An Evolutionary Approach to the Theory of Entrepreneurship

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There is wide agreement among economists that entrepreneurship is a crucial factor in the diffusion of new technologies (Science 2001), international competitiveness (Audretsch, Verheul and Wennekers 2002) and the creation of new jobs (Saviotti and Pyka 2004). However, entrepreneurial agents are almost invisible in standard economic theories embedded in the mainstream neoclassical paradigm. A theoretical framework which allows an explicit consideration of this decisive source of the dynamics of capitalist economies is the experimentally organized economy as suggested by Carlsson and Eliasson (2003). Within this essentially non-linear, Neo-Schumpeterian and evolutionary framework, entrepreneurship offers the decisive link between the technological system and the exploitation of business opportunities within the market economy. The framework developed in this paper is closely related to the *experimentally organized economy,* as it also focuses on the nature of entry and exit of new firms, driven by a high potential of business opportunities offered by a new, emerging technology.

Entrepreneurship has always been a controversial topic in economic theorizing. Most of the research work comes to an end at a purely appreciative level. A consistent theory of entrepreneurship is missing; that is, a theory that is adequate to combine the various strands of literature in order to come eventually to an empirically testable model. Besides the early theories that approach entrepreneurship from a rather intuitive perspective, to be traced back to Schumpeter (1911), Schumpeter (1939), Kirzner (1973) and Kirzner (1999), a modern evolutionary approach should also contain some specific theories such as the theory of human capital (e.g. Schultz 1975), social networks (e.g. Granovetter 1973) and Neo-Schumpeterian Economics (e.g. Loasby 1999). In the following paper we present an approach by designing an analytical model that can be applied to different industries and historical settings.

The core elements of our model are the actors. Even though there are two views on this issue – either models explicitly focus on actors or take a more general approach emphasizing the actors' environment only – for our purpose we draw on the actor-centred perspective. We do not look at actors from the perspective of a situational determinism and optimized behaviour, but we characterize the individual actors as procedurally rational,

struggling in a trial-and-error process for survival and prosperity. Consequently, in their entrepreneurial decision-making they do not know the potential economic outcomes, but experiment with different combinations out of a large set of business opportunities enabled by a major technological breakthrough. The actors in our model are heterogeneous in their individual endowment of accumulated competencies and capabilities, available venture capital and entrepreneurial attitude. We present firm formation as a social phenomenon where individuals within a social network decide to found firms. The formation of social networks is approximated by a random permutation process within our population of actors. An arbitrary number of actors, not yet involved in a firm, are randomly matched in each period. The comprehensive endowment of the group's actors constitutes their potential to found a firm. Whether a new firm is founded or not depends on the group's environment. In particular, they take into account the industry's economic development. As they obviously do not have perfect knowledge about all critical factors which drive an industry's development, they evaluate the average industry's performance by a chosen set of economic indicators. These evaluation criteria can be seen as the decision threshold as to whether actors' establish a firm.

Only in those cases where the actors' perceived comprehensive endowment appears to be sufficient to enter a market and the expected economic future signals promising rewards, is a new firm born. The birth process has an influence on the industry level, which in return has a feedback effect on the micro-level and thus the future decision processes of other agents as to whether to found a firm. We thereby manage to model a micro-macro reciprocity. This reciprocity is essential for understanding the endogenous evolution of the foundation threshold (the agents' shared mental model about economic opportunities), as it changes over time.

The act of founding a firm depends on the individual evaluation of the current (micro- and macro-economic) situation. The success of a firm, once founded, is determined by the individuals' resources and their specific managerial capabilities, which are embedded in the combination and complementarities of their skills. In short: their human capital. In the short run, the survival of the firm decisively depends on a balanced relationship between human capital and venture capital. Missing human capital cannot be substituted by venture capital and eventually might lead to insolvency. As the firm has to invest its funds profitably within a certain period of time, the maladjusted firm will not have sufficient human capital to manage proper investment and eventually will face insolvency. In the long run, however, the economic success of a firm depends on its competitiveness. Competition is represented by a heterogeneous oligopoly, which emphasizes the necessity of vertical completeness in a

balanced set of embodied competencies and horizontal variety stressing the qualitative dimension of innovation competition. If the firm has to exit, again, this has a feedback effect on the foundation threshold. Due to the heterogeneous composition of actors and their experimentally organized behaviour, our model is illustrated numerically for the time being.

In our first simulation experiments we are able to show the emergence of new industries and their endogenous evolution from a theoretical stance. Firms do not appear continuously but in swarms, showing a high degree of sensitivity to the coincidence of entrepreneurial behaviour and environmental conditions. Our model is designed in a very general way and the promising results achieved so far support the application of this basic setting to recent empirical observation of developments in new industries. Finally, this should improve our knowledge about conditions favouring/hindering the emergence of successful knowledge-intensive industries such as in the information technology and biotechnology sectors. This will be the agenda for our future research.

Theoretical motivation

Historical sketch of entrepreneurial functions and ideas

The importance of entrepreneurial behaviour for economic development has always been stressed in economic history but the existence of entrepreneurship in orthodox economic theory has almost been undetectable. Economists wonder why the entrepreneur has almost vanished in economic theory (Barreto 1989). The reason apparently is that with the introduction of entrepreneurial behaviour in orthodox theory, a model runs the risk to losing its consistency, and therefore the entrepreneur remained a stranger in economic theory. Classical economists touched on this subject matter more than neoclassical theorists, who by using the equilibrium concept, might never be able to. This strict methodological apparatus appears to rule out the possibility of placing an endogenous equilibrium-disturbing element as the centre piece of economic development.

The first one to take up thinking about the role of entrepreneurs in economy was Cantillon (1680's - 1734) (Cantillon 1755). He classified economic agents into three groups: (1) landowners (2) entrepreneurs and (3) hirelings (See Hebert and Link 1982). Whereas the first and the third group are characterized as being rather passive, the entrepreneurs play the central part in his *Essai sur la nature du commerce en général.* They play the role of coordinator, connecting producers with consumers, and also the role of the decision maker engaging in markets to earn profits and struggling with uncertainty. His concept of

uncertainty was constrained to the entrepreneur though, and it had to wait for Frank Knight (1921) for a detailed distinction between risk and uncertainty as an economy-wide feature affecting all economic agents. Cantillon was also the first to emphasise the entrepreneur's economic function while distinguishing it from the agents' social status. A functional perspective was maintained by Cantillon's successors associated with the French school. Quesnay (1888), the precursor of the *Physiocrats,* shifted the field of concentration to the significance of capital for economic growth, thereby reducing the role of the entrepreneur – instead of an industry leader – to a pure independent owner of a business, though endowed with individual energy and intelligence (Hebert and Link, 1982: 31).

Baudeau (1771) suggested that the function of the entrepreneur as an innovator and thus brought invention and innovation into the discussion. Furthermore, he emphasized the capacity to process knowledge and information as that which makes the entrepreneur a lively and active economic agent. Another rather capitalistic view was set up by Jacques Turgot (See Groenewegen 1977). According to him, the entrepreneur is the outcome of a capitalist investment decision: the owner of capital can either simply lend his money and just be a capitalist, or decide to buy land for lease and hence become a landowner, or decide to buy goods to run a business and thus become an entrepreneur. Say (1803; 1828) continued Turgot's ideas and elevated the entrepreneur to a key figure in economic life. In contrast to Turgot he made a sharp distinction between the entrepreneur and the capitalist. The entrepreneur might give capital to a firm but he does not have to. Consequently, this also allows for a negligence of risk and uncertainty,[1] when considering the entrepreneurial element explicitly. Say suggested a twofold approach. He looked at the entrepreneur from an empirical perspective to establish actual entrepreneurial behaviour, which he then tried to reduce in a second step to a general entrepreneurial theory by subtracting all incidental aspects attributable to certain social and institutional circumstances (Hebert and Link 1982). The function of his entrepreneur was to understand technology and to be able to transfer that knowledge into a tradable product that meets the customers' needs.

Say paved the road for Schumpeter's theory on entrepreneurship, and Schumpeter's entrepreneurial concept has to be seen as the pivotal point in this field of research. Most of the economists before Schumpeter - with some exceptions - worked within equilibrium theory and most of the theories on entrepreneurship after Schumpeter are built on his ideas (See Hebert and Link 1982).

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[1] Delimiting Say's concept from Cantillon's.

Before we proceed to the discussion of Schumpeter's concept, we briefly have to display the neoclassical treatment of the entrepreneur.

Neoclassical Constraints

The question "What about the entrepreneur in orthodox neoclassical theory?" is easy to answer, but it takes quite an effort to set out the argumentation. The answer is: There is no space for an entrepreneur in neoclassical theory. The relevant discussion can be found in Barreto (1989) *The Entrepreneur in Microeconomic Theory*, where he describes the disappearance of the entrepreneur in economic theory. He shows that with the advent of the modern theory of the firm, economists lost track of the entrepreneur. Basically, the framework of assumptions does not allow for a consistent implementation of entrepreneurial behaviour. The main problem is rooted in the perfect rationality assumption which is a necessary condition for optimal behaviour. This does not allow for a 'real' choice and excludes the treatment of true uncertainty subject to entrepreneurial behaviour. This whittles down the role of the entrepreneur to a static, passive and therefore redundant economic agent within a self-running firm. It is beyond the scope of this paper to recount the anamnesis of the entrepreneur in economic theory. Basically Schumpeter's legacy can be regarded as the outcome of such reflection.

Schumpeter's entrepreneur

To tell the story the right way, we cannot start right at Schumpeter's concept of the entrepreneur. As mentioned above, Schumpeter's work was tremendously influenced by a critical review of equilibrium theory. Though fascinated by Walras' system of equilibrium, he stated that equilibrium theory contributed as much as it could; but further insights could not be expected.[2] Schumpeter's circular flow is a less formal representation of Walras' general equilibrium theory.[3] To reach equilibrium, Schumpeter suggests that economic actors' decisions and actions have to be repeated over and over again in the same way, so that

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[2] Surely, Walras was not the only one who influenced Schumpeter's thinking. There are many others that delivered preparatory work such as Marx, Weber, Menger, Wieser, Say, Hayek, Böhm-Bawerk to name a few. But as the equilibrium concept being the bone of context we quote Walras in this context. See Hébert and Link (1982) for a quick overview.

[3] Although Schumpeter was fascinated by Walras concept of equilibrium, the bifurcation point of their intellectual paths originated in the different treatment of the subject. Walras thought it to be permissible to abstract beyond the adjustment processes in an economic system starting right at the end, which is the equilibrium. Schumpeter concentrated more on the process that destroys equilibrium and, if at all, might lead to equilibrium.

eventually all actors' plans coincide to end up in equilibrium. Schumpeter characterised this result as a static situation that did not allow for change (Barreto 1989). His aim was to investigate the dynamics behind empirically observable economic change. The explanatory element he called *innovations.* The economic agent to bring along *innovations* (i.e. *"new combinations"*) he called the *entrepreneur.*

When we look back to the existing literature at that time, Schumpeter's entrepreneurial concept is a synthesis of, firstly, Say's and Badeau's work and, secondly, the critique associated with the Austrian school.[4] Schumpeter's entrepreneur was and still is the most renowned concept. Therefore, we also take it as the intellectual foundation for our model. Another economist to be mentioned in this context is Israel Kirzner.

Kirzner and the Austrian school

There is a long-standing debate, partly stirred up by Kirzner himself, about what the significant difference is between Schumpeter's and Kirzner's entrepreneur. Both Schumpeter and Kirzner took up an the Austrian critique of general equilibrium theory. Whereas Schumpeter developed a - to our minds - more general approach to entrepreneurship based on economic change, Kirzner focused on the market process. For the reader's convenience, the intuition of the Austrian school is recalled briefly. Equilibrium theory neglects market processes. If all plans of economic actors match, then there is no need for markets. In a state of disequilibrium, however, actors' plans do not match. They have to be revised and adapted to the new market situation.[5] Economic agents have to change their minds continuously and this generates a dynamic process which Kirzner calls the *market process* (Kirzner, 1973: 10). This suggests that a Robbins-type of maximization calculation[6] is impossible. von Mises (1959) solved this task by introducing *human action (* See Barreto, 1989: 17)). Besides the agents' attempt to calculate economic problems, they are also alert to opportunities. Once an economic agent recognizes a market opportunity, he acts on it to improve his position. Opportunities are abundant in a situation of disequilibrium. That is where Kirzner's entrepreneur comes from. While von Mises admitted the ability of *human action* to every economic agent, Kirzner confined it to a certain group of agents which he labelled

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[4] Ludwig von Mises and Friedrich von Hayek as the alleged leaders of the Austrian school engaged in the analysis of disequilibrium conditions focusing on market processes. To get a good intuition of Hayek's attitude towards mainstream economics, see Hayek (1937). Concerning Ludwig von Mises, some necessary amendments will be given when introducing Kirzner's entrepreneur later on in this paper.

[5] This is the point to stress the role of information and knowledge as Hayek, Mises and Kirzner do.

[6] Robbins puts forward the economic agents task to economize an scarce resources efficiently. But efficiency is no more possible in an Austrian-school-like market-process (Robbins 1962).

entrepreneurs. Hence, the entrepreneur as an arbitrageur that equilibrates markets was born (Barreto, 1989: 21)).

The Schumpeter-Kirzner-entrepreneur discussion

Kirzner (1999) distinguished the Schumpeterian entrepreneur, as the innovator and the creative destroyer of equilibrium, from his own, the equilibrating entrepreneur alert to market opportunities. We leave it to the reader's taste to make this distinction between an equilibrium-disturbing and an equilibrium-creating entrepreneur. As a matter of perspective, if we allow alertness to market opportunities and the agent's implied human action to be part of innovativeness, neglecting the question of whether a state of equilibrium in a dynamic economic world will ever be reached before another dynamic entrepreneur comes to prevent economy from equilibrium, it would leave us with the centre-piece of the Schumpeterian dynamics of economic change, i.e. the entrepreneur.[7] In short, Schumpeter's stream of thought is as follows: no entrepreneur – no innovation – no dynamics – no evolution.

"Giving up the Holy Grail"

Ever since economists started to theorize on human behaviour, they have been looking for consistency in theory. What classical theorists could not achieve, neoclassical economists succeeded in. The marginal school and in particular the Walrasian general equilibrium theory eliminated the shortcomings in terms of inconsistency within economic theory. They managed to refine the patchwork of classical thoughts to a consistent unity, but - as we see from the discussion above - at the cost of the entrepreneur. Yet, if we give up on the equilibrium concept, for the sake of the entrepreneur, we might run the risk of losing consistency in return. Then, we have to do disequilibrium economics without such a powerful mathematical apparatus as that of the neoclassical school. *Equilibrium* needs *optimal behaviour. Optimal behaviour* needs *perfect rationality. Perfect rationality* requires *perfect foresight* and *information.* Regardless which of these assumptions we relax, at the same time we question the validity of the remaining ones, and, even worse, we question the methodological approach. This all foreshadows another era of patchwork in (evolutionary) economic theory, concerning the investigation of entrepreneurship, until an appropriate methodology is found.

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[7] As we do neither use an equilibrium concept in our entrepreneurship model, nor think that entrepreneurial behavior can be investigated within an equilibrium concept, we will not take up this discussion.

These misgivings can be confirmed when we look at the existing literature which refers to entrepreneurship and at the same time abandons the equilibrium concept.[8]

Evolutionary approach to an evolutionary concept of the entrepreneur

"(…) the word 'evolutionary' is extremely vague. It is now widely used, even by economists using neoclassical techniques. "Evolutionary game theory" is highly fashionable. Even Walras is described as an evolutionary economist [Jolink 1996]. (...) In precise terms it signifies little or nothing." (Hodgson 2000)

As Hodgson's comment shows, there is an ambiguity about the meaning of the word 'evolutionary'. For this reason, we decided to discuss briefly what evolutionary means to our minds. The model presented in this paper is meant to be a general approach to entrepreneurship delivering constructive propositions for a basic evolutionary setting.

Consolidating the critique of Schumpeter, the body of thought from the Austrian School, and accordingly Kirzner's adaptations to the entrepreneurial case, research on entrepreneurship becomes the pivotal issue for a micro-based evolutionary theory. A lot of factors are addressed that boil down to questioning the phenomenon of innovation in an economic system. Innovation means novelty and in accordance with Arrow's epistemological reservation, an assumptional house of cards built on perfect foresight (complete information), meaning perfect rationality, is a contradiction in itself. It ignores economic change spurred by the dynamic entrepreneur. Each of the assumptions mentioned above entails a huge discussion leading to various strands of literature. Of course, it is not the aim of this paper to cover all of these strands, but they have to be taken into account, implicitly.[9]

Along these lines, in our model we begin at the micro-level. The agents are heterogeneous and differ in their individual endowment. Information is incomplete, in particular with respect to future economic development. Because of imperfect foresight, agents have to deal with true uncertainty.[10] Furthermore, these boundedly rational[11] agents are

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[8] Note: on the one hand, the entrepreneur cannot be a homo oeconomicus which is a necessary condition to use equilibrium analysis. But on the other hand, the homo oeconomicus is the only agent that performs optimally and therefore deterministic. Hence, the question to answer is, how a less perfect agent such as the entrepreneur can be modelled, not getting lost in indeterministic arbitrariness?

[9] For a succinct setting of an evolutionary theory see for example Nelson (1995).

[10] As the reference work an uncertainty see Knight (1921) and his distinction between risk and uncertainty. In the entrepreneurial context we have to deal with 'true' uncertainty. The agent does neither know the outcome nor is he able to calculate corresponding probabilities.

[11] To this discussion see e.g. Simon and Egidi (1992).

limited in their cognitive capabilities to perceive and process the accumulated information. Owing to the high degree of novelty attached to entrepreneurial behaviour, true uncertainty does not allow for a calculation of expected values. The agent neither knows the set of possible outcomes nor the corresponding probabilities. As we thus deprive the agents from optimizing capabilities, they have to make decisions using the best of their knowledge. They have to perform, in the words of Mises, human action. The agents therefore have to form expectations in various respects: they have to evaluate their individual endowment of resources, capabilities and competencies and the overall economic situation, and also consider the possibilities for acquiring missing complementarities (to be specified later on).

The light of perfect rationality missing, agents consequently make individual forecasts motivated by their personality[12] and current (economic) environmental factors. Decisions are thus the outcome of a path-dependent process: the evolution of the agent's individual (accumulated) endowment (resources, capabilities and competencies including experience) and non-individual, environmental factors subsuming the economic situation. The latter gives us the notion of feedback effects. The economic agents' decisions are influenced by economic factors (economic situation) and in return influence economic factors by their actions, e.g. by the decision to establish a firm. It goes without saying that we implicitly consider irreversibility to round off the assumptional frame of our evolutionary perspective.

In the following, we flesh it out with some less abstract ideas of entrepreneurial behaviour. Since our main intention is to show the basic structure of an evolutionary model of entrepreneurship, we decided to tolerate some simplifications to be discussed in the following section.

Actors

We divide an agent's individual endowment into three components which we call entrepreneurial spirit, human capital and venture capital. These three factors form the individual agent.[13]

Entrepreneurial component: The entrepreneurial component can be thought of as the residual of the agent's individual endowment which is hard to measure empirically. It comprises the intangible characteristics of the heroic Schumpeterian entrepreneur. By doing

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[12] By personality we mean the conglomerate of accumulated knowledge, information and experience.
[13] Each component is the result of a cumulative evolutionary process which will not be discussed in this paper. With respect to an empirical application, each component requires sector-specific observations.

this, we follow empirical evidence that does not allow detecting a stereotypic entrepreneur and furthermore, we take up on Mises saying that every human being has the potential for human action.

Human capital: With the second component we refer to one of the more successful strands of research. The human capital approach, constituted by Theodor W. Schultz (1971), and elaborated by Gary S. Becker (1993) among others, allows for an empirical application. It tries to explain optimal investment in human capital and delivers insights on income distribution. The theoretical concept is basically derived from investment theory in physical capital using marginal analysis. We do not use the human capital concept this way,[14] but we emphasize the importance of human capital for establishing a firm. Agents do not know the actual return when they decide in favour of founding a firm, although they might know their remuneration when offering their human capital to the labour market. Therefore, agents decide in a dichotomous way; if they expect the returns of going entrepreneurial will be higher than being an employee, they will decide to become an entrepreneur.

Moreover, we refer to the literature on knowledge originating from the Austrian School. Hayek (1937) discusses the importance of knowledge in a disequilibrium situation i.e. a situation of uncertainty. Loasby (1999) provides a good overview in *Knowledge, Institutions and Evolution in Economics*. For our purpose, we interpret the agents' role of human capital as the crucial productive element for the long-run survival of the firm, once it is founded by the agents. It is needless to say that human capital encompasses both technological as well as economic competencies of agents.

Venture capital: The third element we include into the agents' endowment vector is a component of venture capital. In so doing, we pay attention to the discussion of whether the roles of capitalist and entrepreneur can be separated. The "early French view" saw the entrepreneur as a risk bearer while the "English view" identified the entrepreneur as the capitalist. Schumpeter (1939) discusses the role which money plays in entrepreneurship as well. The bottom line is that potential entrepreneurs need to have capital to start their business, regardless whether they own it themselves or borrow it from others. Empirical

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[14] We are conscious of our tightrope walk to use a strictly neoclassical concept within our model that we explicitly claim to be evolutionary. We assume a link between the agents' set of capabilities and their economic performance. For the time being, we rather use it as a metaphor to stress the importance of knowledge in our model leaving the necessary "evolutionary" clarification of this concept for further research.

evidence supports the hypothesis that entrepreneurs in general face financial and liquidity constraints (Blanchflower and Oswald 1998).

From this discussion we draw out the assumption that each agent is endowed with a certain amount of capital which he can spend on a business venture. Again, we do not bother about the details, whether he inherited or accumulated a certain amount of money by saving.

So far, we have characterized the individual agents by their endowment factors.[15] Each actor possesses the potential to be an entrepreneur as von Mises suggests from a theoretic perspective and as empirical data shows (Blanchflower and Oswald 1998). Thereby, the decision (human action) is not necessarily a behaviour of optimality, calculating what the maximal return to total human and (free disposable) venture capital is. However, the long-run survival of a firm once founded is highly dependent on the agent's human capital. As we vested all agents with the option to own venture capital, we can incorporate the notion of risk bearing and uncertainty. But as we will see later on, the "mainly"[16] entrepreneurial agent need not be the risk bearer.[17]

By defining agents in that manner, it allows to consider not only the agents' isolated decisions but also the application of a broader system perspective. As Carlsson and Eliasson (2003) point out, a technological system is characterized by various components, which have a collective meaning: the set of technological possibilities, which can be interpreted as a combinatorial design space (Stankiewicz 2001) formed by a cluster of mutually complementary technological capabilities. The organizational and institutional dimension basically denotes the interaction between heterogeneous agents and the respective combinations and cross-fertilizations. The economic dimension stands for the selection processes of markets. In order to take into account such a systemic view, we introduce social network theory.

Social Networks

To acquire the overall endowment actors regard as necessary, they can choose several ways to acquire the missing endowment factors. They have to figure out how to get access to required resources (Penrose 1959) and whether the necessary competence to combine these resources is available (Foss 1993). To draw on Coase (1988), some of the resources and competencies can be inherent to the agent, others have to be acquired on the market or otherwise. We will not go further down this road and leave that task to the modern evolutionary theory of the firm

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[15] Besides the suggested endowment factors any other desired factor can be included into the endowment set.

[16] As we proceed we will not confine the entrepreneurial behaviour to a single agent but to a number of agents.

[17] This goes along the lines of Schumpeter (1939, chapter: Entrepreneur).

still to be developed,[18] since we do not argue on the firm level but, following Birley (1985), investigate the "pre-organization" phase in order to stress the importance of an agent's social network as a main source of help to obtain resources and competencies to start a business. Furthermore, we discuss the role of social networks (Granovetter 1983) for two reasons. First, for methodological reasons: by introducing social networks into the model, we climb up one step further upon the aggregation ladder and thus leave the micro-level (individual's level) to bring the collective dimension (the agent's social context) into discussion. Second, for empirical reasons: personality-based theories – that is, purely micro-based theories – try to find personal traits unique to entrepreneurs.[19] These attempts have not yet been successful in identifying the entrepreneur when not considering the social group context (Hall 1982).

It is beyond the scope of this paper and not our intention to discuss social network theory comprehensively. We put together existing fragmental theories on entrepreneurship in an evolutionary model setting. Within this project social networks are incorporated as one of various critical elements in entrepreneurial behaviour.[20]

The Model

In the following section we introduce the basic structure of our model of entrepreneurship evolution. The model is designed in a very general form so that it will eventually allow us to investigate different scenarios, and also to implement the relationships and specificities of certain sectors. In a way the basic design has to be seen as a platform approach allowing several extensions with regard to the theoretical perspective as well as with regard to a closer look at the empirical sphere.[21]

The Actors

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[18] We could include learning into the model and thus reflect on the human capital component. Coase (1937), Penrose (1959), Demsetz (1973),Wernerfelt (1984) will definitely give enough inspiration to extent our model.
[19] See Aldrich and Wiedenmayer (1993) as an example.
[20] In case agents do not have a sufficient set of endowments and, hence, need additional resources, complementary assets and competencies, networking plays an important and a manifold role (Pyka 2002). Not only does the social network provide the opportunity to have access to additional and complementary endowment factors, networks have a crucial influence on the actual entrepreneurial decision to start a venture itself. Suppose a single agent thinks himself to be unable to start a business all by himself, he has to convince others in order to be supported. Otherwise, the lack of legitimacy may prevent entrepreneurial actions. On the other hand, a high degree of innovativeness, the so-called liability of newness, might be ended by an agent's objecting social network, a synergetic outcome of either strong or weak ties within a network can be an enhanced and by the group subjectively high-valued business idea. In other words: a social network functions as a catalyst to spark or prevent a venture. In detail the social networking process can be found in Grebel (2004).
[21] Interested readers may request the details from the authors.

To model the evolution of entrepreneurship and the founding of new firms, we obviously have to go one step further down the micro-level, i.e. not only down to the firm level but to the individual actors' level and in particular to the individuals' specific endowment. The individuals are characterized by the crucial features identified in the previous section: (i) entrepreneurial spirit es_i^t, which describes an actor's tendency not to become an employee but an independent firm leader; (ii) human capital hc_i^t, representing an actor's specific level of technological as well as economic knowledge and skills; and finally (iii) the actor's endowment and/or access to venture capital vc_i^t. These different features are all represented as real numbers on a cardinal scale in the interval [0, 1], higher values indicating higher levels of the specific characteristics. Accordingly, the n different actors in our model are described by the following vector:

$$(1) \qquad\qquad a_i^t = \left\{ w_i, \left\{ es_i^t, hc_i^t, vc_i^t \right\} \right\}$$

where $a_i^t :=$ actor i at time $t, i \in \{1,...,n\}$. Since entrepreneurial behaviour is about innovative behaviour, actors first have to get to know a new technology in order to be able to innovate on it. The diffusion of new knowledge is a time-consuming process, whereby the rate of knowledge diffusion also has an influence on entrepreneurial behaviour seen from a macro perspective. To model this, we introduce w_i which indicates an actor's stock of new knowledge. In the case when the actor has absorbed the new knowledge, $w_i = 1$, if not, w_i remains 0. The diffusion process itself is modelled using a von-Neumann cellular automaton.[22]

To build a starting distribution of the population of actors (2) we create randomly n of these triples where the features es_i^t, hc_i^t and vc_i^t are uniformly distributed within the relevant interval.

$$(2) \qquad\qquad A^t = \left\{ a_i^t \right\}_{i \in \{1,...n\}}$$

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[22] For brevity this aspect is not outlaid any further here. For a detailed description of the knowledge diffusion process and how it is implemented into this model see Grebel (2004) or email the author.

Matching Process and Founding Threshold

For each iteration, the population of actors not yet involved in a firm is permuted and k different actors are randomly brought together in order to evaluate their chances to found a possibly successful firm. For this purpose, we consider the specific attributes of the actors to be additive so that also a potential firm pf_q^t can be characterized by the triple of attributes of its k members:

$$(3) \qquad pf_q^t = \begin{pmatrix} \sum_{i=1}^{k} es_{i \in k_q^t}^t \\ \sum_{i=1}^{k} hc_{i \in k_q^t}^t \\ \sum_{i=1}^{k} vc_{i \in k_q^t}^t \end{pmatrix}$$

so that the set of potential firms at time t is:

$$(4) \qquad PF^t = \left\{ pf_q^t \left(= ce_q^t \right) \right\}_{q \in \{1,\dots m\}}$$

where $q \in \{1,...,m\}$ denotes the specific potential firm and m the number of potential firms, i.e. the number of temporarily formed k-groups q in period t. Each group of actors has to evaluate if their comprehensive endowment ce_q^t, which for simplicity is equal to pf_q^t, is adequate. Yet, the actors' mere perception of their common resources, attitudes and motivation is not the only determinant for founding a firm. The actors involved are also influenced by their environment and the respective mood within the population. For modelling reasons, we introduce the so-called founding or entry threshold, y^t, as a "meso-macroeconomic signal" which endogenously depends negatively on the growth rate of the sector's sales w^t. The growth rate of the sector's sales decreases the threshold in return. Furthermore, the threshold depends negatively on the return on sales ru^t, depends positively on the rate of exits dt and positively on time t:

$$(5) \qquad y^t = y\left(\frac{dw^t}{dt}, d^t, ru^t, t \right)$$

If the k-group's, that is the potential firm pf_q^t's, comprehensive endowment ce_q^t exceeds the foundation threshold $\mathbf{y}^t$, the k actors decide to found a firm, thus the potential firm pf_q^t turns into an actual firm f_q^t, and the formerly potential firm's comprehensive endowment ce_q^t becomes the actual founded firms comprehensive endowment ce_j^t. The set of newly founded firms F_{new}^t in period t is thus given by (6):

$$(6) \qquad F_{new}^t = \left\{ pf_q^t : \sum_{q_j}^{q_k} pf_q^t > \mathbf{y}^t \right\}_{pf_q^t \in PF^t}$$

Hence, the set of all firms that have been founded up to time t is given in (7). In case equation (6) does not hold, the potential firms simply represent a social network subject to future change. Consequently, their resources remain available for potential business ventures. Equation (8) gives the firm j's comprehensive endowment.

$$(7) \qquad F^t = \left\{ f_j^t \right\}_{j \in \{1, \dots x^t\}} \Leftrightarrow \bigcup_0^T F_{new}^t$$

$$(8) \qquad f_j^t = ce_j^t = ce\left(\sum_{i=1}^k es_i^t, \sum_{i=1}^k hc_i^t, \sum_{i=1}^k vc_i^t \right)_{j \in \{1, \dots x^t\}, i \in a}$$

If the threshold is not exceeded, the option to found a firm, for the time given, is rejected by the actors. Consequently, the actors that do not get engaged in a firm are free to go for further trials in the following period. In the case of a successful foundation of a firm f_j^t with $j \in \{1, \dots, x^t\}$, the k actors involved are no longer available to found another firm. At the same time, this reduces the probability for other actors to find adequate partners. On the other hand, according to equation (9) the number of existing firms x^t is increased by the number of firms F_{new}^t founded within a period, thereby also exerting a positive influence on the sector's aggregate turnover which positively feeds back on the founding threshold in the next period.

$$(9) \qquad x^t = x^{t-1} + \left| F_{new}^t \right|$$

$x^t :=$ number of firms in the industry at time t.

Survival and Exit

Whether a firm f_j^t survives in the market or is threatened by exit depends on its set of endowments and composition of aggregated capabilities. They determine a firm's competitiveness. The ratio between human capital and venture capital determines the fixed cost. The variable unit costs decline over time owing to a learning-curve effect while accumulating output. In combination with the firm's individual demand curve (equation 10) the firm's profitability (fitness) relative to other firms is determined. Hence the hazard of exit if facing insolvency is stated.

A heterogeneous oligopoly is the formal expression of the interdependence of firms in the sector. Using an oligopoly module, we manage to implement a selection process taking into account the heterogeneity of firms. Equation 10 show a firm's individual demand curve which basically depends on the relative quality y_{jt} of the products of firm j compared to others.

(10) $$p_{jt} = y_{jt} - \boldsymbol{h}x_{jt} + \frac{h_{jt}}{n-1}\sum_{\substack{l \\ l \neq j}} p_{l,t-1} \; ; \qquad j,l \in \left\{1,...,n\right\}_t ; [23]$$

This heterogeneous oligopoly is a myopic optimisation module as it is used for example by Meyer et al. (1996) and Pyka (1999). It is necessary only to flesh out the founding threshold. It generates the data (stylized facts) which influence actors' behaviour. But at the same time, the data in return is the outcome of actors' behaviour, thus the micro-macro reciprocity as suggested above is modelled. The module may be replaced by a more elaborate competition module to render a perhaps more precise concept of firm behaviour and competition. Nevertheless, as long as the stylized facts which influence the actors entrepreneurial behaviour do not change, the basic propositions about micro (entrepreneurial) behaviour, the focus of this paper, do not change.

So, we obtain data on sales and exits necessary to model the founding threshold.[24]

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[23] $p_{jt} :=$ product price of firm j at time t; $y_{jt} :=$ price limit of firm j at time t; $\boldsymbol{h} :=$ price elasticity of demand; $x_{jt} :=$ output of firm j at time t; $h_{jt} :=$ oligopolistic interdependence of firm j at time t;

$n_t :=$ number of firms at time t. For more details see Grebel (2004).

[24] This module is discussed in detail in Grebel (2004). The interested reader may also just contact the author.

Basic Structure of the Model

Figure 1 summarizes the basic structure of the model. To start with, we distinguish several levels of analysis: the actors' level, the firm level and the sector level. The entrepreneurial process primarily takes place on the actors' level. A set of actors with heterogeneous endowments is given. Actors form social networks that change over time, expressed by a random matching process.

The actors, grouped together, constitute a potential firm. Since they neither have perfect foresight nor complete information about future prospects, their decision will be myopic, based on their common evaluation of the economic situation which is influenced by their subjective perception of measurable economic indicators. The more economic indicators paint a promising picture of a possibly prosperous outcome of entrepreneurial actions, the lower the threshold for actors to decide in favour of such action. The same holds in reverse. If actors decide against founding a firm, they return to the set of actors available for another trial to evaluate entrepreneurial actions within a changed social environment. If they decide to found a firm, the firm is established and actors' resources are bounded within the firm so that they are excluded from a further firm founding process. On the sector level, the firm is forced to compete with incumbent firms. Their competitiveness is determined by their comprehensive set of endowments constituted by the founding actors' individual endowments. The selection process, which is competition, has an effect on each firm either worsening or improving its fitness to stand future competition. The short-run exit criterion, competing "for the market", is insolvency. Firms with an unbalanced set of endowments run out of money (venture capital) and finally have to exit the market. The long-run selection process via market competition, or to put it in other words competition "in the market", decides over the competitiveness of the actual business idea.

Figure 1: Basic structure of the model
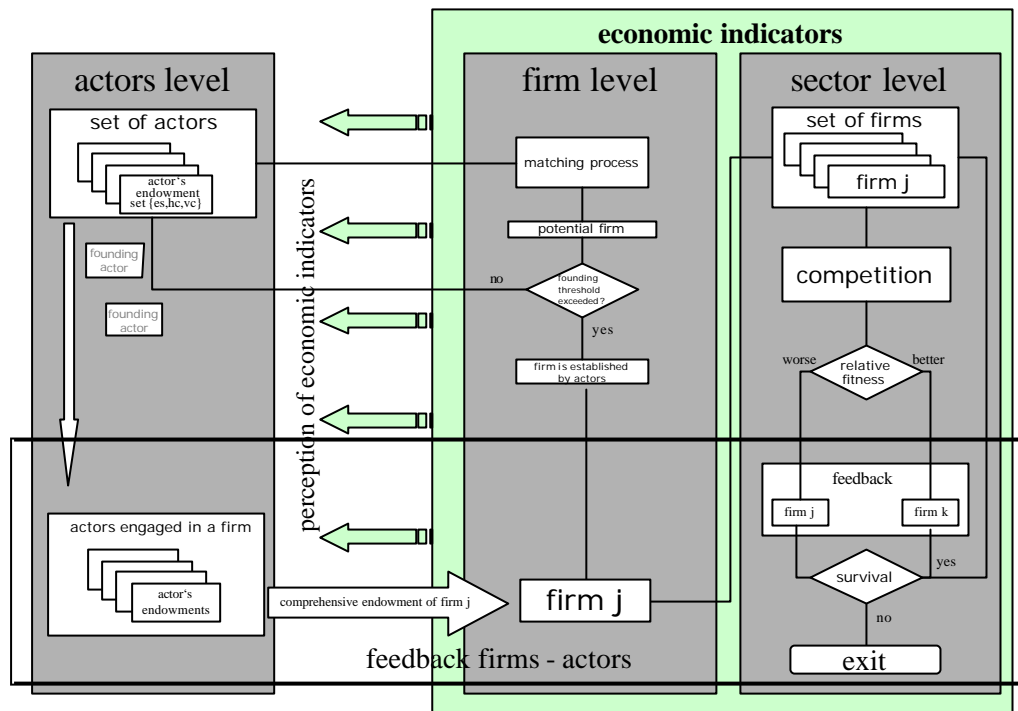
Results

In this section we present some simulation results of the model. Though our focus is on entrepreneurial behaviour, we have to take a rather holistic view. Combining the manifold theoretical contributions in the realm of the analysis of entrepreneurial behaviour, we also have to touch some peripherals of the subject investigated in order to show the endogenous dynamics of entrepreneurship. Otherwise, it would not be possible to include the feedback effects suggested in the model. Nevertheless, we neglect further specification of those peripheral, economic phenomena and leave it with a purely theoretical case. The simulations we ran all show the same qualitative features.

Figure 2 summarizes the simulation results. To start with, a stereotypical development of the emerging sectors' total sales is shown in figure 2 a). Once firms are founded, the industry's total sales increase sharply. The high growth rates at the beginning function as a signal for other economic actors to enter the market (to innovate), too. From a certain point in time, as competitive pressure increases, as more firms enter the market and as the market diffusion of products based on the new technology proceeds, growth rates decline though remaining positive. Thus, the total sales curve takes a stylized sigmoid shape. Firms do not enter all at once. Some enter early whereas others enter at a later point in time. Early entrants

might have a first-mover advantage whereas late entrants might have to struggle for survival competing with larger firms. It is not just the time of entry that makes firms different, but also their set of endowments, which is crucial for their overall economic performance.

We consider actors' cognition to be the guiding element of entrepreneurial behaviour as illustrated in figure 2 d). Actors have to evaluate their chances to found a potentially successful firm. Due to their bounded rationality, they have to decide on grounds of their accumulated knowledge and experiences whether to found a firm or not. They make a subjective decision as influenced by their perception of market opportunities, represented by the individuals' interpretation of the economic indicators. The higher a sector's growth rates are, the better market opportunities are evaluated, hence, the actors' inhibitions for entrepreneurial behaviour decrease and more and more firms are founded. This is the story the decreasing foundation threshold tells us until compensating effects set in: with an increasing number of firms in the market, the competitive threat is increased. Furthermore, growth rates shrink and some firms already have to exit the market. As economic indicators get worse, the foundation threshold starts rising.

Correspondingly, we observe a swarm of entrepreneurs (figure 2 b)) along the plummeting foundation threshold until first exits occur. Then, the number of firm entries decreases. The foundation threshold starts rising again. Fewer actors positively evaluate market opportunities and therefore fewer actors found a firm. Eventually, exits exceed entries (figure 2 c)) and we observe a fierce shakeout (e.g. Klepper 2002). After a phase of consolidation, the founding threshold decreases again when overall returns on sales become positive. As time goes by, the innovation potential of the technology declines and the founding threshold rises, i.e. the actors common evaluation of such technology becomes increasingly negative (compare Grebel 2004). Note that the long-run evolution of the sector is not considered explicitly. In order to do this, we would have to change the selection process of firms and try to model the demand side more precisely.

Figure 2: Entrepreneurial behaviour within an endogenously evolving sector

total sales

a)

time

# of firms

b)

time

net entry

c)

time

founding
threshold

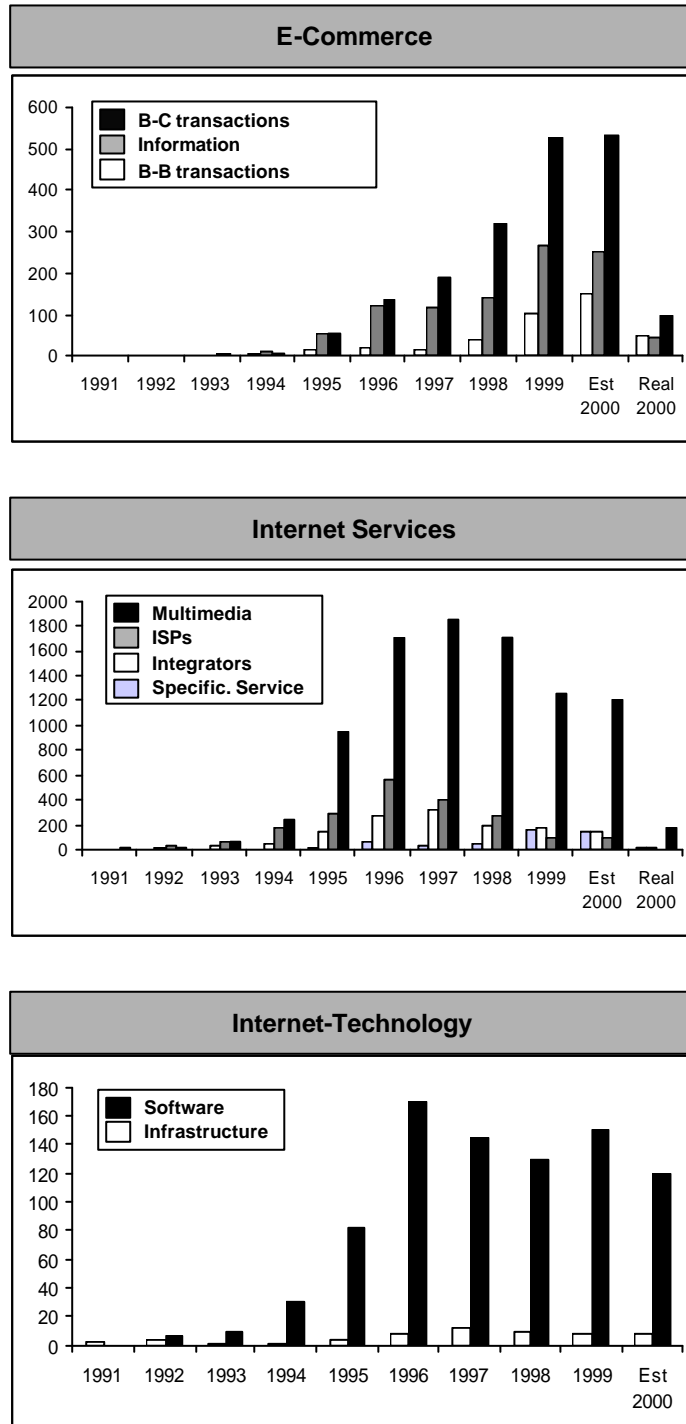d)

time
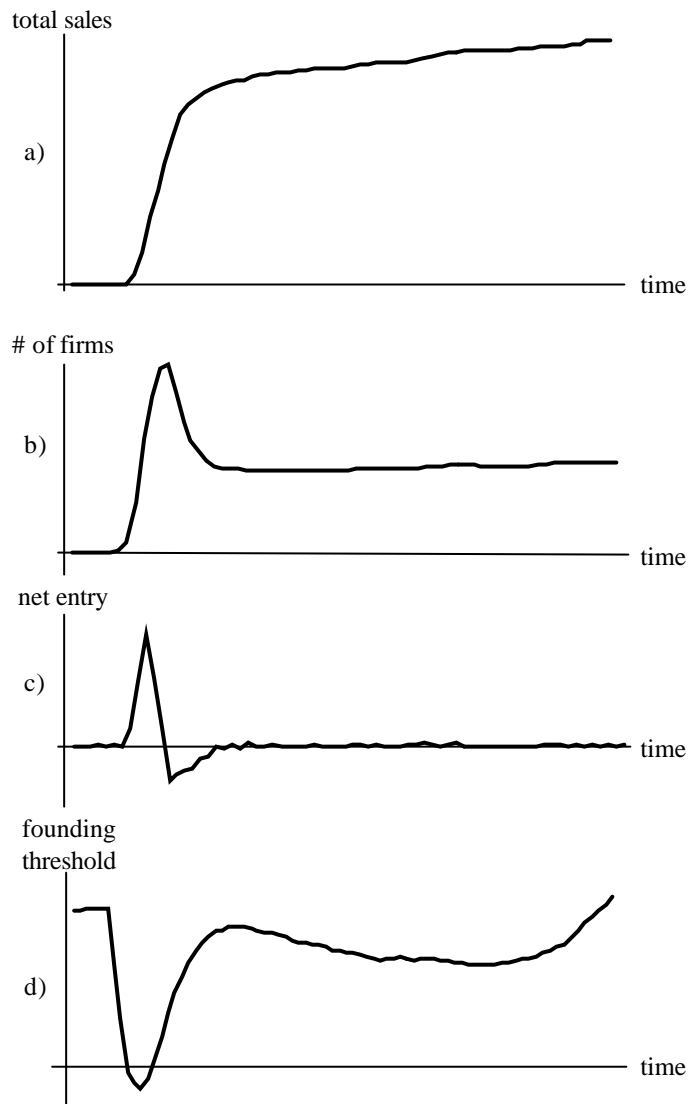
Some Empirical Comparisons

The formulation of the model and the first simulation results confirmed our intuition and the functioning of the model. In a next step an empirical validation has to be undertaken to round off the analysis. It has already been stated that the model is to serve as a platform to be calibrated and possibly reformulated to achieve robustness of the model's implied hypotheses. The construction process of the model itself was inspired by various empirical works such as Klandt (1984), Szyperski and Nathusius (1977) and Brüderl, Preisendörfer and Ziegler (1996). The endowment set of actors summarizes all possible characteristics of the individuals which might have an influence on entrepreneurial behaviour. The role of social networks in a pre-entrepreneurial phase has been discussed by Birley (1985). Klandt and Krafft (2001) investigated the foundation of internet/e-commerce firms in Germany, surveying 8,989 newly founded firms via a online-questionnaire (In detail see www.e-startup.org). They state that on average 1.9 (in firms not financed by venture capital, Business Angels or strategic investors) to 3.1 (in firms financed by venture capital, Business Angels or strategic investors) individuals take part in a foundation.

The analysis of 1,890 start-up firms delivered the results depicted in Figure 3. In each sector a wave of firm foundations shows up. The first wave was in the technology sector followed by internet services and then e-commerce. Figure 4 shows insolvencies of internet/e-commerce firms per month, where we can see a surging number of exits following the swarms of foundations. Venture capital has a significant influence on the firms' growth. In 1999, start-up firms financed by venture capital generated sales of 2.6 million DM on average, whereas start-up firms without venture capital came up only to 1.4 million DM (compare Klandt and Krafft 2000). Besides, the propensity to insolvency is higher among venture-capital-financed firms (Figure 5). Though we have not included a differentiation between venture-capital-financed and not venture-capital-financed firms yet,[25] the data suggests that the relation between a high amount of venture capital and the propensity to insolvency can be corroborated. Concerning the actors' attitude towards innovative technologies such as the internet, we cannot yet offer an empirical validation of the so-called founding threshold, which represents the dynamic change of the actors' evaluation of market opportunities,

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[25] All actors in our model have a certain amount of "venture capital", i.e. free disposable money capital. So there is no such differentiation between venture-capital-financed vs. not venture-capital-financed firms. Nevertheless, once we incorporate different populations in our actors' base, including a population of venture capitalists and, furthermore, work on a proper representation of a search process that brings the appropriate actors together, the model will deliver corresponding results.

contingent on the underlying feedback processes we assumed in our model. This will be left for future research.

Figure 3: Swarms of firm foundations

E-Commerce

B-C transactions
Information
B-B transactions

Internet Services

Multimedia
ISPs
Integrators
Specific. Service
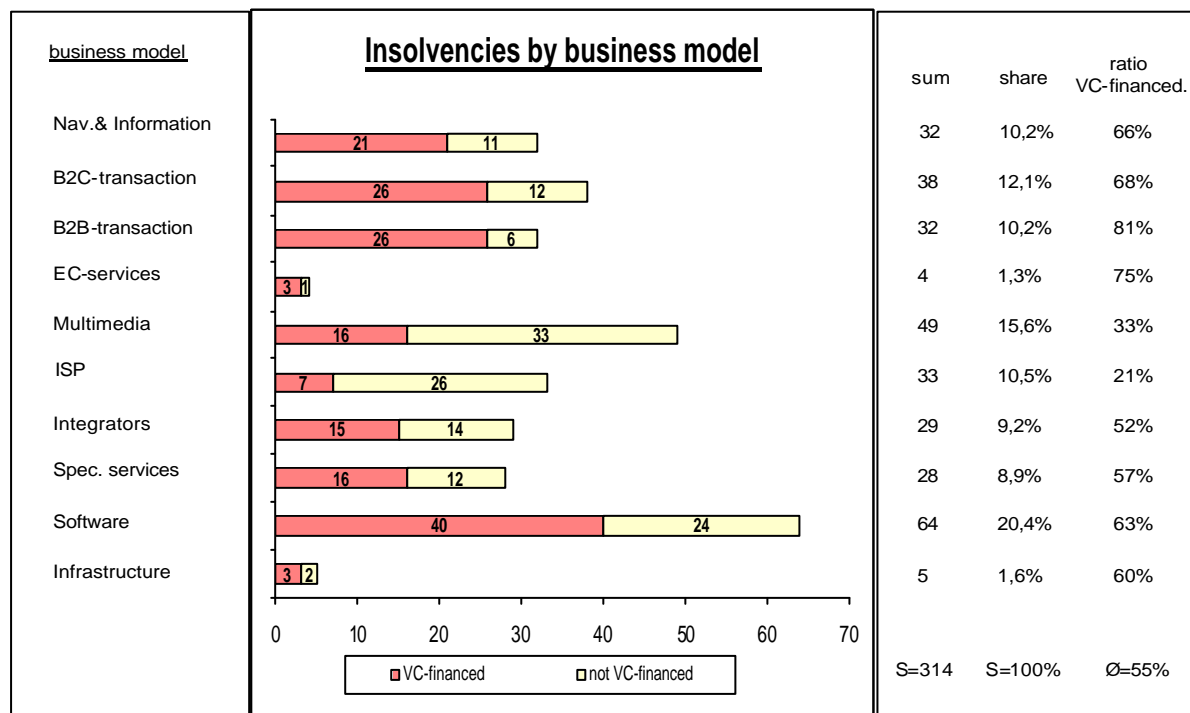
Internet-Technology

Software
Infrastructure

Source: e-startup.org database, Newsfeeds, RWS-Verlag (www.rws-verlag.de/inda/inso.htm), Insolnet GmbH.

Figure 4: Insolvencies of internet/e-commerce firms per month
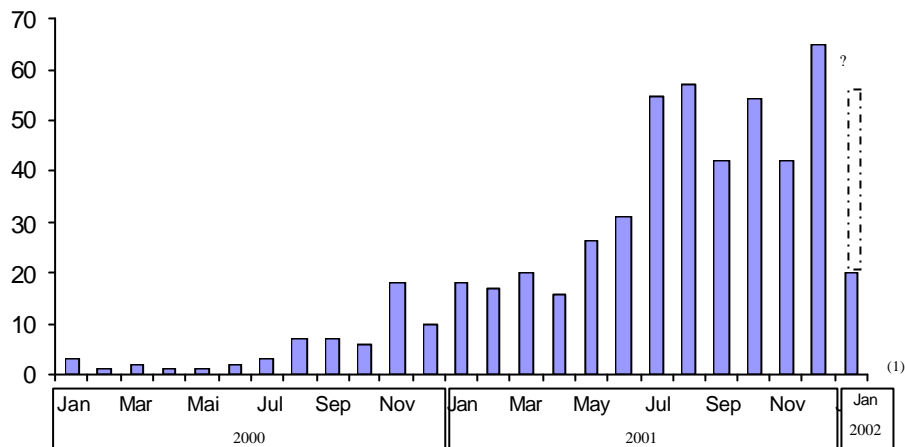
Source: e-startup.org database, Newsfeeds, RWS-Verlag (www.rws-verlag.de/inda/inso.htm), Insolnet GmbH, (1) January 2002 is an estimate.

Figure 5: Insolvencies by business model: VC-financed vs. not VC-financed

business model	Insolvencies by business model	sum	share	ratio VC-financed.
Nav.& Information	21 / 11	32	10,2%	66%
B2C-transaction	26 / 12	38	12,1%	68%
B2B-transaction	26 / 6	32	10,2%	81%
EC-services	3 / 1	4	1,3%	75%
Multimedia	16 / 33	49	15,6%	33%
ISP	7 / 26	33	10,5%	21%
Integrators	15 / 14	29	9,2%	52%
Spec. services	16 / 12	28	8,9%	57%
Software	40 / 24	64	20,4%	63%
Infrastructure	3 / 2	5	1,6%	60%
	■VC-financed □not VC-financed	S=314	S=100%	Ø=55%

Source: e-startup.org database, Newsfeeds, RWS-Verlag (www.rws-verlag.de/inda/inso.htm), Insolnet GmbH(I).

Concluding Remarks

We developed a model of entrepreneurial behaviour which we claim to be an evolutionary one. Once again, we emphasize that we explicitly consider entrepreneurial behaviour, i.e the birth process of firms and industries. Though possible, a further discussion of the industry life cycle was not intended. The core elements of the model are the heterogeneity of actors, their boundedly rational behaviour to make myopic decisions in favour of founding a firm (which might eventually lead to sub-optimal outcomes), the feedback effects from the micro- to the macro level and vice versa, the (irreversible) historicity of events and the variation and selection mechanisms that put the economic process into a dynamic context.

Not using an equilibrium concept nor assuming optimal behaviour, we managed to avoid a "survivor bias" at least from a theoretical point of view: some actors decide to run a firm even though they have to exit in the short run because of a lack in the necessary and adequate comprehensive endowment.

Economic change is brought along, firstly, by the actual economic development driven by the market process and, secondly, by the changing attitude of actors driven by their perception of the economic situation.

At the beginning of the up-coming new sector, actors have to deal with true uncertainty prevailing in the decision-making process. Actors have to rely more on their subjective and possibly "false" intuition concerning their entrepreneurial actions, which leads to market turbulence in the early phase of the sector life cycle. As time goes by actors are better able to understand new technologies, to assess market opportunities and their chances for successful innovative, and entrepreneurial behaviour. Consequently, uncertainty decreases, more precise predictions and more careful decisions will be made, and thus stabilizing forces set in.

Our future research work is motivated by empirical applications. Therefore, some specifications will be necessary. Starting at the actors level, we have to investigate the actors individual set of endowments in order to identify the actual essential components that spur entrepreneurial behaviour, including the creative process of generating a business idea. A possible classification of actors and the formation process of their social networks that have an impact on entrepreneurial behaviour will have to be considered. In this context, we will have to introduce an interaction-based component into our model to illustrate the qualities of the actors' search process.

The most challenging part of our future research work will be to analyze the cognitive part of the story, which is the role of the founding threshold. It is to investigate the way economic actors perceive the economic situation and how a universal mental construct comes into existence leading to a bandwagon effect in entrepreneurial actions showing swarms of innovations.

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