient in our model only because of its simplicity. This result is not robust at all. For example, extend the model to allow for double-sided effort. Hence let the surplus generated by each project depend on the screening activity of venture capitalists and prior human capital investments by entrepreneurs. In the monopoly solution all the surplus is extracted by the venture capitalist. As entrepreneurs anticipate such rent seeking activities, their incentives to invest in human capital and project specific expertise is impaired relative to competitive situations, when entrepreneurs can secure larger share of the returns of their project proposals.[17] In other words, competition in the venture capital industry is vital to stimulate research by potentially innovative entrepreneurs. A lack of competition will undoubtedly stifle entrepreneurial investment incentives. Consequently, an overall evaluation of competition among venture capitalists involves a tradeoff of the effects whereby competition induces on the one hand stronger innovation incentives for the entrepreneurs and on the other hand higher volatility potentially including longer periods of inactivity.

Presumably, in a long-term perspective entrepreneurial investment incentives are of higher order relevance to the performance of the venture capital industry than the inefficiencies caused by investment cycles. Therefore, regulation of market structure or

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[16] See also Sah and Stiglitz (1988) for a theory that highlights potential costs of decentralization.

[17] See Padilla and Pagano (1997) for such an analysis in a banking context.

a coordination-friendly attitude by competition authorities can hardly be supported to improve the societal performance of the venture capital industry.[18]

B) Information Sharing

On the basis of our model we identified the lack of coordination as the fundamental source of investment cycles. The applicant pool deteriorates over time because of cherry picking by the venture funds, which leaves the less-promising projects to be repeatedly evaluated by competing financiers. As long as those projects are not perfectly screened out of the applicant pool, for example due to classification errors in the screening technology, those project holders might still want to exploit their option of receiving finance by addressing other venture funds. The more venture funds are available, the higher is the probability for less promising projects to receive funding. In other words, decentralized information production by venture financiers does not communicate negative information of earlier screens to later ones. Of course, common evaluation registers or some form of information sharing that tracks individual entrepreneurs from their first project application could represent mechanisms making it possible to improve the information base available to the venture capitalist industry.

If we were to allow such information sharing, in our framework B-types would only receive a single screen, after which they would not get another chance for further funding. In other words, with industrywide information sharing all venture capitalists could learn the negative scores from the first application. In such a world all venture

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[18] With societal performance we mean real variables such as number of innovations and patents as well as rates of real production (and consumption) growth and aggregate profits (in the venture capital industry as well as in the real sectors).

funds would effectively be able to concentrate on the inflow of new ideas and projects only. As in the monopoly case cycles would cease to exist.

Indeed the common practice of venture capitalists to fund specific proposals as joint ventures with further venture capitalists can be viewed as a mechanism to share information with other venture firms that potentially have access to different and potentially complementary information sources, and, therefore, to reduce the impact of the informational externality. Nevertheless, recent empirical work shows that those venture typically consist of only few partners only leaving ample room for decentralization and duplication of screening between different “teams”. Therefore, such ventures are unlikely to completely annihilate the pool externality.

While information sharing seems to be a reasonable response to the problem of investment cycles, however, some important caveats remain. Firstly, the activities of information acquisition and credit evaluation seem to represent the core competences of venture capitalists. Consequently, these activities essentially form the primary dimensions of competition in the venture capitalist industry. Thus, the primary non-cooperative incentives would challenge an information sharing regime to a much higher extent in the venture capitalist industry than in the banking industry. Secondly, imperfections in the screening technology would limit the potential benefits of information sharing. For this reason the benefits of information sharing would be lower when the financiers face a higher degree of uncertainty if increased uncertainty translates into larger classification errors of the screening technology.[19] Thirdly, and importantly, information sharing provides incentives to venture capital firms to engage more aggressively in “poaching”, i.e. the activity of luring away successful start-ups from

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[19] This aspect is elaborated in greater detail in Gehrig and Stenbacka (2003).

competitors. As ex-post competition after a successful start-up intensifies, ex-ante competition, and possibly ex-ante screening incentives get diluted. Hence, information sharing may have costs in terms of ex-ante competition and ex-ante information production.[20]

Gehrig and Stenbacka (2002) provide a two-period model of information sharing in the banking industry with precisely those properties. They even show that in the presence of imperfect competition overall competitiveness in the banking market is reduced when information is shared.[21] Clearly, this argument applies to venture capital firms equally well as to banks.

In light of these arguments, the benefits of information sharing in terms of reduced cyclicality of venture investments have to be balanced against the potential costs of increased anticompetitive conduct in the venture capital industry. Since anti-competitive conduct does adversely affect entrepreneurial research incentives, again it seems that information sharing should be regarded rather cautiously.

Finally, it should also be noted that information sharing by increasing market transparency could also be misused as a collusion enhancing mechanism in the venture industry.

C) *Subsidies and Tax Incentives*

Finally, let us consider Pigouvian arguments to improve market performance via a tax-subsidy scheme. Since venture capitalists withdraw from screening when the pool

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[20] These aspects are not present in our model in a formal sense. However, these concerns naturally arise when evaluating the policy implications from a broader perspective.

[21] In their model aggregate profits increase in the amount of borrower switching costs. They show that information sharing is particularly profitable for banks when switching costs are high.

composition is sufficiently bad, one might think that subsidizing screening activities could reduce, or even annihilate investment cycles. To the extent that the government subsidizes screening costs it effectively reduces the costs c borne by the venture capitalist. Indeed such a policy may affect cycles and reduce their length. In fact, this feature was already established through the robust comparative static property whereby $\frac{\partial \underline{\lambda}}{\partial c} = \frac{1}{\pi R_G - R_0} > 0$ in a monopoly or $\frac{\partial \underline{\lambda}(2)}{\partial c} = \frac{1}{\left(1-\delta_e^2\right)\pi R_G} > 0$ in a duopoly. Consequently, a policy with the effect of reducing the screening costs would reduce the frequency of inactivity, i.e. it would reduce the critical level of $\underline{\lambda}$. In the limit as the full screening costs are subsidized, venture capitalists will always screen each applicant since $\underline{\lambda} \to 0 \quad as \quad c \to 0$. Overall, this subsidy will generate more screens and, therefore, imply more funding for worthwhile projects as well as higher aggregate screening costs mainly for unworthy projects. Subsidizing screening costs, however, may meet serious problems of implementation and generate serious allocational inefficiencies (in addition to the increase in overall screening outlays).

Implementation of an efficient subsidy of the screening expenses requires that c is observable. Note also that in more realistic settings, the screening costs c would typically vary according to project characteristics. Since governments do not observe project characteristics – after all this is why venture capitalists are so important to fund innovative firms – they cannot reimburse true screening costs. Moreover, it seems that most of the cost components of screening are rather intangible. Screening requires specific project and market expertise and private information acquisition, as well as access to networks and "hard" accounting information. It would seem very difficult to separate necessary cost components from fringe benefits and information that could be used for other (consulting) activities. In other words, compensating venture capital firms for true costs would not seem feasible since firms may want to exaggerate their expenses.

Subsidizing observation costs may, however not be desirable either. Consider a market environment with $\lambda < \underline{\lambda}$. In this case, under competitive conditions no market activity would occur, i.e. venture capitalist would neither screen nor fund. To the extent that screening is subsidized, $\underline{\lambda}$ may decline to a level that venture capitalists find profitable again. Now venture activity could resume. However, from a societal point of view the returns to the subsidies will not cover the outlays under these circumstances, i.e. the returns will be negative.

Given that screening costs c per se may be difficult to subsidize, governments might want to subsidize potentially innovative entrepreneurs directly. In fact, such a subsidy scheme describes the essential features of many industrial policy or technology policy instruments employed by the European countries in order to foster innovation and the creation of jobs. How does such a subsidy affect venture financing in our framework?

By subsidizing entrepreneurs, cash flows are enhanced by the amount of the subsidy. Obviously, if the subsidies are excessive, venture capitalists can refrain from screening because financing becomes essentially a riskless activity. But even for moderate subsidies venture financiers might want to screen and fund projects that would not be viable in the absence of such subsidies**.** Within the framework of our model this conclusion is formalized through the comparative static properties whereby $\frac{\partial \underline{\lambda}}{\partial R_G} = \frac{-\pi c}{(\pi R_G - R_0)^2} < 0$ in a monopoly or $\frac{\partial \underline{\lambda}(2)}{\partial R_G} = \frac{-\pi\left(1-\delta_e^2\right)c}{\left(1-\delta_e^2\right)^2 \pi^2 R_G{}^2} < 0$ in a duopoly. Independently of the market structure the subsidy is basically transferred to venture capitalists, resulting in socially excessive screening, and possibly funding.

Ultimately, however, the effects of such subsidy schemes have to be judged against their implications for the incentives of entrepreneurs to innovate. Our contribution merely highlights some of the indirect costs and undesirable consequences of such types of industrial policies for innovative activities. To the best of our knowledge the literature has not so far focused on these aspects

V. Concluding Comments

While our theory accords well with the observations of the U.S. venture capital industry the questions arises to what extent it is applicable to the European experience in this regard. According to Bottazzi and Da Rin (2002) a major structural difference between the U.S. and the Continental European markets seems to be the late development of trading platforms for newly established firms in Europe. The venture capital activity did not "take off" in most of Europe until after the creation of the "new markets" as the designed technology segments of the European Stock Exchanges in 1997/8. Before 1997 meaningful venture activity can be identified only in countries with low cost access to technology markets, such as the UK and, perhaps a little surprisingly, in the Netherlands (see Bottazzi and Da Rin, 2002).

Ironically, after the first downturn of the first meaningful European venture cycle it appears likely that those trading platforms, which may be crucial for venture activity, may be closed or transformed. The Deutsche Börse has just decided in September 2002 to close its "Neuer Markt" , because popular press identifies the "Neuer Markt" as one of the main culprits for the speculative stock bubble 1998-2002. Apparently, numerous formerly rising stars turned out to be economically unhealthy ventures. It would sound particularly bitter, if it turned out that many of the IPOs in the "Neuer Markt" would have to be regarded as the result of distorted screening and funding incentives at the venture financing level as a (rational) response to misguided public funding programs.[22]

On a general level, of course, the question remains: What do venture capitalists do better than banks in the U.S. and Europe? What is different between the activities of today's venture capitalists and the banks during the periods of industrialization? Empirical work by Kortum and Lerner (2000) and Da Rin and Hellmann (2002) suggest that venture capitalists and early banks do/did better – but what?

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[22] Wallsten (2000) documents for the U.S. that a the specific Small Business Innovation Research Programme did not have any positive effect on R&D activity, but did merely crowd out private R&D.

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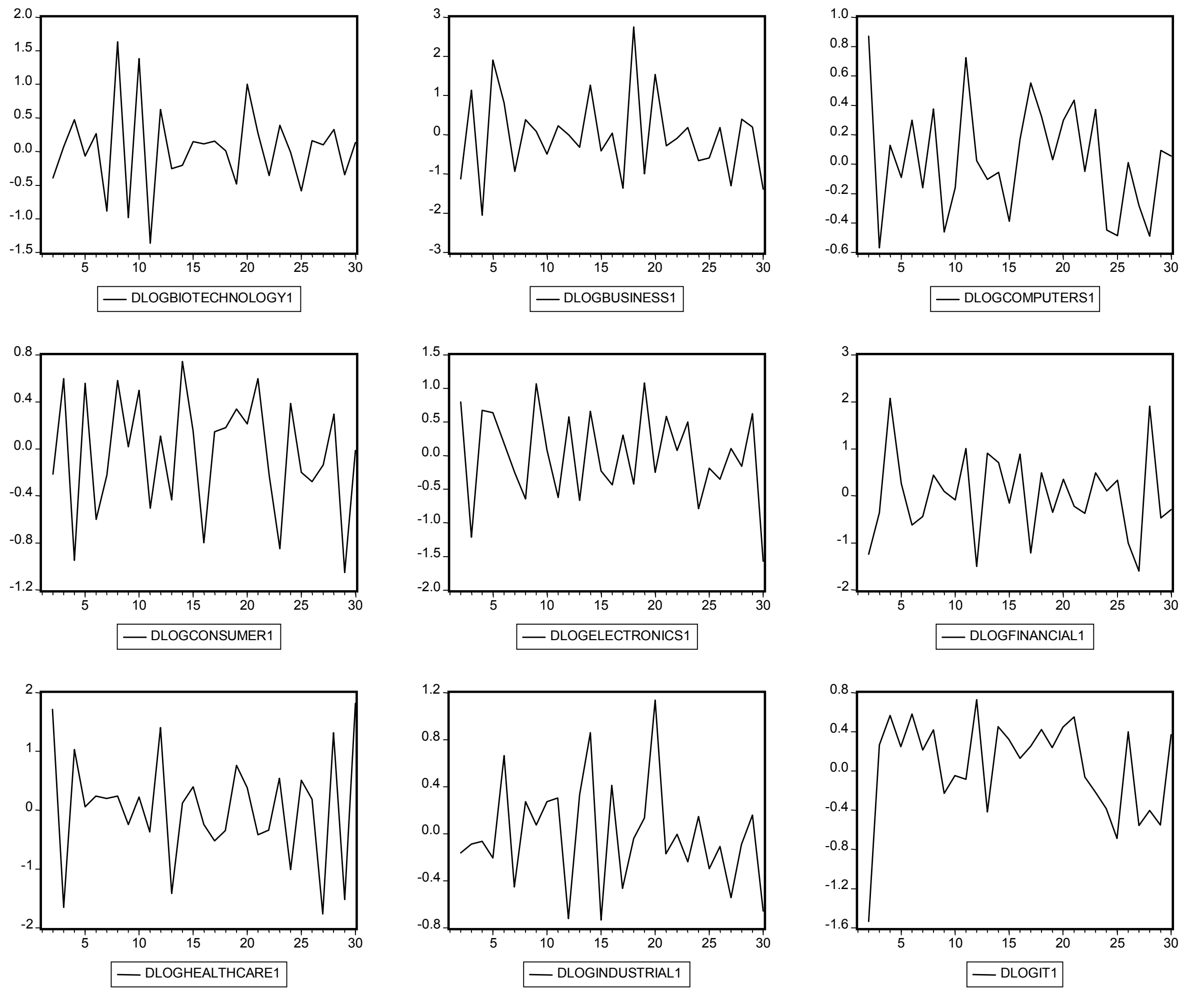
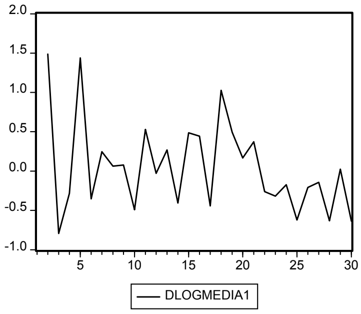
Appendix 1: Growth rates of "Transactions Volume"

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0.0
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-1.0
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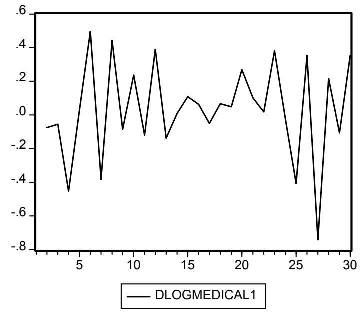
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-.2
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-.6
-.8
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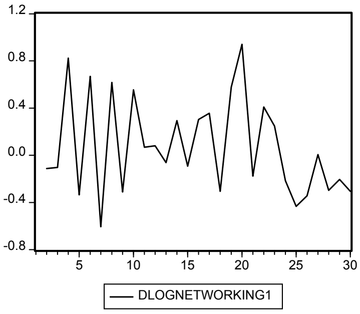
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0.4
0.0
-0.4
-0.8
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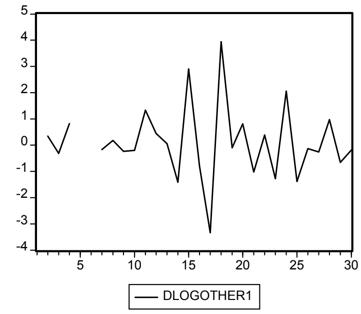
DLOGNETWORKING1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3
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1
0
-1
-2
-3
-4
5 10 15 20 25 30
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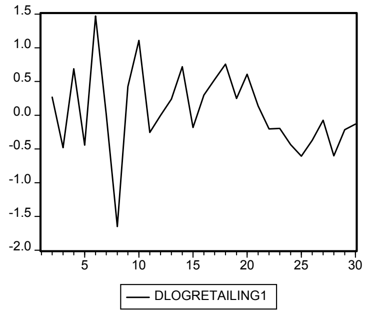
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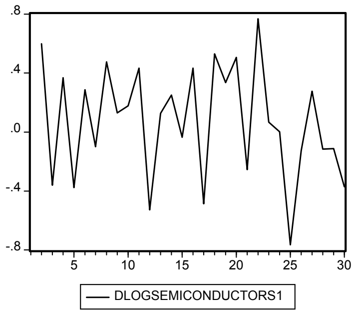
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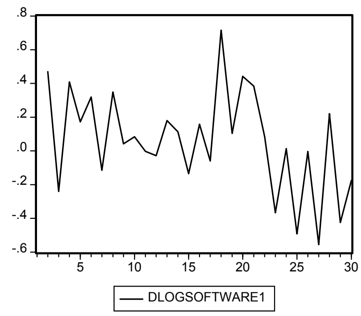
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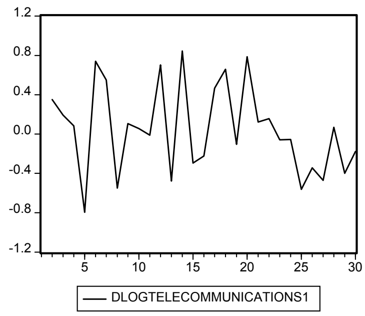
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0.4
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-1.2
5 10 15 20 25 30
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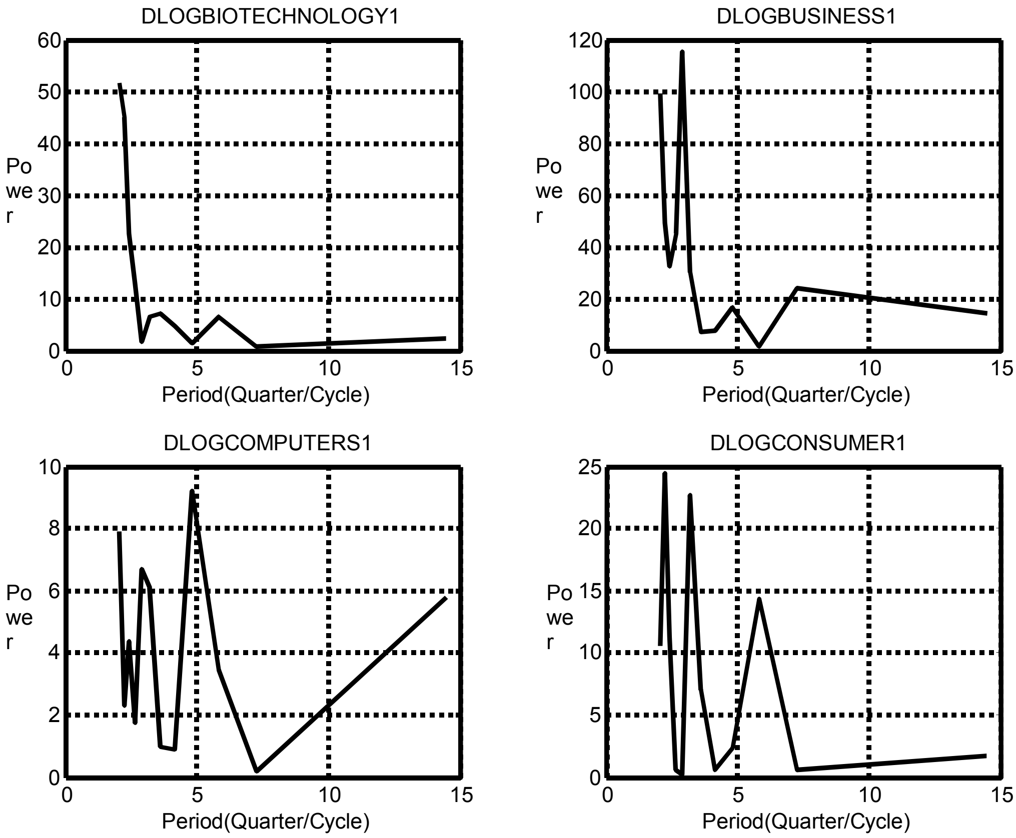
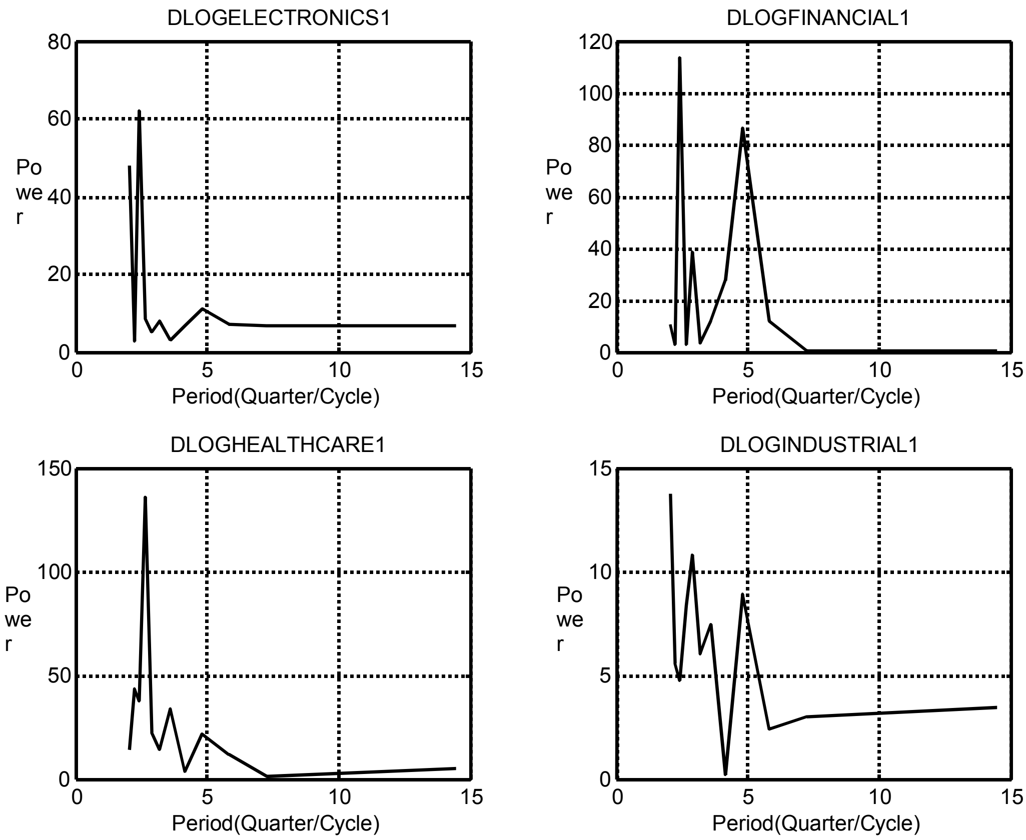
Appendix 2: The spectrum of "Volume" series

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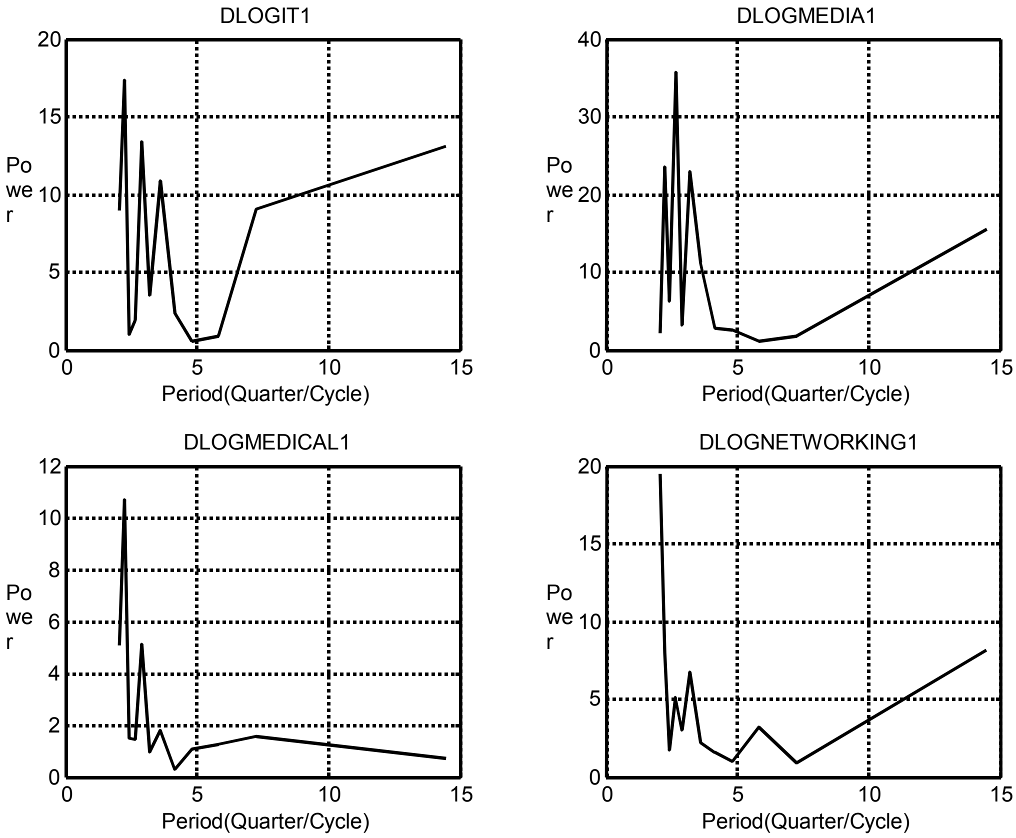
Power
Period(Quarter/Cycle)
DLOGFINANCIAL1
Power
Period(Quarter/Cycle)
DLOGHEALTHCARE1
Power
Period(Quarter/Cycle)
DLOGINDUSTRIAL1
Power
Period(Quarter/Cycle)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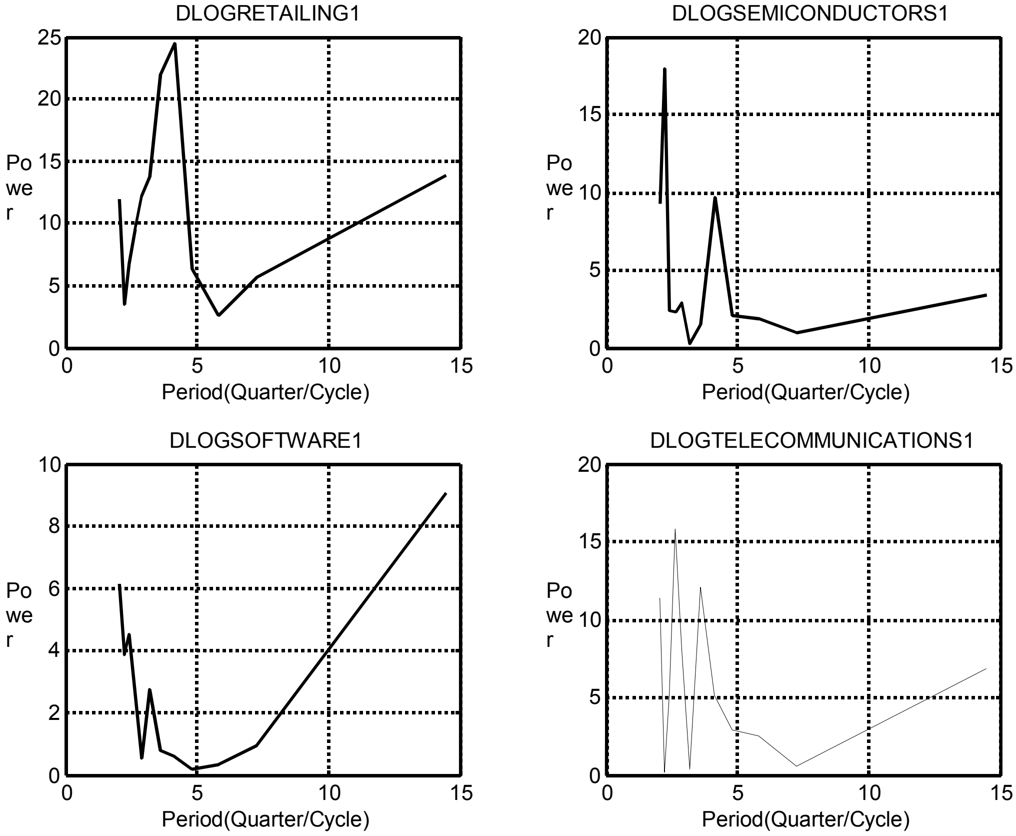
Power
Period(Quarter/Cycle)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DLOGSOFTWARE1
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Power
Period(Quarter/Cycle)

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