

SCREENING CYCLES*

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April 24, 2004

We demonstrate how endogenous information acquisition by financiers creates investment cycles when competing financiers undertake their screening decisions in an uncoordinated way, thereby highlighting the role of intertemporal screening externalities induced by screening competition as a structural source of instability. We show that uncoordinated screening behavior of competing financiers may be not only the source of an important financial multiplier, but also an independent source of fluctuations inducing investment cycles. The screening cycle mechanism is robust to generalizations along many dimensions.

* We are grateful for the comments by seminar participants at the Swedish School of Economics, London School of Economics, ESSEC Paris, University of Frankfurt, Ente Luigi Einaudi, Fondation Banque de France, Deutsche Bundesbank, Mannheim University, Bank of Finland, University of Pennsylvania, the American University, the EEA 2002 meeting in Venice and the NORIO 2003 workshop in Copenhagen. We are particularly grateful to Elena Carletti, Hans Gersbach, Luigi Guiso, Robert Hauswald, Martin Hellwig, Heinz Herrman, Dirk Krüger, Joshua Lerner, Dima Leshchinski, Robert Marquez, Michel Robe, Andrei Sarychev, Frank Schorfheide, Per Strömberg and Hannu Vartiainen for constructive comments and suggestions. Philip Jung and Almira Buzaushina provided excellent research assistance. Financial support of the Academy of Finland, the DAAD, the Deutsche Forschungsgemeinschaft (DFG), the Hanken Foundation, the Yrjö Jahnsson Foundation, and the Volkswagenstiftung is gratefully acknowledged. - Correspondence: Thomas Gehrig: University of Freiburg, D-79085 Freiburg, Germany, thomas.gehrig@vwl.uni.freiburg.de, Rune Stenbacka: Swedish School of Economics, P.O.Box 479, 00101 Helsinki, Finland, rune.stenbacka@shh.fi .

I. Introduction

At the doorstep of the information economy many observers have repeatedly emphasized the critical importance of innovation and human capital as promoters of sustained firm profitability and economic growth. In most cases, however, the transformation of innovative ideas into viable business ventures imposes considerable challenges to the financial system. Namely, due to the inalienability of human capital, innovative activities and R&D-projects typically require unsecured funding, in particular in cases of start-ups. Many modern technology leaders like Amazon, Apple, Cisco, e-Bay, Genentech, Intel, Microsoft and Sun Microsystems are evidence for the success of the American financial system in channeling unsecured initial funding to promising high-quality start-ups. In fact, all of these firms started with the financial support of venture capital firms.

Interestingly, and possibly surprisingly, the funding activities of innovative start-up companies are typically accompanied by a large degree of cyclicity. Hence, industry experts such as W. Sahlmann claim: "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). How can we make economic sense of such an experience? What is the mechanism that renders cycles in innovative activity inevitable?

In our model, screening cycles arise, because competing financiers cannot identify applicants who have previously been rejected by rivals. Hence, we argue that decentralized screening may be the key to explain such cyclicity, which we refer to as screening cycles. Rejected funding by one financier typically imposes a negative externality on rival financiers, since a rejected applicant will typically submit his application to another financier. Accordingly, the total pool of applicants is adversely selected compared to the original pool of incoming projects. Thus the screening activity of financiers necessarily generates a pool-worsening externality, which can affect the whole funding industry. By cherry picking the most promising innovators in a narrow market segment, financiers leave an adversely selected pool for further screening by competitors at later rounds of evaluation. Thus, after a period of intensive screening this

activity will by necessity face diminishing returns in the immediately subsequent period(s). This screening externality will reduce the monitoring incentives for the whole industry until the pool of applicants has recovered to a sufficient extent through the entry of new innovators. When the negative externality is sufficiently strong there might be a phase when screening is no longer profitable. Hence financiers prefer to wait until the pool of projects has improved to a sufficient extent by the arrival of new projects. After a phase of inactivity this pool improvement ultimately triggers positive screening incentives in some later period leading the industry into cycling between states of high and low screening activities, thereby constituting the basis for screening-induced investment cycles. These screening cycles emerge endogenously and by necessity¹ unless the economy is in such a stationary state where the optimal funding strategy is to constantly fund all projects without screening or to constantly grant no finance at all. These screening cycles result from uncoordinated search for creditworthy projects. In a more coordinated setting, i.e. in a cartel or under information sharing, endogenous cycles cannot occur.

Screening cycles occur under conditions where the pools of applicants are adversely selected to a sufficient degree and where screening costs are significant. These conditions are most likely to be met in the venture capital industry. Bengtsson et al. (2002) provide evidence about substantial costs of screening for a particular venture capital fund. They report that the acceptance rate in their sample ranges from 2 to 5 percent², and that the screening process typically involves several rounds of increasing screening intensity by highly qualified experts. Thus screening typically involves significant delay in the order of several weeks and even months until approval of a single successful project. It also comprises significant opportunity costs in terms of expert salaries.

Our model proposes a new mechanism, which is able to explain the high-frequency fluctuations in the number of projects (as well as the investment volumes)

¹ In the case of exogenous random shocks our mechanism will amplify these shocks and generate persistence similarly to alternative mechanisms like the credit cycles analyzed by Kiyotaki and Moore (1997).

² These numbers were communicated by Per Strömberg in a seminar at the Swedish School of Economics, Helsinki.

funded by the venture capital industry in the US. In order to demonstrate this we start our analysis by presenting descriptive evidence for a number of high tech industries, which exhibit funding cycles with typical cycle durations of 3 to 6 months.

In the literature models addressing financial accelerator effects emphasize mechanisms whereby adverse shocks to the economy are endogenously amplified and propagated by credit market imperfections. These models are surveyed within a dynamic general equilibrium framework by, for example, Bernanke, Gertler and Gilchrist (2000). On an intuitive level already Fisher (1933) discussed how credit constraints propagate the effects of shocks on aggregate output and asset prices. According to Fisher, the more the private sector places emphasis on solving its debt problem the deeper the economy will be caught in a debt trap. In an influential recent article Kiyotaki and Moore (1997) constructed a model of a dynamic economy where borrowers' credit limits are affected by the prices of the collateralized assets. Their analysis shows how the dynamic interaction between credit limits and asset prices will constitute an important transmission mechanism whereby shocks to the economy persist, amplify and spill over across different sectors. In contrast to these theories focusing on how asset price fluctuations are amplified and propagated by credit market imperfections our theory does not require the existence of exogenous stochastic shocks.

Our model also sheds light on the relationship between banks' incentives for ex ante monitoring and lending market structure. The existing literature focusing on this relationship within the framework of a static context, for example, Gehrig (1998), Shaffer (1998), and Kanniainen and Stenbacka (2000), has shown that competition tends to undermine the incentives to avoid project-specific classification errors. In this respect the present paper emphasizes an additional mechanism. Uncoordinated screening by competing banks generates a pool-worsening external effect whereby competition opens up a probability of entering a phase of inactivity, where no projects are funded. Furthermore, if the pool-worsening effect is not strong enough to induce inactivity, it will nevertheless increase the lending rate relative to that which a static banking oligopoly would charge.

Our analysis proceeds as follows. In section II we provide descriptive and novel evidence on high frequency cyclicity in the US venture capital industry. Section III presents the basic framework. Section IV analyses a coordinated funding industry operating in the absence of competition. Section V presents the central result and

demonstrates how competition among duopoly financiers gives rise to dynamic instability and cycles in screening and investments. Section VI outlines generalizations and briefly discusses some policy implications. Finally, in Section VII we present some concluding comments.

II. Empirical Observations

While it is generally difficult to empirically identify investment cycles on an aggregate level, Gehrig and Stenbacka (2002b) descriptively document cycles of the length of only few quarters for numerous U.S. high-tech sectors for venture financing in the period of 1995.1-2002.2. Figures 1 and 2 provide the power spectra and the basic histograms of start-up venture capital financing of various US-industries based on quarterly data from 1995/1-2002/4.³ While these figures reveal significant cross-industry variation between biotechnology, computer and peripherals, consumer products, electronics, medical devices, the energy sector and IT-services, they all document significant mass on high frequency variation. So in all sectors the cycles covering 2-6 quarters attain significant if not most of the overall mass. The maximal weight is given to cycles of 2 (computers, medical devices, consumer products, semiconductors), 3 (business products, electronics, financial services, energy, software, telecommunications) and 4 (IT-services) quarters. This holds for sectors that were significantly affected by the stock market bubble (e.g. software, IT-services, telecommunications) as well as to sectors which were not affected in an essential way (e.g. biotech, consumer products, medical equipment).

As outlined above, the cycles seem particularly prevalent in biotechnology, electronics, financial services, healthcare and medical services and consumer products. This evidence tends to document a high degree of industry-specific cyclicity in start-up financing. Moreover, this evidence seems to suggest that the typical period length of our model would vary between 3 to 6 months. The empirical findings reported by Gehrig and Stenbacka (2002b) complement scant earlier evidence. 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. venture capital data from 1965-1996.

³ In current work the authors analyse the dynamics of venture financing form 1970-2003. The high frequency component remains a striking feature of the data in the longer time series.

III. A Model with Costly Screening

Let us now present a stylised model of unsecured financing in a dynamic adverse selection framework. So consider a pool of risky projects. Each project requires an entrepreneurial idea and one unit of funding. The projectholders are equipped with an entrepreneurial idea but do not hold any capital of their own, nor do they have access to outside equity. Thus, we assume that the projects will have to be fully financed by outside financiers such as banks or venture capital firms.

Financiers have access to a competitive capital market. Their opportunity cost of capital equals the (safe) interest rate $r_0 \geq 0$. For subsequent use we let $R_0 = 1 + r_0$. Both types of agents, the financiers as well as the entrepreneurs discount future payments at the same rate of $\delta_0 = \frac{1}{R_0}$. In section IV we will analyse the case of a single financier, while in section V we will allow for two (or more) competing financiers.

Entrepreneurs can be of two types. Either they have a potentially valuable idea and control a project of type G (good) or their idea is fundamentally flawed, in which case we denote the project type as B (bad). We assume that a project of type G has a success probability π as well as an associated return under success, R_G , satisfying $\pi R_G > 1$. Type-G projects yield a zero return only under failure, but the success probability of this project type is sufficiently high so as to justify funding. Projects of type-B are assumed to always generate a zero return. We call entrepreneurs of type G creditworthy, whereas type-B entrepreneurs are not.

Since only successful projects of type G generate a positive cash-flow and since borrowers are protected by limited liability, the negotiations about repayments to the financiers may usefully be interpreted as negotiations about lending rates. Note, however, that we could easily reinterpret these negotiations in terms of an equity share of a venture capitalist. The contractual form of the financing arrangement is not uniquely identified in our highly stylized framework with two-point return distributions. Nevertheless, for ease of presentation we prefer to use the terminology of debt contracts.

Further, as we primarily focus on R&D-projects we assume these to exhibit a depreciation factor δ ($0 < \delta < 1$). This feature captures the return-significance of

timing for high-tech products. It could also be given the interpretation that product-market competitors might be able to imitate the idea incorporated in the project and that this happens at the probability rate δ .

The funding industry operates with an infinite time horizon $t=0,1,2,\dots$. Each period new potential projects enter the banking 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, the size of the pool of new projects as well as its composition may vary over time in the business cycle. Since our concern is to analyze how the conduct of financiers 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.⁴ Thus, we assume $\eta_t = \eta$ and $\lambda_t = \lambda$ for $t=1,2,\dots$.

Financiers cannot directly distinguish type-G from type-B applicants. However, they have access to a screening technology. We assume that access to this screening technology is costly and imperfect. Hence type-I and type-II errors will be made. With α we denote the conditional probability that a truly good project is mis-classified (type-I error), whereas β denotes the conditional probability that a truly bad project passes the credit test (type-II error).

The conditional probability that a project of the pool of new projects classified as creditworthy is truly of type G can be calculated as

$$\tau(\alpha, \beta) = \frac{\lambda(1-\alpha)}{\lambda(1-\alpha) + (1-\lambda)\beta} \quad (1)$$

Therefore, $\lambda < \tau(\alpha, \beta) < 1$ and $\tau(\alpha, \beta) \rightarrow 1$ as we approach perfect screening (i.e. $\alpha, \beta \rightarrow 0$). Furthermore, it can immediately be verified that $\tau(\alpha, \beta)$ is a decreasing function of both α and β .

The project-specific monitoring expenditures are summarized by a parameter $c > 0$.⁵ If the financier makes use of the screening technology it is optimal to grant **funding** to those projects classified as G , while denying finance to those classified as B .

⁴ Clearly, while we predominantly concentrate on the endogenous generation of cycles, our analysis has implications for the amplification of exogenous shocks.

⁵ Hence, in the baseline model we do not allow banks to strategically finetune the quality of information. See Gehrig (1998) for a model with a strategic choice of information quality.

It is worth stressing that the resource cost c may be quite significant. It is meant to measure, for example, the opportunity costs of experts evaluating projects. Moreover, in addition to the financial cost of screening there is a cost of delay because screening requires time. In line with evidence documented in the venture capital industry we assume that screening requires time. Specifically, we assume that screening requires one time period.⁶ Bengtsson et al. (2002) demonstrate that successful applications in the venture capital industry typically require a screening period ranging from a couple of weeks up to a few months.

In each period t financiers typically 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 depend among other things on whether banks recall earlier applications, on the extent to which the funding industry adopts information sharing and on the classification errors prevalent in the screening technology. We assume *perfect recall* on the side of the financiers. Hence a rejected applicant will direct future funding applications to the rival financier and leave the pool of applicants when the set of financiers is exhausted. Moreover, we assume that financiers do *not share information* about earlier screening results. Accordingly, the pool of applications for a given financier consists of a random allocation of the new vintage of projects and a share of opportunistic applications of formerly rejected entrepreneurs.

With a perfectly accurate screening technology, type-B entrepreneurs would have no chance to pass an evaluation test and the pool of funded projects would exclusively consist of creditworthy projects. However, with imperfect credit tests B-type entrepreneurs enjoy an additional positive probability of funding due to banks' classification errors. Thus, in the presence of screening imperfections each competing financier increases the chances of funding for bad entrepreneurs. On the other hand, the screened pool of project applications will be less adversely selected than under a regime of almost perfect screening, since with screening imperfections some good entrepreneurs may have been rejected earlier due to the α -errors.

⁶ In fact, this can be seen as our definition of a period within the context of the present model. However, we want to emphasize that our model focuses on qualitative aspects and the quantitative aspects of this interpretation should not be taken too literally.

In each period t , financiers need to decide about their screening and funding activities. They can grant funds without screening in order to economize on the screening costs, they can provide screened funding only, or they can remain inactive altogether.

After a decision has been made to finance a project the terms of funding have to be negotiated. We assume that financiers submit take-it-or-leave-it offers. These offers, though, can be made conditional on the screening history of the borrower. Thus, the financier will typically take into account the information transmitted if a borrower can produce evidence of a lending offer from a rival financier.⁷ Optimal lending offers to entrepreneurs who pass the evaluation test are typically designed so as to keep the borrower indifferent between accepting and waiting to solicit another evaluation from a rival lender in some future period.⁸

If the new entrants find that their chosen financier does not process their application speedily they can decide to stay with this incumbent or to switch to a rival financier in the next period. Switching is attractive, when other financiers are active in that period. However, when the market is generally inactive they could as well stay with their chosen financier and await periods of higher screening and lending activity. While, in principle, many scenarios are conceivable concerning the rematching behavior, our analysis focuses on two extreme versions, which we call passive rematching (P) and random rematching (R).

- (P) Passive entrepreneurs stay with the inactive financier until it starts screening again.
- (R) Passive entrepreneurs of period t are rematched randomly in the next period $t+1$, and thus join the pool of entering entrepreneurs.

The rematching assumption can potentially affect financiers' strategies. For example, in scenario (P) financiers will not have to worry about the potential loss of good customers in periods of inactivity, since those are staying until the screening restarts again. In case (R), on the contrary, the financier has to be concerned about

⁷ In other words, financiers are allowed to discriminate among borrowers with different screening histories.

⁸ Of course, for reasons of consistency take-it-or-leave-it offers are also made in the case of unscreened finance.

loosing good risks to other financiers in periods of inactivity.⁹ Clearly, entrepreneurs that have been rejected after the first screen will strategically select the next application. For reasons of tractability we focus most of our analysis on rematching pattern (P).

This completes the description of the basic model. We proceed in section IV by characterizing screening and financing decisions for a coordinated (cartellized) funding industry. In section V we subsequently extend our analysis to the case of a competitive financing sector.

IV. The Monopoly Financier

The case of a monopoly financier is particularly simple, since in such an environment the financier can always extract all the project surplus. Thus pricing is straightforward and we can concentrate on the screening activity of the monopolist.¹⁰

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

Overall, in each period the total number projects classified as creditworthy will be $\eta[\lambda(1-\alpha) + (1-\lambda)\beta]$. When facing the proportion λ of creditworthy projects and equipped with the imperfect screening technology delineated above, the monopolist will engage in project-specific monitoring rather than granting finance to all the applicants if

$$\eta(\lambda(1-\alpha)\pi R_G - (\lambda(1-\alpha) + (1-\lambda)\beta)R_0) - \eta c \geq \eta(\lambda\pi R_G - R_0),$$

or equivalently

$$c \leq R_0 [1 - \lambda(1-\alpha) - (1-\lambda)\beta] - \pi\lambda\alpha R_G. \quad (2)$$

⁹ We will see in section V that the rematch assumption will affect the intensity of competition between banks for high-quality projects.

¹⁰ We do not consider potential effects on entrepreneurial effort as Padilla, Pagano (1997) for example.

Thus, project-specific screening dominates relative to a strategy of granting funding to all applicants if the monitoring cost is lower than the expected difference between the costs of granting funding to unprofitable projects and the return on good projects incorrectly classified as bad ones. Condition (2) can be re-arranged according to

$$\lambda \leq \bar{\lambda} = \frac{R_0(1-\beta) - c}{R_0(1-\beta) + \alpha(\pi R_G - R_0)}. \quad (3)$$

Thus, project-specific monitoring does not pay off when the financier faces a pool of applicants of sufficiently good quality. However, as the proportion of good applicants lies below the threshold defined by (3), the financier's screening investment is profitable. Intuitively, such an upper bound makes sense, because the financier cannot regain the screening outlays unless the proportion of creditworthy applicants is sufficiently low.

Furthermore, the option with project-specific screening is feasible only insofar as the bank finds it worthwhile to offer screened funding rather than to be inactive. Analytically, we can express this condition as

$$\eta(\lambda(1-\alpha)\pi R_G - (\lambda(1-\alpha) + (1-\lambda)\beta)R_0) - \eta c \geq 0,$$

which is equivalent to

$$\lambda \geq \underline{\lambda} = \frac{c + \beta R_0}{(1-\alpha)(\pi R_G - R_0) + \beta R_0}. \quad (4)$$

Hence, under circumstances with a sufficiently unfavourable pool of project applications, i.e. for $0 \leq \lambda < \underline{\lambda}$, it is optimal for the banking industry to simply withdraw from the funding activities. Such an economy will be characterized by inactivity.

In order for project-specific monitoring to be optimal with respect to a non-empty interval of pool compositions we have to ensure that $\underline{\lambda} < \bar{\lambda}$, which is readily verified.

While the argument so far only applies to a single period of lending, it readily generalizes to the case of repeated lending. Because of perfect recall in each period the

financier is only concerned about the pool of new projects. Hence lending decisions in each period will depend on the composition of the pool of new projects in each period. A stationary pool (in size and quality) will mean that the financier's lending decision will remain constant across periods.

Hence, we can summarize the characterization of the lending decisions of a financier operating in a stationary lending environment and without competition in Proposition 4.1.

Proposition 4.1: *In a stationary environment, i.e. when $\eta_t = \eta$ and $\lambda_t = \lambda$ for all t , the composition of the pool of project applicants determines whether a monopoly financier will never grant a loan, screen each period and grant loans to approved projects or always grant loans without screening in all periods. Such stationary equilibria are characterized by the stationary quality of the pool of applications $\mu_t = \lambda$ in each period with*

- | | |
|---|--|
| (i) inactivity for each t ($t=1,2,\dots$) | if $0 \leq \lambda < \underline{\lambda}$ |
| (ii) screening with lending at rate R_G for each t | if $\underline{\lambda} \leq \lambda \leq \bar{\lambda}$ |
| (iii) funding all projects without screening at the rate R_G for each t | if $\bar{\lambda} < \lambda \leq 1$. |

Proof: See derivation above.

We can conclude that screened funding is optimal for an intermediate interval $\underline{\lambda} \leq \lambda \leq \bar{\lambda}$. According to (7) and (8) these boundaries vary with the technological properties of the screening technology and the project characteristics. These properties are collected in Corollary 4.2

Corollary 4.2 (Comparative Static Properties): *The screening region is affected by*

a) *the screening technology:*

$$\frac{\partial \bar{\lambda}}{\partial \alpha} < 0, \quad \frac{\partial \underline{\lambda}}{\partial \alpha} > 0, \quad \frac{\partial \bar{\lambda}}{\partial \beta} < 0, \quad \frac{\partial \underline{\lambda}}{\partial \beta} > 0$$

$$\frac{\partial \bar{\lambda}}{\partial c} < 0 \quad \frac{\partial \underline{\lambda}}{\partial c} > 0$$

b) *the project characteristics:*

$$\frac{\partial \bar{\lambda}}{\partial \pi} < 0, \quad \frac{\partial \underline{\lambda}}{\partial \pi} < 0, \quad \frac{\partial \bar{\lambda}}{\partial R_G} < 0, \quad \frac{\partial \underline{\lambda}}{\partial R_G} < 0$$

Proof: Standard and omitted.

Consequently, the upper threshold (7) satisfies intuitively appealing comparative static properties: it is decreasing as a function of the project-specific monitoring costs, of the expected value of a good project as well as of both types of classification errors associated with the screening technology. The lower threshold (8) is increasing as a function of the project-specific monitoring costs as well as of the classification errors associated with the screening technology, whereas it is decreasing as a function of the expected value of a good project.

Proposition 4.1 implies that with a completely coordinated funding industry (monopoly) the lending activities are necessarily stable in a stationary environment.¹¹ The monopolist implicitly exercises perfect recall and implicitly ensures perfect communication across periods. Both assumptions guarantee the absence of any other potential dynamic links. Hence, in a coordinated environment lending cycles require exogenous variation in the composition of the pool of new applicants across periods. A distinguishing feature of competition is the decentralization of decisions among competing financiers and a decrease in the level of coordination among those.¹² In the next section will see that this breakdown of coordination may actually render financing cycles inevitable.

¹¹ Note, however, that (exogenous) fluctuations in the cost of funding R_0 may translate into fluctuations of the screening intensity, since it affects the critical levels $\underline{\lambda}$ and $\bar{\lambda}$. In the sequel we focus on a stationary environment with a constant interest rate to demonstrate the endogenous emergence of cycles due to uncoordinated screening.

¹² See Bolton, Farrell, 1990.

V. Competition among Financiers: The Case of Duopoly

In this section we introduce competition by shifting our attention to a duopolistic funding industry. Uncoordinated decentralized funding competition generates an important intertemporal link. Rejected projectholders can apply for funding from the rival financier in future periods. The renewed presence of these entrepreneurs in the pool of applicants tends to reduce the pool quality of applicants approaching the competitor. Hence, in addition to the new entrants the pool of applicants at any given point in time also comprises formerly rejected applicants. Thus, the overall pool of applicants gets adversely selected relative to the pool of new entrants. How does this pool-worsening effect impact on financiers' screening incentives and lending rates in equilibrium?

We plan to address this question for the case when *classification errors are independent* across financiers and when *communication is not feasible*. This aims at modelling the classical case of uncoordinated competition among independent financiers.

First, let us focus on a stationary symmetric competitive equilibrium in subsection V.1. We will show that it may not exist when the underlying pool is significantly adversely affected. We will then in subsection V.2 discuss alternative dynamic patterns of competitive equilibrium. Section V.3 finally explores generalizations.

V.1. Stationary symmetric competitive equilibrium

In order to define a competitive equilibrium we need to specify the time profile of the screening activity $s_i = (s_i^t)_{t=0,1,2,\dots}$, where $s_i^t \in \{screen, no\ screen\}$ for each intermediary $i=1,2$ as well as an intertemporal vector of take-it-or-leave-it offers $R_i = (R_i^t)_{t=0,1,2,\dots}$ for borrowers with a single positive evaluation¹³ and offers $Q_i = (Q_i^t)_{t=0,1,2,\dots}$ for borrowers with two positive evaluations. Moreover, we need to specify the acceptance behaviour of entrepreneurs $a^t \in \{accept, get\ another\ application\}$ in each period. Entrepreneurs maximize discounted project surplus whereas financiers maximize the discounted

¹³ In case of unscreened funding no evaluation will be available.

expected value of profits associated with the funding decisions. We assume that they hold rational expectations about future pricing behavior of intermediaries $(R_i^e, Q_i^e) = (R_i, Q_i)$. A competitive equilibrium (with rational expectations) is a vector $(s_i, R_i, Q_i)_{i=1,2}$ of screening and lending strategies of the intermediaries and a vector of strategies $a^t(R_i^e, Q_i^e) = a^t(R_i, Q_i)$ of acceptance decisions of entrepreneurs, which maximize discounted expected profits and discounted expected surplus, respectively.

A competitive equilibrium is *symmetric*, when $(s_1, R_1, Q_1) = (s_2, R_2, Q_2)$. It is *stationary*, when (s_i, R_i, Q_i) are constant over time for all $i=1,2$, i.e. when $s_i^t = s_i$, $R_i^t = R_i$ and $Q_i^t = Q_i$ for all $t=0,1,2,\dots$.

We first report the crucial result that a stationary symmetric competitive equilibrium may not exist if the adverse selection problem is sufficiently severe.

Proposition 5.1 (Non-existence of a stationary symmetric competitive equilibrium):

$$\text{Let } R^* = \frac{1}{1-\alpha\delta_0} \left((1-\delta\delta_0)R_G + \frac{1-\alpha}{\gamma\pi} \right). \quad \text{If } \underline{\lambda} \leq \lambda \leq \frac{c + (2-\beta)\beta R_0}{(1-\alpha^2)(\pi R^* - R_0) + (2-\beta)\beta R_0}$$

there does not exist any *stationary* symmetric competitive equilibrium with constant screening activity in each period..

Proof: The proof consists of establishing two claims: (i) For the given pool quality there cannot be a symmetric competitive equilibrium with constant screening activity by both financiers. (ii) The given pool is of sufficiently high quality that constant denial of funding by both financiers cannot be an equilibrium either.

Proof of claim (i): When financiers are active in each period, creditworthy entrepreneurs are able to elicit evaluations in each period. Hence, financiers have to offer terms lending R_i to positively tested applicants that keep them indifferent between accepting the offer and waiting to elicit another evaluation next period. More precisely, financiers want to keep the good types indifferent, while they would like to induce the bad types to not accept their terms.

A good entrepreneur can expect another positive screen with probability $1 - \alpha$. In this case, both financiers enjoy the same (symmetrical) informational status and engage in Bertrand-competition to reduce the lending terms down to the fair rate $Q^* = \frac{R_0}{\gamma\pi}$,

where

$$\gamma = \frac{\lambda(1-\alpha)^2}{\lambda(1-\alpha)^2 + (1-\lambda)\beta^2} \quad (5)$$

is the conditional probability that a project with two positive evaluations is truly of the good type.¹⁴ However, due to the classification errors, with probability α the good entrepreneur cannot acquire another positive evaluation, in which case he accepts the current offer. Hence the current offer needs to balance the good entrepreneur's surplus from immediate acceptance and the expected surplus from one round of waiting, i.e.

$$R_G - R^* = \delta_0 (\delta R_G - (1-\alpha)Q^* - \alpha R^*) \quad .$$

Hence the equilibrium lending rate is given by

$$R^* = \frac{1}{1-\alpha\delta_0} \left((1-\delta\delta_0)R_G + \frac{1-\alpha}{\gamma\pi} \right) \quad (6)$$

With this lending rate the expected return on lending to can be evaluated by taking into account the pool characteristics, which in this case are constant over time, i.e. $\mu_t = \mu$ for all t . Intermediary i faces half of the incoming pool of projects plus the pool of projects previously rejected from his rival. So the overall pool quality is:

$$\mu_t = \frac{\frac{\eta}{2}\lambda + \frac{\eta}{2}\lambda\alpha}{\frac{\eta}{2} + \frac{\eta}{2}(1-\lambda(1-\alpha) - (1-\lambda)\beta)} = \frac{(1+\alpha)\lambda}{2 - (1-\alpha)\lambda - \beta(1-\lambda)} \quad (7)$$

¹⁴ Observe that $\gamma > \lambda$ as long as the test is informative, i.e. $\alpha + \beta < 1$.

The return on lending is positive, if

$$\lambda(1+\alpha)(1-\alpha)\pi R^c - (\lambda(1+\alpha)(1-\alpha) + (1-\lambda)(2-\beta)\beta)R_0 - c > 0$$

or alternatively

$$\lambda > \frac{c + (2-\beta)\beta R_0}{(1-\alpha^2)(\pi R^c - R_0) + (2-\beta)\beta R_0} \quad (8)$$

This completes the proof of the claim.

Proof of claim (ii): If all other financiers are inactive, according to Proposition 3.1 financier i has an incentive to deviate from a proposed equilibrium of inactivity by screening and lending at the monopolistic rate to projects with positive evaluations.

Q.E.D.

This result is in stark contrast to the monopoly case. It highlights the dynamic implications of the pool-worsening externality and it shows how this externality may generate complex dynamic interactions in otherwise stationary lending markets.¹⁵

The non-existence results characterized in Proposition 5.1 might naturally raise the issue of mixed strategy equilibria. Clearly, with a sufficiently extensive pool of project applications in a stationary environment, a potential mixed strategy equilibrium would, by the law of large numbers, generate an essentially constant number of funded projects. However, in this paper we are primarily concerned with the design of a mechanism to explain the high-frequency fluctuations in the number of VC-funded projects. For that reason the mixed strategy equilibria are simply outside the scope of this paper.

¹⁵ Broecker (1990) is the first to analyse the impact of this pool-worsening externality in a static model of banking competition.

V.2 Symmetric competitive equilibrium and screening cycles

While Proposition 5.1 establishes that a stationary symmetric competitive equilibrium may not exist when the pool quality is adversely selected to a sufficient extent, we may ask whether there is any kind of symmetric equilibrium at all in our framework. The type of equilibrium will among other things depend importantly on the re-match assumption. Let us start with the case of duopoly and passive entrants (P) since this allows to demonstrate the role of the externality on the dynamic pattern of screening activity most easily. We will then continue to analyse random rematches and comment on more general market structures in section V.

Let us first describe the pool dynamics for a special case in order to highlight the role of the pool-worsening externality. Suppose for the moment that the financiers have both engaged in screening in period t and remain passive from then on. Also assume that the financiers face a stationary environment with subsequent generations of project applications exhibiting constant size and quality from one period to another. Under these circumstances we can prove the following useful lemma about the dynamics of the pool composition.

Lemma 5.2: *Suppose both firms are actively screening in period t and do not screen from then onwards. Then the proportion of high-quality projects in the pool of applicants in period $t+n$ is given by*

$$\mu_{t+n} = \frac{\lambda(\alpha+n)}{n+1-(1-\alpha)\lambda-\beta(1-\lambda)} < \lambda . \quad (9)$$

Moreover the pool characteristics satisfy the following comparative static properties: $\frac{\partial \mu_{t+n}}{\partial \alpha} > 0$, $\frac{\partial \mu_{t+n}}{\partial \beta} > 0$, and $\frac{\partial \mu_{t+n}}{\partial n} > 0$.

Proof: Based on the given screening technology the number of projects denied funding by each of the two financiers is given by $\frac{\eta}{2}[1-\lambda(1-\alpha)-(1-\lambda)\beta]$. Thus, in period $(t+n)$ the number of projects turning to each of the two financiers is given by the denominator of (1). In this pool of applicants, consisting of those denied by the rival financier in period t as well as all the unscreened projects born after period t , the

numerator of (1) denotes the number of creditworthy ones. The inequality $\mu_{t+n} < \lambda$ formally holds because the denominator can be written as $\frac{\eta}{2}[n + \alpha + (1 - \lambda)(1 - \alpha - \beta)]$. Thus, we can conclude that $\mu_{t+n} < \lambda$ if and only if $\alpha + \beta < 1$. But, the latter always holds as long as the credit test is at all informative.¹⁶ Consequently, funding market competition will always induce a pool-worsening effect, the magnitude of which depends on the imperfections of the screening technology as well as on the frequency of screening.

We know that the limit case of a completely uninformative screening technology corresponds to the combination of classification errors with $\alpha = 1 - \lambda$ and $\beta = \lambda$. With an informative screening technology it always holds that $0 \leq \alpha < 1 - \lambda$ and $0 \leq \beta < \lambda$, respectively. Furthermore, one can make use of ordinary analysis to establish that $\frac{\partial \mu_{t+n}}{\partial \alpha} > 0$ and $\frac{\partial \mu_{t+n}}{\partial \beta} > 0$.

In particular, $\mu_{t+n} \rightarrow \lambda$ for the limiting case with $\alpha = 1 - \lambda$ and $\beta = \lambda$, i.e. the case of a completely uninformative screening technology. Furthermore, one can easily verify that $\frac{\partial \mu_{t+n}}{\partial n} > 0$, i.e. that the proportion of creditworthy projects is increasing as a function of the number of periods without screening.

Q.E.D.

According to Lemma 5.2 the pool-worsening effect is increasing with the precision of the screening technology. Moreover, pool quality improves in periods of passivity due to the inflow of new projects with a higher average quality. In this sense the pool recovers in periods of inactivity and this effect counteracts the pool deterioration induced by screening. The conflict between these two forces constitutes the main mechanism in generating the cyclical nature of lending arrangements in such markets.

For given pool characteristics it is now rather transparent to see how cyclical pool dynamics can evolve in equilibrium. For example, there may be equilibria where the initial pool-worsening effect after one period of screening will render screening

¹⁶ With a completely uninformative screening technology it holds that $\alpha + \beta = 1$.

unprofitable for all financiers in the next period. However, the inflow of sufficiently many good projects one further period ahead may incite screening again. This process could repeat itself regularly, thus generating a 2-cycle. The next result provides the precise conditions for the existence and the properties of such a 2-cycle in equilibrium.

Define

$$\lambda^c = \frac{c + \beta(3-\beta)R_0}{(1-\alpha)(2+\alpha)(\pi R^*(1) - R_0) + \beta(3-\beta)R_0} . \quad (10)$$

Proposition 5.3 (2-Cycles with Passive Entrants) :

Consider the case of passive entrants, i.e. assumption (P). When the composition of the original pool of applicants satisfies

$$\max(\underline{\lambda}, \lambda^c) \leq \lambda \leq \frac{c + (2-\beta)\beta R_0}{(1-\alpha^2)(\pi R^*(1) - R_0) + (2-\beta)\beta R_0}, \quad \text{there is a symmetric}$$

equilibrium with a regular 2-cycle, consisting of phases alternating between screened funding and inactivity. In active periods the lending rate is given by

$$R^*(1) = \frac{1 - \delta_0^2 \delta^2}{1 - \alpha \delta_0^2} R_G + \frac{1 - \alpha}{1 - \alpha \delta_0^2} \frac{\delta_0}{\gamma \pi} .$$

Proof: The strategy of the proof is to first characterize the properties of a candidate symmetric equilibrium. Then it is shown that given the candidate equilibrium prices, and the profitability of lending, the bounds on the pool quality are chosen such that there is no symmetric equilibrium with constant screening and no symmetric equilibrium without screening. It is then established that the 2-cycle indeed is an equilibrium.

(i) *Candidate equilibrium pricing:* In a 2-cycle the phases of screening and inactivity alternate regularly. Hence, there is delay of one period between two screens. As defined

by (5) $\gamma = \frac{\lambda(1-\alpha)^2}{\lambda(1-\alpha)^2 + (1-\lambda)\beta^2}$ denotes the conditional probability that a project

classified to be creditworthy is truly of type G . Financiers price loans $R^*(1)$ such that creditworthy customers are just indifferent between their offer and the potential offer they receive two periods later after a successful screen by a competing financier, i.e.

$$R_G - R^*(1) = (1-\alpha)\delta_0^2[\delta^2 R_G - Q^*] + \alpha\delta_0^2[\delta^2 R_G - R^*(1)],$$

where $Q^* = \frac{R_0}{\gamma\pi}$ is the fair rate applied to a project with two positive evaluations. This

can be rewritten to yield

$$R^*(1) = \frac{1 - \delta_0^2 \delta^2}{1 - \alpha \delta_0^2} R_G + \frac{1 - \alpha}{1 - \alpha \delta_0^2} \frac{\delta_0}{\gamma \pi}. \quad (11)$$

By comparing (6) and (11) it can be shown that $R^*(1) > R^*$ meaning that the repayment rate is higher under an equilibrium configuration with alternative phases of screening and inactivity than under the hypothetical regime with constant screening in each period. Intuitively, with alternative phases of screening and inactivity the delay in funding increases the financier's bargaining power, because it creates a switching cost related to depreciation and the possibility of classification errors. For that reason the intensity of competition between financiers will be reduced in the configuration with alternative phases of screening and inactivity.

(ii) *Non-existence of stationary equilibrium:* Since $R^*(1) > R^*$ the upper bound on λ is tighter than the upper bound of Proposition 4.1, i.e.

$$\frac{c + (2 - \beta)\beta R_0}{(1 - \alpha^2)(\pi R^*(1) - R_0) + (2 - \beta)\beta R_0} \leq \frac{c + (2 - \beta)\beta R_0}{(1 - \alpha^2)(\pi R^* - R_0) + (2 - \beta)\beta R_0} \quad (12)$$

Hence the pool characteristics satisfy the conditions of Proposition 4.1 and a stationary equilibrium cannot exist.

(iii) *Existence of symmetric equilibrium:* The existence of a 2-cycle requires that pool recovery is fast enough such that after one period of inactivity the pool is of sufficient quality to render screening profitable. According to proposition 4.2. the pool quality after one round of inactivity is:

$$\mu_{t+2} = \frac{\lambda(\alpha + 2)}{3 - (1 - \alpha)\lambda - \beta(1 - \lambda)}. \quad (13)$$

Thus, the mass of truly good applicants is $\lambda(2 + \alpha)$ and the mass of truly bad applicants is $(1 - \lambda)(3 - \beta)$.

Screened lending at the rate $R^*(1)$ is profitable as long as

$$(1 - \alpha)(\lambda(2 + \alpha))R^*(1) - [(1 - \alpha)(\lambda(2 + \alpha) + \beta(1 - \lambda)(3 - \beta))]R_0 \geq c,$$

which is equivalent to the condition

$$\lambda \geq \frac{c + \beta(3 - \beta)R_0}{(1 - \alpha)(2 + \alpha)(\pi R^*(1) - R_0) + \beta(3 - \beta)R_0} = \lambda^c. \quad (14)$$

Hence, as long as $\lambda^c < \frac{c + (2 - \beta)\beta R_0}{(1 - \alpha^2)(\pi R^*(1) - R_0) + (2 - \beta)\beta R_0}$ a symmetric 2-cycle will be

profitable for a non-empty set of pool characteristics. It is readily verified that this condition can be satisfied¹⁷.

It remains to be shown, that financiers cannot profitably deviate from the proposed candidate equilibrium. Note that we have already established the equilibrium prices for a periodic equilibrium with a 2-cycle. Thus, we need to check deviations in screening behaviour (potentially cum price setting).

Due to discounting there is no value in delaying screening. A profitable pool should be screened at the earliest possibility. This is what the proposed equilibrium implements. Could it be profitable to deviate during a (proposed) period of inactivity, and screen instead? In the case of passive re-matching this strategy does not pay off, since it does not affect the initial choice of entrants. Under this re-matching assumption the competitor's clients will simply wait for the evaluation of the incumbent financier independently of the screening behavior of rivals. Hence, screening in periods with adversely affected pools does not generate more future business. Moreover, lending rates could only be maintained at the level of $R^* < R^*(1)$. Finally, the costs of screening

¹⁷ This is most easily seen for the (limiting) case of $\beta = 0$.

predominantly bad projects are forwarded. Since financiers discount future payoffs, waiting until pool recovery has taken place is actually preferable.

Q.E.D.

The intuition behind this result is quite straightforward. If the pool quality is adversely selected to such an extent that the pool worsening induced by one period of collective screening makes the average pool quality next period decline below the threshold quality to warrant screening, it is not profitable for the intermediaries to screen during that period. If on the other hand, pool improvement is rapid one period later it may already pay to screen again. The parameter restrictions of Proposition 5.3. are chosen so that pool recovery is fast enough while at the same time the adverse selection effect is sufficiently strong. This scenario is illustrated in Figure 3. In general, by

concentrating on the interval $\max(\lambda, \lambda^c) \leq \lambda \leq \frac{c + (2 - \beta)\beta R_0}{(1 - \alpha^2)(\pi R^*(1) - R_0) + (2 - \beta)\beta R_0}$ we can fully characterize the pool composition under which a 2-cycle will emerge.

If adverse selection is not a serious problem, a stationary equilibrium may, in fact, exist even under conditions of competition. The pool-worsening externality is still present and affects screening costs. However, in this case it does not generate delay.

Proposition 5.4 (Stationary Equilibrium) :

Consider the case of passive entrants, i.e. assumption (P). When the composition of the

original pool of applicants satisfies $\frac{c + (2 - \beta)\beta R_0}{(1 - \alpha^2)(\pi R^c - R_0) + (2 - \beta)\beta R_0} < \lambda$, there is a

unique stationary symmetric equilibrium with lending activity in each period at the

lending rate $R^ = \frac{1}{1 - \alpha\delta_0} \left((1 - \delta\delta_0)R_G + \frac{1 - \alpha}{\gamma\pi} \right)$.*

Proof (sketch): Despite pool worsening based on Proposition 5.3 it pays off for both intermediaries to continue screening or to provide even unscreened funding (in case λ is close enough to 1). So a stationary equilibrium exists with financiers offering competitive terms to creditworthy applicants each period.

Q.E.D.

While Proposition 5.4. seems to offer re-assuring evidence about the virtues of competition it should be emphasized, however, that it only applies to high-quality pools of applicants. Hence, Proposition 5.4 may not apply to important real world markets such as venture capital markets, where project-specific screening represents a core activity. Bengtsson et. al. (2002), for example, report findings from a detailed case study of one particularly successful European capital venture fund that only 2-5 percent of applicants are accepted on average. This evidence suggests serious adverse selection problems in the venture capital industry.

Figure 3 illustrates the potential case discussed in Propositions 5.4. However, as can be easily seen from this figure, one could easily imagine parameter constellations that generate different types of dynamics in the lending market.

V.3 Robustness and Generalizations

So far the analysis has concentrated on the case of two financiers and the existence of regular 2-cycles. However, the analysis above suggests that the present framework can generate substantially richer dynamics even in the case of only two financiers. Moreover, the results can be quite easily generalized to larger numbers of financiers as well as to alternative types re-matching. In this subsection we briefly explore generalizations along these dimensions.

V.3.1 Cycles of General Length

While the previous section has established the possibility of regular 2-cycles, our framework does in fact generate a much richer set of possible dynamics. With different pool characteristics we may find cycles with different length of the phase of inactivity. In fact, pool recovery may be fairly slow and require n periods rather than 2. In this case our model will generate asymmetric cycles with short phases (one period) of screening and longer phases of pool recovery ($n-1$ periods).

In this section we concentrate on perfect screening technologies with $\alpha = \beta = 0$ in order to simplify the pool dynamics. The basic qualitative insights are not affected by this modelling choice.

Proposition 5.5 (n-Cycles with Passive Entrants) :

Consider the case of passive entrants - assumption (P) - and let $\alpha = \beta = 0$. When both

$$\mu_{t+n-1} < \frac{c(n-\lambda)}{\pi R_G (1 - \delta_0^{n-1} \delta_0^{n-1}) + \delta_0^{n-2}} \text{ and } \mu_{t+n} \geq \frac{c(n+1-\lambda)}{\pi R_G (1 - \delta_0^n \delta_0^n) + \delta_0^{n-1}},^{18} \text{ there}$$

is a unique and symmetric screening equilibrium with regular n-cycles consisting of alternating phases of one period of funding and n-1 periods of inactivity. In active periods the lending rate is given by

$$R^*(n-1) = R_G (1 - \delta_0^n \delta_0^n) + \frac{\delta_0^{n-1}}{\pi} .$$

Proof: See Appendix

Proposition 5.5 determines the characteristics of the screening cycle. In terms of interpretation a period refers to the time required, in terms of information acquisition, information processing and decision making, to complete a project evaluation. From Proposition 5.5 we can conclude that the length of the screening-induced cycle is determined by industry-specific features such as the potential return of a successful project and the depreciation rate of the cutting-edge technology. If we take a higher degree of technological level to be associated with high potential returns and high depreciation factors we can draw the conclusion that screening cycles tend to be short in high-tech industries, whereas lower potential returns or lower depreciation factors tend to prolong these cycles.

In equilibrium the lending rate is increasing as a function of the length of the cycles. This captures the idea that a longer delay causes a larger switching cost related to depreciation and therefore relaxed competition. In particular, the lending rate approaches that of a monopoly as the length of the phase of inactivity approaches infinity.

¹⁸ These conditions can most easily be interpreted in the chosen representation. Clearly, the left hand sides describe increasing functions in λ while the right hand sides define decreasing function in λ .

V.3.2 Random Re-matching

The complete absence of strategic interaction associated with passive entrepreneurs may also seem artificial and too strong. Alternatively, entrepreneurs could actively solicit a rematch, or just search a match with the competing financier. In both cases, the incentives of financiers to remain inactive are reduced, since a period of inactivity implies a loss of a positive measure of profitable clients in the period of inactivity. Accordingly, the existence of cycles will require a certain amount of discounting by the financiers in order to render deviations unprofitable. Hence, we here establish that an alternative assumption about entrepreneurs' behaviour, assumption (R), will tighten the conditions for the existence of symmetric equilibria, but such an assumption of active entrepreneurs neither completely eliminates the occurrence of symmetric cyclical equilibria nor does it necessitate the occurrence of such equilibria.

In order to highlight the implications of random re-matching we focus on a simple environment with a perfect screening technology ($\alpha = \beta = 0$) and we demonstrate the emergence of 2-cycles with alternating screening and inactivity.

Proposition 5.6 (2-Cycles with Random Rematching)

Let $\alpha = \beta = 0$ and consider the case of random rematches, i.e. assumption (R). There is a critical level $\bar{\delta}_0 < 1$ such that for any $\delta_0 < \bar{\delta}_0$ there is a unique and symmetric equilibrium with a regular 2-cycle consisting of one period of lending and one period of inactivity, if $\frac{\lambda}{2-\lambda} < \frac{c}{(1-\delta^2)\pi R_G}$ and $\frac{2\lambda}{3-\lambda} > \frac{c}{(1-\delta^2)\pi R_G}$. In active periods the lending rate is given by $R(2) = (1-\delta^2)R_G + \frac{R_0}{\pi}$.

Proof: See Appendix.

The argument of Proposition 5.6 is similar to that of Proposition 5.3. However, under the random rematch assumption financiers can strategically affect the number of profitable entrepreneurs they are funding. This feature renders inactivity more costly to financiers and enhances their incentives to deviate from inactivity in a given period. This incentive is counteracted by the costs of screening an adversely selected pool. If time

preference is high enough, deferred screening will remain valuable, even at the cost of losing some profitable projects.

The requirement of a higher degree of time preference implies that screening cycles will be more likely in periods of higher real rates of interest.

Overall the basic mechanism characterized by Propositions 5.3 and 5.6 delineates how uncoordinated screening by competing financiers will generate an externality causing substantial instability in the funding markets. 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 funding market does not channel funds to profitable projects.

V.3.3 Dynamics with Many Financiers

In the presence of the screening technology outlined above, low-quality entrepreneurs will belong to the pool of loan applicants for a longer period as the number of financiers increases. This will have two effects, both contributing to the detrimental welfare implications of intensified funding market competition in the sense of a larger number of financiers. Firstly, of course, an extended number of financiers means that the screening costs associated with unprofitable projectholders are multiplied by the number of financiers performing credit tests. Secondly, as the unprofitable projects are present in the pool of applicants for a longer period it follows that the quality of this pool deteriorates. For that reason, the economy will face prolonged phases of inactivity as the dynamic process of recovery to activity threshold will be slower. However, in our setting the lending rate negotiations will not be affected by the number of financiers exceeding two, since a successful entrepreneur only needs one additional screen to force potential financiers into Bertrand type competition. In this respect, the returns to policies promoting competition seem to be highly restricted within the framework of our model. In particular, expansions of entry seem to yield no advantages once there are at least two competing financiers.

All extensions demonstrate the robustness of our main result. Even in a stationary environment it is difficult to maintain stationarity of screening and funding activities in decentralized markets. The empirical evidence strongly supports our theory, suggesting a typical period in our model would vary between 3 to 6 months. These cycles have not

been analysed in the literature so far. It is a challenging task to separate those screening cycles from other dynamic forces such as the dynamics of the composition of new projects entering the pool.

VI. Policy Implications

Our theory has a number of policy implications. When they occur, cycles result from a lack of social memory. Cycles and duplication of screening primarily arises because of the decentralized nature of information acquisition and a lack in communication. In particular, negative evaluations are not shared with the community. This lack of communication implies the inefficient duplication of screening of an adversely selected pool of projects that were already rejected in earlier evaluations. In other words, from a societal point of view the decentralized process of information acquisition implies a lack of memory of unfavourable information. One way to restore efficiency could be information sharing. On the other hand, to the extent that cycles result from the unwillingness to screen adversely selected pools one might remove cycles by subsidizing screening expenses or even applications. Such Pigouvian intervention is discussed in the subsequent subsection.

VI.1 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 financiers, 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 subsequently addressing competing financiers. The more financiers are available the higher the probability of less promising projects to receive funding. 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 funding industry.

If we were to allow such information sharing, in our framework B-types could survive in the pool of funding applicants only by referring to misclassifications as a justification re-evaluations. In the absence of screening imperfections information sharing would simply eliminate screening cycles as in the case of a funding monopoly.

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 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 annihilate the pool externality. Likewise the common institutional practise of information sharing between banks might reduce the informational externality in the banking industry. While in most countries financiers engage in information exchange, information sharing typically covers only “black” information, i.e. ex-post information¹⁹. Furthermore, we would also expect financiers to have strategic reasons for misrepresentation of initial assessments. In fact, financiers typically have strategic reasons to transmit inaccurate information to rivals in order to raise their costs, which will have the strategic advantage of reducing the aggressiveness of rivals. The costly establishment of institutions for verification of shared information seems to be the only way of overcoming these incentives for strategic information transmission. Consequently, the establishment of such an institution for truthful information transmission would represent one mechanism for elimination of the externalities created by non-coordinated screening activities of competing financiers.

While information sharing seems a reasonable response to the problem of investment cycles, however, some important caveats remain. Importantly, information sharing provides incentives to venture capital firms to engage more aggressively in “poaching”, i.e. the activity of attracting attached successful start-ups away from 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. Gehrig and Stenbacka (2002a) provide a two-period model of information

¹⁹ See Japelli and Pagano (1999).

sharing in the banking industry with precisely those properties. Furthermore, we would also expect financiers to have strategic reasons for misrepresentation of initial assessments. The costly establishment of institutions for verification of shared information seems to be the only way of overcoming these incentives for strategic information transmission.

Overall, the benefits of information sharing in terms of reduced cyclicity of venture investments need to be balanced against the potential costs of increased anticompetitive conduct in the venture capital industry. Since anti-competitive conduct does adversely affect entrepreneurial risk-taking, 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 funding industry.

VI.2 Subsidy Policies

In this section we briefly discuss Pigouvian arguments for improving market performance via a tax-subsidy scheme. Since financiers withdraw from granting screened funding when the pool 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 financier. Indeed such a policy may affect cycles and reduce their length.

In fact, irrespectively of the market structure under consideration it can easily be verified that the pool quality threshold below which no funding can be granted is decreasing as a function of the screening costs c . Thus, a policy with the effect of reducing the screening costs would unambiguously reduce the frequency whereby the funding industry enters the phase of inactivity. Clearly, in the limiting case of completely subsidized screening costs, financiers would always screen each applicant. Overall, subsidies applied towards screening costs will generate more screens and, therefore, imply more funding for worthwhile projects as well as higher aggregate screening costs to distinguish unworthy projects.

Extensive subsidy programs face the risk of activating projects which are not socially efficient. To illustrate this, consider a market environment where the proportion

of creditworthy projects is below the threshold of inactivity. In such a case the market outcome would be that of no activity. To the extent that screening is subsidized, the threshold for screened funding may decline to such a level that the financial intermediary finds screening profitable again. Thus, project activity could resume in a situation where the returns to the subsidies will not cover the outlays from a social point of view.

Furthermore, subsidizing screening costs may meet serious problems of implementation and generate serious allocational inefficiencies (in addition to the increase in overall screening outlays). In particular, the implementation of an efficient subsidy of the screening expenses requires that c is observable. This condition is hardly met, since the screening costs c will typically vary according to project characteristics. As the government does not observe project characteristics – after all this is why financial intermediaries like venture capitalists are so important to fund innovative firms – they cannot reimburse the 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.

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 many countries in order to foster innovation and the creation of jobs. What are the effects of such a subsidy 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 risk free activity. But even for moderate subsidies financiers might want to screen and fund projects that would not be viable in the absence of such subsidies. Independently of the market structure the subsidy is basically transferred to financiers, 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 the details of these aspects.

VII. Concluding Comments

Our analysis has highlighted the role of the inter-temporal screening externality induced by competition as a structural source of instability in financial markets granting unsecured project funding. While earlier work focusing on banking markets has already emphasized the potentially harmful consequences of screening on competition in banking (Broecker (1990)), our article is the first strategic analysis drawing out the dynamic implications of the screening externality. We demonstrate how endogenous information acquisition in markets with unsecured funding and characterized by asymmetric information can create lending cycles as long as competing financiers undertake their screening decisions in an uncoordinated way. In the environment of our model such screening cycles emerge in response to competition between financiers, whereas project-specific information exchange between financiers or cartelization of the funding industry would eliminate such fluctuations.

As is well known, stylized facts point to business cycles as substantial, persistent and asymmetric fluctuations in aggregate output.²⁰ Even in big and fairly well diversified economies these fluctuations represent a sizeable fraction of aggregate economic activity. The typical business cycle pattern offers support for the view of these fluctuations as being persistent and asymmetric in the sense that downward movements have been sharper and quicker than phases of economic recovery and fast growth. Random economy wide shocks could represent a natural candidate for explaining business cycles. Such an explanation, however, seems far from sufficient since the fluctuations in exogenous factors such as government policy, natural resources, weather etc. are not large enough to account for the fluctuations in aggregate output. For that reason economists have recently directed much attention to finding and characterizing mechanisms which transform minor shocks to some or all parts of the economy into

²⁰ For example, see Friedman and Kuttner (1993) and Gertler and Gilchrist (1994).

large, persistent and asymmetric fluctuations in aggregate output. In this respect the credit market has been in the focus of much attention. The models addressing financial accelerator effects (surveyed, for example, by Bernanke, Gertler and Gilchrist (2000)) emphasize mechanisms whereby adverse shocks to the economy are endogenously amplified and propagated by credit market imperfections. The influential recent article Kiyotaki and Moore (1997) constructed a model of a dynamic economy where borrowers' credit limits are affected by the prices of the collateralized assets. Their analysis shows how the dynamic interaction between credit limits and asset prices will constitute an important transmission mechanism whereby shocks to the economy persist, amplify and spill over across different sectors. Our present analysis proposes a new mechanism which is able to generate large, persistent and asymmetric fluctuations of economic activity in an otherwise stationary environment. This mechanism builds on endogenous screening investments by specialized financiers engaged in repeated non-cooperative competition. Our mechanism does not require the existence of exogenous random shocks like the credit cycle model of Kiyotaki and Moore.²¹

While there are certainly many complementary mechanisms that may generate or amplify business cycles (see e.g. Kiyotaki and Moore (1997) Holmström and Tirole (1997), Gersbach (2001)), our analysis has established that the uncoordinated screening behavior of competing financiers may be the source of an additional important multiplier for any form of exogenous business cycles. We have also shown that screening cycles may, in fact, be an independent source of lending fluctuations, and hence, cause business cycles even in otherwise stationary environments. Even though our basic model exhibits the basic screening cycle mechanism in a very simple and highly stylized framework we have reasons to conjecture this mechanism to be a very robust phenomenon.

Rajan (1994) has developed an alternative explanation for why banks' credit policies fluctuate, thereby contributing to business cycles. Rajan's explanation builds on bank managers endowed with short horizons boosting credit policies in order to affect the stock or labor market's perceptions of their abilities. Rajan's mechanism has one common feature with our screening externality. The credit fluctuations are generated not only in response to exogenous shocks, but even in a stationary economic environment,

²¹ In the case of exogenous random shocks our mechanism will amplify these shocks and generate persistence similarly to the mechanisms surveyed so far.

like in our model. Rajan, further, reports evidence from the banking crisis in New England in the early 1990's in support of the assumptions and predictions of his model. Note, however, that his theory seems to apply at a much lower frequency band with cycle durations in the order of years, while our theory applies to cycles durations in the order of months or quarters.

In contrast to Rajan's theory, our theory predicts that screening cycles are intimately related to the degree of competition among financiers. So according to our theory the liberalization of formerly cartelized financial systems should generate screening cycles. Also an increasing reliance on unsecured funding would help to generate such cycles. It is an interesting challenge for further work to test our theory in this respect.

VII. References

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Appendix:

Proof of Proposition 5.5: The strategy of the proof follows that of Proposition 5.3. For that reason we will here emphasize the key modifications for the emergence of an n-cycle.

In an n-cycle financiers price loans $R^*(n-1)$ in such a way that creditworthy customers are just indifferent between their offer and the potential offer they receive n periods later after a successful screen by a competing financier, i.e.

$$R_G - R^*(n-1) = \delta_0^n [\delta^n R_G - Q^*],$$

where now $Q^* = \frac{R_0}{\pi}$ denotes the fair rate applied to a project with two positive evaluations in the absence of classification errors. This can be rewritten to yield

$$R^*(n-1) = R_G (1 - \delta_0^n \delta^n) + \frac{\delta_0^{n-1}}{\pi}.$$

In particular, we can see that a phase of infinitely long inactivity, which is equivalent to the absence of competition, would generate the lending rate R_G , i.e. the lending rate charged by a monopolist.

The existence of an n-cycle requires that the inequalities

$$\pi \mu_{t+n-1} R^*(n-2) - (n-\lambda)c < 0$$

and

$$\pi \mu_{t+n} R^*(n-1) - (n+1-\lambda)c \geq 0,$$

have to hold simultaneously. In the absence of classification errors we can conclude from Lemma 5.2 that the pool dynamics is characterized by

$$\mu_{t+n} = \frac{\lambda n}{n+1-\lambda}.$$

Substituting the lending rate equilibrium into the two equilibrium conditions completes the proof.

QED

Proof of Proposition 5.6:

The proof parallels that of Proposition 5.3. Hence, we shall only provide the argument for the existence of a symmetric stationary equilibrium with the regular succession of one period of screened lending and a period of inactivity. Since deferred lending implies discounting of the benefits from screening a profitable pool by one period, only deviations from a period of inactivity have to be considered. Let t be a period of joint screening, $t+1$ a period of inactivity and $t+2$ again a period of screening etc. If financier 1 deviates and screens in period $t+1$ its period payoffs are

$$\tilde{u}_{1,t+1} = \lambda \frac{\eta_{t+1}}{2} (\pi R(1) - R_0) - \left(\frac{\eta_{t+1}}{2} + (1-\lambda) \frac{\eta_t}{2} \right) c$$

and subsequently its profits in period $t+2$ are

$$\tilde{u}_{1,t+2} = \lambda \left(\frac{\eta_{t+1}}{4} + \frac{\eta_{t+2}}{2} \right) (\pi R(2) - R_0) - \left(\frac{\eta_{t+1}}{4} + \frac{\eta_{t+2}}{2} \right) c.$$

In the candidate (symmetric) equilibrium payoffs are

$$\hat{u}_{1,t+1} = 0 \quad \text{and}$$

$$\hat{u}_{1,t+2} = \lambda \left(\frac{\eta_{t+1}}{2} + \frac{\eta_{t+2}}{2} \right) (\pi R(2) - R_0) - \left(\frac{\eta_{t+1}}{2} + \frac{\eta_{t+2}}{2} \right) c.$$

Thus, the proposed deviation is profitable if and only if

$$\tilde{u}_{1,t+1} + \delta_0 \tilde{u}_{1,t+2} > \hat{u}_{1,t+1} + \delta_0 \hat{u}_{1,t+2}.$$

The present value of the continuation payoffs after period $t+2$ is identical in the two regimes. Straightforward calculations establish that the proposed deviation is profitable, whenever²²

$$\delta_0 > 2 \frac{\lambda(\pi R(1) - R_0) - (2-\lambda)c}{\lambda(\pi R(2) - R_0) - (3-2\lambda)c} = \bar{\delta}_0.$$

Substituting the equilibrium values for the rate negotiations yields

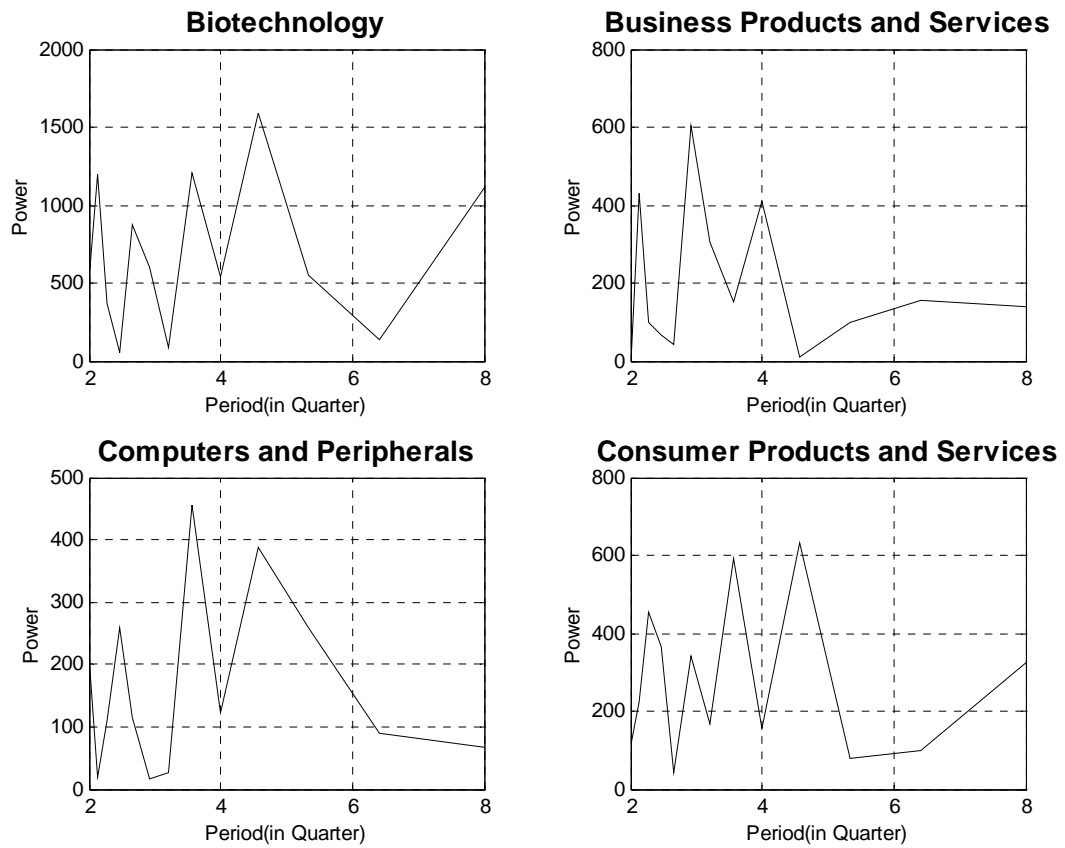
$$\bar{\delta}_0 = 2 \frac{(1-\delta_0^2)\pi R_G - (2-\lambda)c}{(1-\delta_0^2)\pi R_G - (3-2\lambda)c}.$$

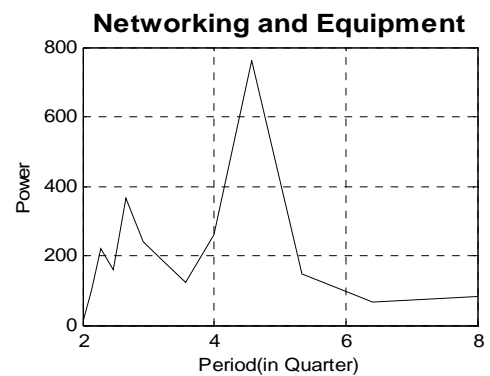
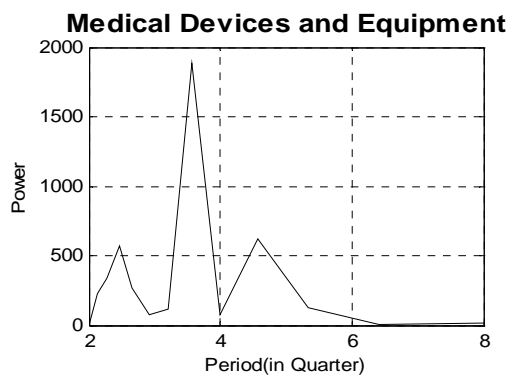
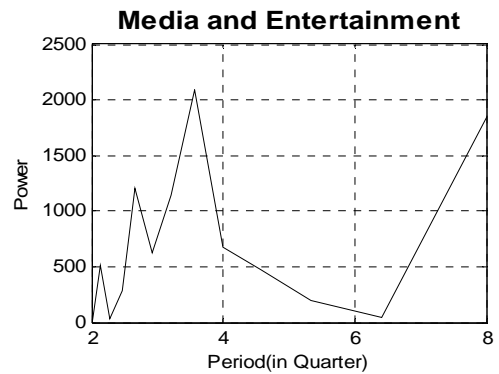
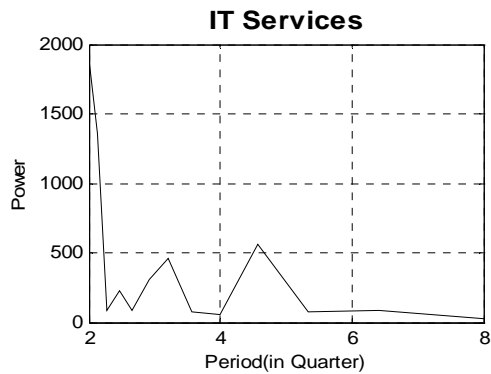
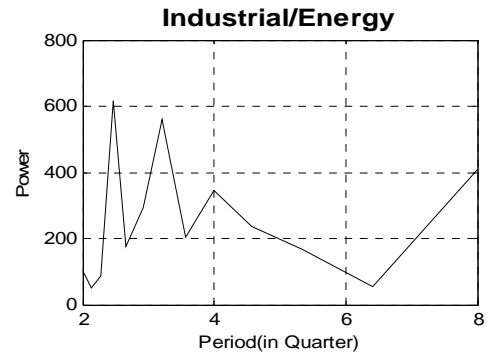
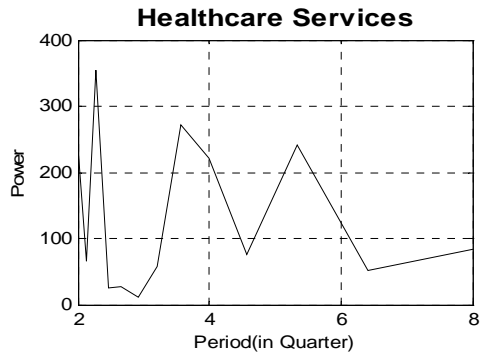
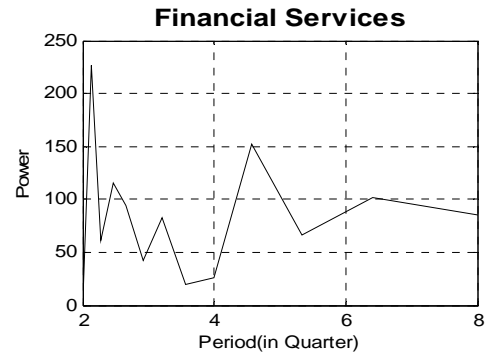
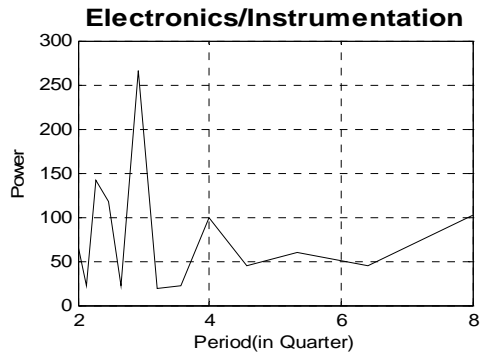
²² The derivation uses the fact that $\frac{\lambda}{3-2\lambda} < \frac{\lambda}{2-\lambda}$ whenever $\lambda < 1$.

Accordingly, for $\delta_0 \leq \bar{\delta}_0$ the symmetric 2-cycle constitutes a screening equilibrium. The argument for uniqueness parallels that of Proposition 4.1

Q.E.D.

Figure 1: Startups: (Number of Deals) Spectrogramm





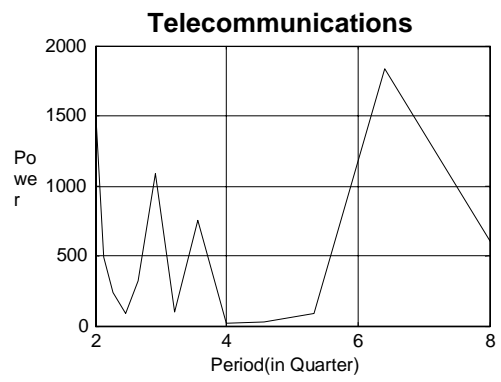
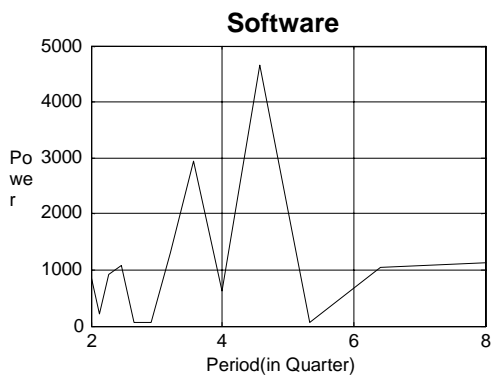
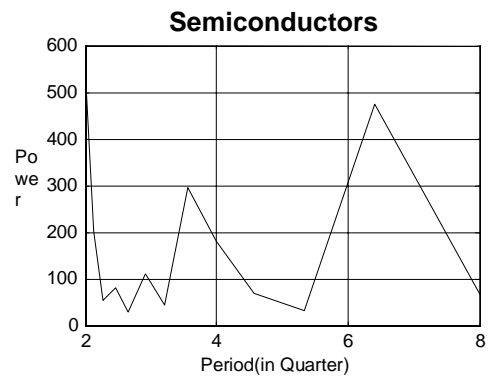
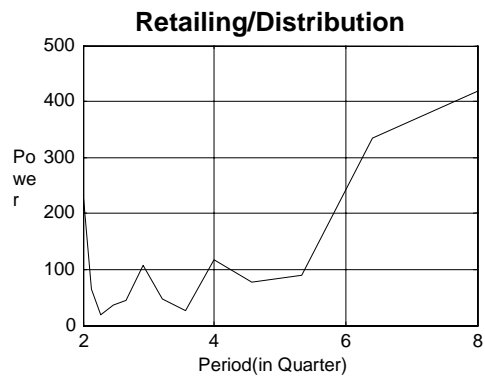
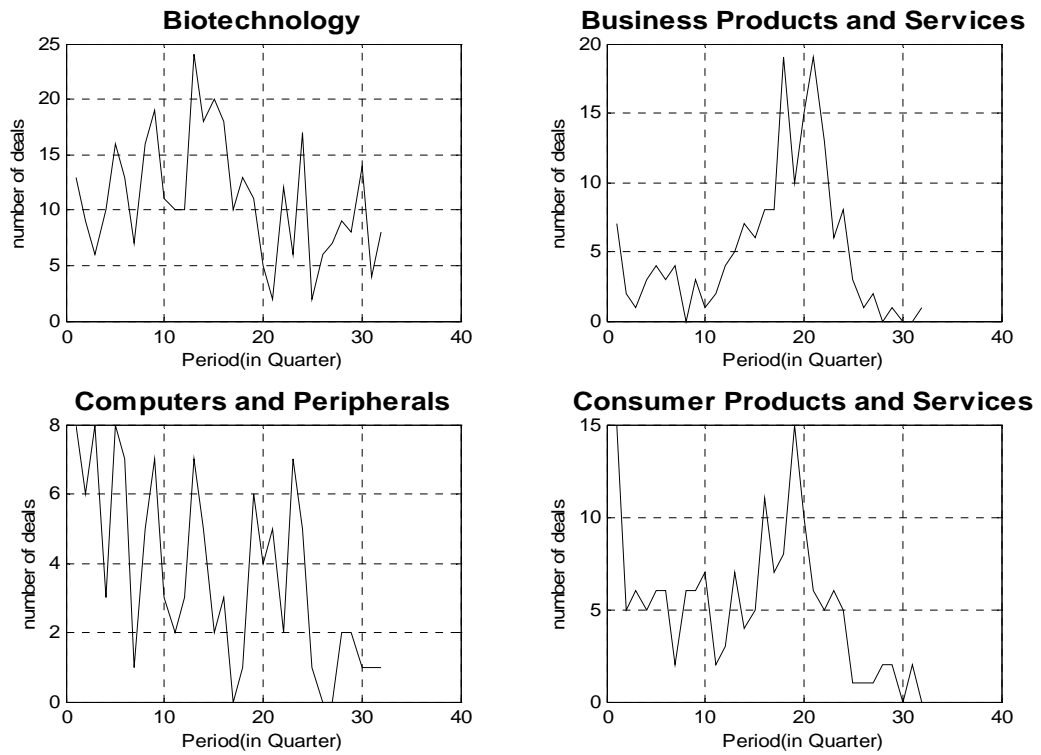
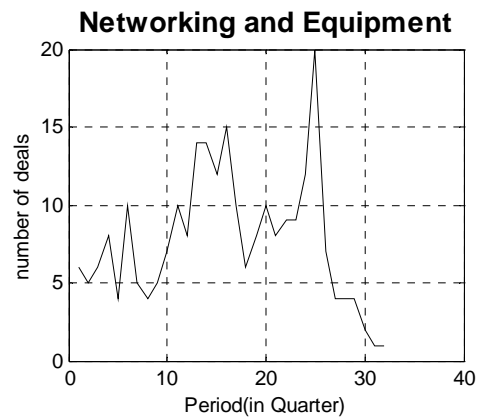
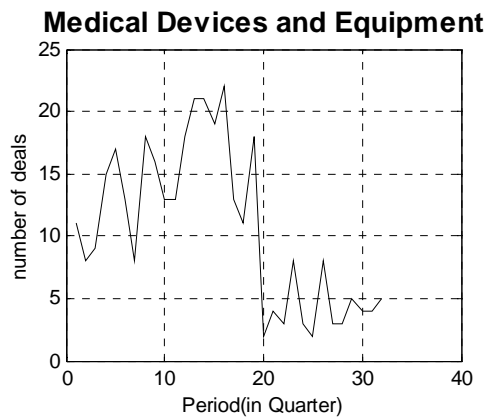
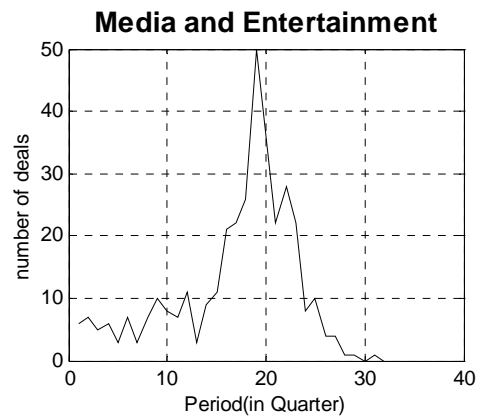
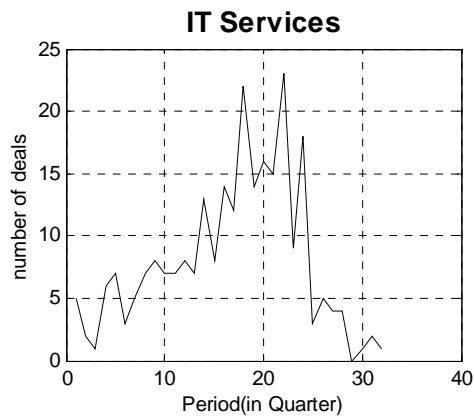
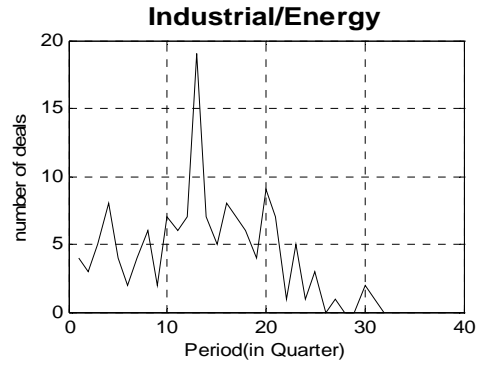
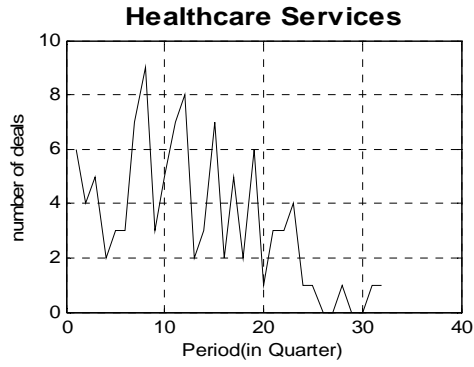
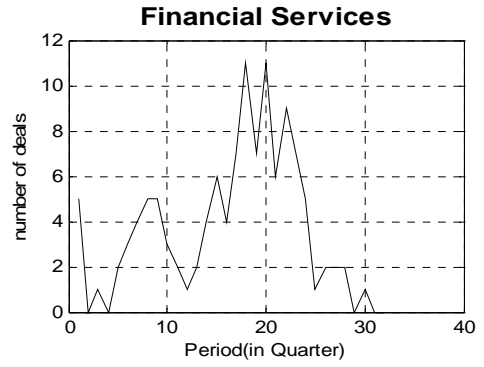
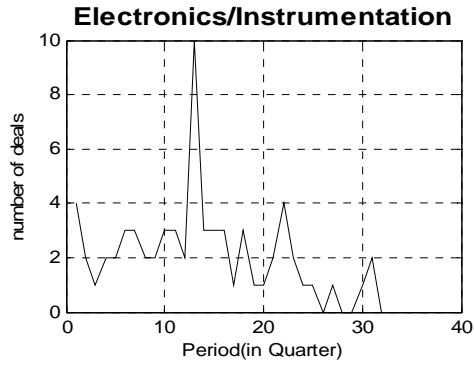


Figure 2: Startup: (Number of Deals) Line charts





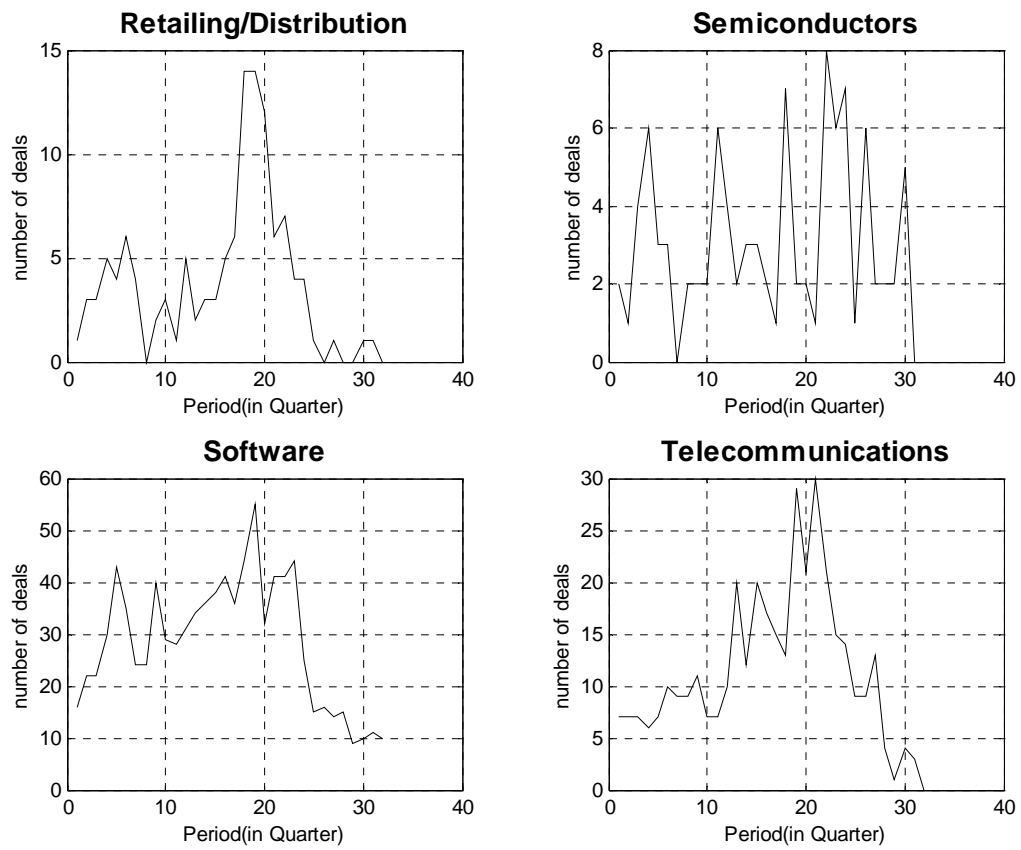
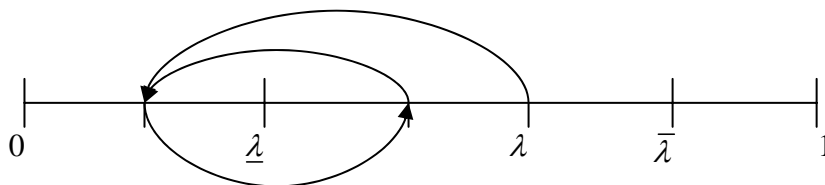


Figure 3: Pool Dynamics

(a) two-cycle



(b) stationary equilibrium

