Psychology in Entrepreneurship and Economic Evolution

Paper for HTSF 2010, Nikos, Twente

Entrepreneurial Heuristics and Decision Making.

Abstract

In this paper I describe the processes of internal and external selection of a business project before official founding. I put particular emphasis on the psychological processes of `internal' selection in an aspiring entrepreneur. The project deals with development and commercialisation of innovative DNA-Biochips. These can be used to detect gene-based health conditions and in drug discovery. The case study is used to test some conjectures on the operation of evolutionary principles in economics and to identify similar and differing characteristics in visionary technologists and entrepreneurs.

Psychology in Entrepreneurship and Economic Evolution

1. Introduction

According to Schumpeter, the entrepreneur is characterized by a vision of how the future will unfold. His role lies in the combination of some or all of the following elements: ideas, technologies, services, people, knowledge, to form a workable product and organization selling it. In the 'Theory of Economic Development' (1911/1934), written before WW I and translated to English afterwards, Schumpeter analyzes the function of the entrepreneur in economic change. Entrepreneurs further innovation as new combinations of (sometimes new) elements that lead to the "competitive elimination of the old" (Schumpeter 1934, 66-7). Entrepreneurs perceive opportunities, combine ideas, resources, and production factors into new products and entrepreneurial ventures that, if successful, lead to innovations and the creative destruction of established enterprises and industries. Schumpeter distinguishes between 5 cases of innovation:

"(1) The introduction of a new good … (2) The introduction of a new method of production … (3) The opening of a new market … (4) The opening of a new source of supply … the organization of a new organization of any industry, …" (Schumpeter 1934, 66).

The paper describes in a case study of an entrepreneur indicates how industry evolution can be influenced by 'internal' selection decisions of potential entrepreneurs and 'external' selection decisions of financiers / investors. It describes the process of planning a particular venture at the intersection of biotechnological, electronics and diagnostics industries. Although the project presently is proceeding slowly due to technological development issues, it can illustrate the operation of mental representations in response to expected market `reactions' respectively selection decisions by potential investors, managers of competing and alliance firms and potential product buyers. In both cases of internal and external selection the mental

representations of the economic actors have a major impact. This links into Schumpeter's interest in the psychological characteristics of entrepreneurial actors (cp. Becker and Knudsen 2004), and an evolutionary interpretation of economic processes.

Alchian (1950) had argued that processes in industrial evolution can be linked to an evolutionary interpretation of economic phenomena. In contrast, Penrose (1952) in a critique had focussed on the individual actors' profit motivation as main explanatory element of economic actions. From an Austrian perspective, Kirzner (1973) perceived the competitive process as one of discovery and learning. Nelson and Winter (1982) have linked Schumpeterian creative destruction into evolutionary accounts and simulations of development. Grebel (2002) has linked entrepreneurship, industry evolution and their simulation. These arguments require a micro-perspective on the entrepreneurial process and its connection to evolutionary principles. Schlicht (1997), based on a systemic school of evolutionary thought, has argued that certain principles from Gestalt theory should influence economic actors and lead to the operation of evolutionary principles in social systems. Here, I link Schlicht's argument and personal construct theory (Kelly 1955) to economic evolutionary processes and the construction of an operationizable theory of economic evolution.

In this paper, I show on the basis of the case study how personal construct theory can be used to analyze processes of internal selection and how external selection can be traced to actors decision's on the basis of mental representations (certain worldviews) which leads to "external" selection by investors and in markets.

2. The Theory

2.1 A Learning Perspective Economic Evolution

One of the problems of evolutionary approaches to economic is the transfer of the genotype-phenotype-concept to social systems. There have been several propositions, the most important being the concept of routines by Nelson and Winter, which nevertheless does not meet a number of criticisms. Elsewhere, it has been proposed to use mental representations from personal construct theory as equivalent to the role of the genotype and routines as translation apparatus between mental and real world. Mental representations are concepts, which actors use to structure their environment in cognitive maps. These can be measured and compared to the structure of reality and action of actors. This is the basis for an evolutionary concept of selecting and characteristics-changing feedback between the perception of actors on the one hand and reality on the other:

$$MR\ //\ CM^{t} \rightarrow p_x^{t} \rightarrow D/A \rightarrow p_x^{t+1} \rightarrow MR\ //\ CM^{t+1}$$

MR: mental representation,
CM: cognitive map,
p: perception,
D / A: decision or action.
MR // CM: mental representation given cognitive map

Figure 1: Structure of evolutionary process over time

For instance, the process of business entrepreneurial strategy formulation and implementation of plans can be seen as a learning process on the individual and group level, and thus as an evolutionary process on a more abstract and aggregated level.[1] In an evolutionary context that links mental representations and actions, the perspective profits from a complementary perspective on the actions of economic actors. A potential perspective filling this need has been proposed by `strategy-as-practice' researchers (Whittington 1996, Hendry 2000). The strategy-

[1] While a learning perspective has already been developed for market processes (cp. Kirzner 1973), this is missing for 'pre-market' processes.

as-practice approach to strategy aims to develop a micro-perspective on strategy-making. Thus it operates on the micro-level of day-to-day managerial actions and routines. This approach can be transferred to the entrepreneurial realm in order to better understand how entrepreneurs think and act, how they succeed, what they need to succeed and what hinders success.

2.2 Psychology

Veblen

According to Veblen (1898), the psychological characterization of the economic agent as mechanic calculator of hedonistic utilities is outdated. The advantage of the evolutionary paradigm - combination of causal explanation and observations - is neglected. Classical economics and the historic school are focussed on taxonomy and description of development processes - partly oriented towards the pre-scientific goal of discovering a `natural order' – without accounting for the genetic (causal) mechanisms of such developments. Modern anthropology shows that human behavior in groups, even in the economic sphere, is guided by tradition. Ever since Thorstein Veblen's critique of economics' dealings with psychology, evolutionary / institutional economists need tools to operationalize and formalize them necessary psychological toolchest. Here is one possible way to get it.

Schlicht

Schlicht (1997) and Kubon-Gilke and Schlicht (1998) argue that social evolution is patterned and essential changes are created by what they define as directed evolution. Directed evolution - to be understood without teleological connotations - refers to structured (or patterned) variation in the sense that regularities in the emergence of variation exist. These regularities are an important part of the process of evolution in creating novel features. In contrast, blind evolution (based on random variation) leads to stabilization of existing characteristics in entities, since variation is often too far off a viable ‘hit’. Existing characteristics are seen as residing at or near

local optima in the fitness landscape, so that too large variations tend to lead away from a 'good' working organization of elements, while small variations may increase fitness values (until the peak is reached).

The argument runs as follows: variations are coupled in social evolution (as in biological evolution), since psychological regularities (gestalts) generate patterns in innovations, and complex organizations (and artefacts, I would like to add) are characterized by functionally correlated traits. Therefore variation must be kept within certain limits and is correlated, but not purely random. Since the structure and elements of an organism determine what variations are possible at all, the structure and elements of technical and social systems influence the type of variations that can occur in social evolution.

Personal Construct Theory

An evolutionary account of social phenomena requires the researcher to juxtapose the perception of actors with its effects in the real world over longer periods. Perception could play an analogous role to the biological genotype while the role of the phenotype is taken by artefacts, designs and documents. The cognitive landscape concerning a field of concepts of an actor could be seen the analogue to a chromosome. Such a conceptualization allows to capture the perception of an actor in a cognitive architecture, based on dichotomous separation between the defining characteristics of concept.

One perspective from psychology that seems useful in an evolutionary characterization of social processes is personal construct theory (Kelly 1955, Addams-Webber 1979, Bannister 1985). It posits that humans perceive and structure their world mentally along dichotomous conceptual poles. These concepts can be seen as elements in cognitive maps describing the structure and content of actors' worldviews. This perspective manages to show the existence of a binary, hierarchical ordering of human concepts. It focuses largely on changes in this ordering and self-perception.

Researchers can construct binary orderings of finite constructs by applying Boolean set theory to cognitive maps. This method, called repertory grid, is based on the analysis of correlations between the elements of cognitive maps. It is also possible to relate the binary orderings of human concepts to observable attributes of real world phenomena such as artefacts and to actions as well as conceptual structures. This approach runs also under the heading of cognitive architecture. The cognitive architecture of a concept is a similar dichtomous splitting of the attributes perceived relevant by actors leading to a hierarchical tree structure of attributes. This approach allows to operationalize the concept of routines (Nelson and Winter 1982). Routines have been theorized about a lot and used in a black box fashion, but progress in identification and observation has been slow (see Becker 1999). A micro-foundation for routines in mental representations is one way to alleviate this situation.

The correlation between the mental structure of perceived attributes and the structure of real world phenomena can be measured over time - showing the process of individual and group learning. If the concept is transferred to groups of people one may be able to identify different systems of belief between different groups of actors. By assigning numerical values to the degree of difference between these belief systems empirical measures can be easily constructed. Likewise the evolution of such cognitive architectures - if sufficiently identifiable from historical documents - should allow the tracking of mental representations. Thus researchers should be able to relate changes in mental representations with effects in the real world over long periods. This theoretical structure would allow for the transfer of the structure of biological evolutionary theory to the social sciences as well as providing the necessary differentiation for social systems.

3. The Case Study

3.1 Introduction

Methodolgy

The case study focuses on the first part of the methodology of personal construct theory – identifying the changes in the mental representation of an individual entrepreneur. Thus I use mainly document analysis and "field" observations. No standardized design or procedure has been used, but research was led by the goal to understand what is going on and why, in order to test developing hypotheses that formed in the process of interacting and observing.

Background

Pharma companies are reluctant to invest in new and unproven technologies since they are doubtful about the consequences of genetic separability of patient population which would enable individualized medicine or at least the identification of patient sub-populations. This might endanger the blockbuster model of big pharma, and certainly creates uncertainty about market size and cost for new pharmaceutical products. Therefore investors are reluctant to invest in the uncertain future of such ventures. In this context, I describe the psychology of entrepreneurial `marketing' decisions taken from versions of the business plans, discussions with the entrepreneur and (internal) background material. From the observations in the case study and comparison with some notable technology visionaries and entrepreneurs, I develop a classification scheme for (un)successful (technology) entrepreneurs and visionaries.

I have come across Dr. K and the project described here in the spring of 2003, when a friend of mine introduced each other in a Cologne soccer pub. At the time the friend was working on a master's thesis on industrial relations and got to read the businessplan of BT AG, a German biotech start-up co-founded by Dr. K. I had a look at the plan, made an offhand remark based on my interest in start-up issues and later contacted Christian K. to discuss strategies in the bio-pharmaceutical industry. The meeting turned into a discussion of his technical ideas and has resulted in me discussing ideas relating to the plan and commenting on various ensuing versions.

The entrepreneurial challenge of the project consists in organizing the project such that it becomes a success, and its acceptance by a diverse set of actors, that act as selecting instance at various stages of the project. These actors include investors, which might involve business angels, venture capitalists, banks, institutions such as regulatory authorities, and customers which might be pharma and / or diagnostics companies and end-customers such as researchers, diagnostics laboratories or physicians.

I will focus here on internal selection by the entrepreneur and external selection by investors, add a little about pharma companies as potential partners and the focus on issues of the possible retention of this technology through institutional arrangements. These are the issues that have an immediate relation on which something can be said with certainty at the present state of affairs. It must be considered though that the adoption of the product is the ultimate selection event from which the necessary requirements and outcomes of other selection events can be (or are tried to be) deduced – rather similar to the process of backward induction in game theory.

3.2 Inner Selection Processes

What we can illustrate with the different versions of the Business plans (in as little time as they were conceived), is the working of the inner and outer selection and the associated shifts in mental representations in an entrepreneur. We observe the mental turning around and recombining of technological elements and their associated economic implications in response to feedback, respectively anticipating the perceived counter argument of investors and (potential) partners.

The project was already two years old when I hit upon it. An earlier lengthy business plan was written by an involved physician on the basis of the advice of a controller, coming from large retail business. This version was not up to the standards business plans are usually. Dr. K had come into the project, since the original participants were looking for a CEO with management experience in the biotech sector. This lead to negotiations with potential investors, which

subsequently derailed as the advisor demanded a high portion of about 44% of shares for himself. The project came to almost a halt then. It seemed to take up speed again in the spring of 2003. The early argumentation as documented in the version I received in the beginning of May (around May 6th) was based on the property of the technology being label free, which eliminates errors due to (optical) mis-registration of fluorescent labels, and being amplification free, which eliminates errors due to chemical reactions necessary to increase the amount of the original probe in order to be able detect the elements in it. Diagnostics company Roche holds a patent on a reaction to achieve this, called polymerase chain reaction (PCR). This was developed by Kary Mullis in the 1980s, for which he received a nobel-price in 1987.

"At the forefront of technological advance today are attempts to eliminate amplification by increasing the sensitivity of DNA detection on the one hand, while on the other hand technology concepts are being proposed which seek to allow for label-free detection.

No technological approach at the present time envisions a process which can combine the advantages of both routes by integrating both label-free and amplification-free detection. A new process with this capability would confer such a strong economical advantage that it could compete successfully against market giants as well as technology driven start-up companies. We have developed a technology which makes possible label-free detection of DNA with a sensitivity which makes amplification unnecessary in most practical applications. Our detection technology is based on an ion-selective field-effect transistor. Field-effect transistors are used in all computer microchips and can therefore be easily and cheaply mass produced.

Whereas, however, transistors for data processing are switched by applying a voltage to the transistor surface, our DNA-sensing transistor measures the changes in surface charge density caused by the binding of a sought-for DNA molecule itself, utilizing the high intrinsic negative charge of all DNA molecules. This eliminates the need for labelling." (Businessplan dated May 2003, p.2-3.)

The technology combines two approaches to eliminate sources of error in measuring DNA fragments. The competitive advantage of the technology itself lies in that it involves less error prone steps and offers a higher sensitivity. The question that arises is how to sell the technology development platform to investors funding further development. An added difficulty is that this actually involves two financing steps if one goes by the (US-American) book, namely a seed-financing round by business angels until a workable prototype or `proof-of-principle' is achieved and a further financing round to cover market introduction and expansion.[2]

Competitive advantage to sell the project to investors is seen in the elimination of the amplification step, i.e. PCR free Chips, which leads to cost savings on the license fee paid to Roche. The argumentation line in favor of the project taken here is based strongly on cost advantages. Chip cost/price estimates by Dr. K at the time were around US$ 200-400. Price is seen as major competitive weapon since entry in the market will be difficult, given high entry barriers:

"One market player is dominant in nucleic acid based diagnostics, namely Roche. Roche's market dominance is based on its proprietary technology for DNA-amplification, the polymerase chain reaction (PCR). Although alternative technologies for DNA amplification exist, PCR is still the most reliable. Roche is moving aggressively into the field of chip-based molecular diagnostics and plans to more than double its diagnostics revenues within the next ten years. Roche will presumably try to retain the advantage of its ownership of the PCR-based amplification technology. Already, the company is demanding high royalties for the use of the PCR-reaction of around $ 50 per diagnostic test. Our technology allows molecular diagnostic tests to be performed in many cases without amplifying the DNA. For our own portfolio of products we will focus on diagnostic tests which we can perform without using Roche's PCR-technology and will team up with major market players for marketing and

[2] A second (and maybe a third) financing round would be negotiated with venture capitalists on successful completion of this step, funding further development and market penetration. If this step is successful often a further financing round, called 'mezzanine' round to brush the company up and prepare for a public offering may be necessary (see Southwick 2001).

distribution. The independence of our products from Roche will make us an attractive partner." (Businessplan dated 21.05.2003, p. 34.)

For our entrepreneur, the problem with Roche and other market players in the diagnostics market is that entry barriers are high. Eight companies serve 80% of the market. Therefore building an independent company and steering it successfully through market expansion seems difficult. The obvious solution to this is a trade sale in which the company is sold to an industry participant interested in the technology and/or an outsider, e.g. from the pharmaceutical market is interested in entering the market. But this possibility is not explicitly written in the business plan until the very last versions, since it reduces the returns for investors (relative to an IPO) and thus is seen hampering chances of finding investors.

Some weeks later the additional advantages in the technology itself are emphasized more. Since the measurement process does not seem to require amplification it is less error-prone than PCR-based measurement methods. Therefore data accuracy should be higher. This argumentation comes into play since the argument on being able to compete on a cost basis by saving PCR-fees is limited to a small window of time until patents on PCR run out in (presumably) 2007. A pure cost advantage therefore would therefore be of limited duration. The time frame of advantage amounts to roughly 2-3 years assuming a development time until 2005 which is not necessarily interesting as sole basis for competitive advantage.

"From an outside viewpoint it might appear to many analysing the state-of-the-art in microarray technology that existing procedures, i.e. the PCR-amplification and fluorescent labelling protocol described above, are readily amenable to routine applications in diagnostic laboratories. Indeed, the technology is highly sensitive and error-free results can be obtained if the tests are executed by skilled labour and if the necessary laboratory infrastructure is in place.

Deeper analysis of the actual laboratory reality, however, reveals that these prerequisites are rarely in place, especially in the largest regional market, the US. For a routine laboratory the state-of-the-art

procedure is regarded as costly (infrastructure, instrumentation, reagents), highly complex (demanding intense training of users), error-prone (due to the sensitivity of PCR-amplification to contamination), and difficult, if not impossible, to automate for high-throughput and essentially push-button operation." (Businessplan dated 21.05.03, p. 5.)

Later, in the fall of 2003, the only comment in the business plan on the technology being PCR free is the following, putting even stronger emphasis on data sensitivity due to the nano-transducer which should enable high sensitivity.

"We have already embarked on a project which uses nano-scaled electronic transducers, with the aim of increasing the sensitivity of our system to a level of several hundred DNA-molecules. This will enable the detection of nucleic acids from biological specimens without prior amplification by PCR or other biochemical methods." (Businessplan dated 28.11.2003, p.6.)

Rather the focus has shifted to a number of technological key advantages:

"Low cost: the electronic read-out device is no more than a conventional electronic chip-card reader; its production will cost less than 1000.

Label-free: DNA is detected solely by virtue of its intrinsic high negative charge, completely eliminating the labelling step;

Time-resolved measurement: Our technology uniquely enables us to measure the kinetics of DNA-binding. We can thereby determine the absolute concentration of individual genes in a biological sample, achieving an entirely new level of precision.

Highest specificity and speed: The special DNA-analogous structures used as probes lead to higher discriminative specificity and faster measurement.

Potentially reusable chips: Our microarrays are more stable than those currently in use and can be reused more than 50 times.

1.4. Our Technology Addresses Key Drivers of Customer's

Purchasing Decision

Set-up cost: Our read-out system, costing a fraction of those currently available, allows us greater flexibility of marketing strategy. This will help to overcome market entry

barriers for new technologies. Low-cost instrumentation will also open up new markets such as point-of-care diagnostics.

Cost per test (chips and reagents): Our system, dispensing with labelling reagents will lower the cost per test. The reusability of our chips could, if desired, lead to additional

savings.

Ease-of-use: Our technology avoids complex instrumentation and directly delivers unambiguous, digital data, reducing the need for technically trained personnel.

Reliability: Our system is geared to fulfil the highest customer demands in respect to specificty, reliability and robustness.

Enabling technology: Our label-free, time resolved DNA-chip technology will provide quantitative measurement capabilities that researchers have long sought for." (Businessplan dated 28.11.2003, p. 5.)

3.3 External Selection

'External' selection takes place by by investors, cooperation partners and finally stock-market investors / analysts to which all actions must be geared to ensure a successful IPO.

One problem of the project that involves external selection is a bad reputation of DNA-Chips among investors. Therefore attention is drawn to the issue of gold electrodes (which are not used but that have been used by competitors such as Siemens). Companies using gold electrodes have run into trouble stabilizing them, which seemingly discredits the whole idea of bio-chips. The problem is that investors are often not able to differentiate enough between different versions of technologies, but act on category-labels such as `electronic DNA-detection'. The task of putting straight such matters falls on the entrepreneur / technologist

developing the business-plan, who often has the problem that he takes such differentiating issues for granted, based on his specialized and more differentiated mental representations.

"We do not employ gold electrodes. In contrast, the surface of the transistors use in our chips consist of silicon dioxide, the same material as the glass slides commonly used for DNA-microarrays. Our system therefore relies on the same surface preparation and DNA-immobilization technologies as the conventional fluorescence-based systems currently in use around the world. Our special DNA-chemistry renders our chips even significantly more stable than today's commercial standard." (Businessplan dated 24.11.2003, 8-9.)

Similarly investors are cautious due to general problems with the state of the DNA-Chip market and process of approval of DNA-Biochips. There are estimates that more than 400 companies try to develop and sell such products. Thus one US American investor responds to the business-plan proposal as follows:

„Dear Dr. K,

Thanks much for the opportunity to review your proposal. This certainly represents a novel approach that may enable label-free detection in nucleic acid arrays. For strategic reasons however, we have decided not to pursue new DNA array technologies at this time due to the crowded market and the low valuations placed on new entrants to this space as well as the exiting of some larger players such as Corning from this area due to the presence of large established platforms in the research area such as Affy's. I could certainly imagine this having interesting applications in the diagnostics field, however, it is still too early, in our opinion, to introduce such a platform in the diagnostics area due to the lack of clear FDA guidance on this type of use. …" (email to C. K., underlining added by the author).

In this case the lack of established `rules of conduct' by a public authority, the FDA, is quoted among the main reasons for not pursuing the investment opportunity further. (Actually, the

FDA developed a guideline at that time and published it shortly thereafter.) The FDA approves and oversees products on medical and health care markets to prevent harm to patients. Additionally, in the summer / fall of 2003 Roche had tried to market such Chips as application specific reagent (ASR) which does not require official approval by the FDA. This approach was not accepted by the FDA. An alternative would be to claim the status of an experimental device, which requires less deep scrutiny by the FDA.

Uncertainty about viable technologies and market prospects hinders the funding of the project. This links into Alchian's (1950) story about evolutionary selection of those choosing the right approach to an economic goal and Knight's (1921) argument that uncertainty breeds heterogeneity in economic actors responses. Here, the absence of formal institutional rules prevents positive selection of the proposal at the given time. These rules would direct actions of market actors as well as differentiate (select) between acceptable and unacceptable technological approaches (respectively products). These rules allow evaluation of the possibility to make profits from such projects. The existence of rules which require testing would likely hurt some projects or products that either cannot meet the requirements or garner the necessary resources to do the testing, but not all and would actually have a positive impact on the the development of the field as a whole. Whether the particular project described here is among them is another question, but given the potential characteristics of the technology and the implicitly positive evaluation of the just cited investor, by wanting to stay in touch, the prospects cannot be judged to be entirely dim.

3.4 The Personality of the Entrepreneur

The background of Dr. K is an education as chemist, with a specialization in biochemistry, working on the synthesis of artificial oligo-nucleotides at Harvard and the ETH Zurich. This was later, after a spell as post-doc, followed by the founding of one of the first German biotech companies, which went public as BT AG and survives until today. The motivation for this was

an interest in evolution and origin of life, combined with the idea to do research, but not in a "slow" academic environment. The solution to what could be done in this area that also had a commercial application, to fund the project, was the human immune system. The approach chosen was that of applying artificial evolution to the development of artificial antibody libraries. This techniques is based on combinatory chemistry where relatively well performing candidates are selected from a number of randomly generated compounds and used for further refinement.

From what I observed and concluded from questions there is a recurring pattern of novelty search, of 'research activities': sifting through masses of information, combining and linking information concepts, as well as a search for partners, activities to connect (with) them and build a network.

On Technology

The monoclonal antibody technology (Mab) developed by BT AG with Dr. K's involvement is a combination of several elements:

1. High Throughput Screening (HTS)
2. Combinatory chemistry
3. Robotics to automatically produce antibody compounds
4. protein-coding nucleotides which are recombined

(Presentation Dr. K at btS seminar, Cologne, November 25, 2003)

Likewise the project aiming at the development of Bio-chips for the identification of marker genes for health conditions is a similar combination of a set of technologies:

1. a nano-technology transducer element
2. a silicon carrier basis for capture probes

3. particular type of synthetic capture probes emulating DNA structure, but having better chemical properties in terms of stability than DNA

While he was actively involved in the development of monoclonal antibody technology at BT AG, his role in the diagnostic chip venture is purely on the commercialisation side of activities.

On Management

"Well, well management. One should not be too much in awe. … Jobs and Gates did not have management in the beginning. Important is that the technology works just really well." (email C. K., 15.11.2003, translation by author.)

Here we can discern a strong focus on technology. This trait hampers many technological entrepreneurs in that they do not start to worry about the market or even in some cases on managing the project organization when the need arises. This is possibly related with personal traits, abilities and interests of the entrepreneur. Therefore it is important to have a team with complementary capabilities that serve all needs.

Motivation

The personality, based on my own personal and subjective impression, is that of a winning, people-oriented, very marketing-capable, (an activity he stated he actually dislikes), social and intellectually-analytical person, who is also characterized by a hidden insecurity and the feeling of a pressure to have to achieve something, to prove his worth. The family may matter in an entrepreneurial socialization in as much as the father was a successful lawyer who co-founded one of the larger law-practices in Germany. Already during studying in the 1980s in Berlin, he participated in a removal operation renting out a little bus and himself with friends.

The motivation of our entrepreneur seems to rest largely on the possibility to bring about a technically excellent solution, which offers an "ultimate" solution to the problem at hand. This certainly also helps, if successful, the financial wealth and social status of the entrepreneur. Altshuller in a large scale analysis of Soviet-russian patent applications has shown that seminal discoveries and technological advantages are based on a logical reasoning as to which would be the best possible solution (cp. particularly Altshuller 1977). [3]

"I lay awake last night and thought about all. Why am I doing this? Because I believe that transistors and semiconductor technology, which we control like nothing else in the world (with respect to sensitivity and miniaturization[)], is the best basis for biological measurements. Full stop.

Basically, it is just a visionary belief. They might be miles ahead of us, [but] what we have is the final and best version. Sustainable to eternity. But who believes this[?] Proteins will be measured at some point like this, too. The system can become sensitive in the future. One-electron-transistor, they work on it already. Nevertheless it is despairing. […]" (email C. K. 11.12.2003, translation by author.)

Particularly interesting is the remark on proteins. In the first meeting at the beginning of our acquaintance, I had asked about the possibility to measure proteins (as opposed to DNA) with the technology. The answer of Dr. K was he could hardly imagine how that should be possible, given the instability of proteins. So part of the motivating factors seems also to be the potential to develop a general approach that has a wide impact on society or the relevant community. The economic importance of protein identification is debateable, since a lot of the practically relevant information can be inferred from other sources such as the DNA and messenger RNA from which proteins are derived in the cell, according to industry participants' perception

[3] The wealth motive should have been less important in an absolute sense but may still matter in a relative sense in the Soviet-russian society, and can well be compensated for by a motivation aiming at status improvement.

(Pfenning and Luithle 2003). If one wants to know what is going on in cell it might nevertheless be necessary and helpful to detect proteins, particularly in a time-resolved fashion.

The focus of thinking of our entrepreneur is the competition that has a lot more resources at its disposal and better market access. Advantages of technology that potentially solve the problems that others have in applying their technologies (knowing well that there lie many problems and pitfalls ahead) and economic advantages. Only later, in the spring of 2004 (in the context of a debate on rewriting and promoting the business plan), I realized that the lack of a marketing person posed a certain problem for Dr. K, who seemingly is feeling well in the realms of technological development. But it is already contained in the following from December 2003, particularly the quote at the end which implies that investors (and customers) will come on their own. Here we find the motive of technical excellence again:

"Well, researched the whole day. Printed hundreds of pages. Especially [on] FDA approval but also normalization of micro-arrays. On competition. Motorola's chip is around since ages. Based on gold. Gold chemically not stable. far too complicated. There is no comparable technology to ours, if it works. Chips went out to […] for functionalization. Results before Christmas if everything works fine. […]

I have the strong feeling that nobody has thought about time-resolved measurement of absolute concentration on 10.000 spots. But I am sure that such a chip would be a breakthrough. People are laboring very hard to get good data. Problems are non-uniform spot size, background and unspecific fluorescence, normalization and the execution of statistically significant of multiple measurements. […] reusable chips are important. SNPs cannot be differentiated, especially not if they are heterozygotic. And then [there is] the design of Oligos with respect to equal melting points. The whole microarray business is a mess. Groping in the dark and hoping for software solutions. Only, since nobody thinks that measurement of concentration might be possible, no one has thought about the benefits of this. I am solving a problem that nobody has recognized yet. Very difficult to sell. We just have to do […] the measurements with PNA. The experiments must be designed in such a away that the potential is visible.

Then publishing it, and letting the scientific community fire back. One could build on that in the sense of preaching to the converted. On marketing. The best market are newborns. […]and whatever there is in terms of hereditary diseases. All of it on a chip and offer for 50-100 Euro inclusive PCR. Just opening our own laboratory. Good PR and all mothers will want to know whether the child is healthy. […]

After today's research I think that such a test can be marketed as `experimental'. Another question: Is our RT and self-calibrating reusable platform not much better suited to be approved for quality control by the FDA than inhomogenous Affymetrix chips? Beadbased systems (Illumina and Luminex) already are perceived to be better suited for approval (you take a sample and check, then you know how the rest is). Affymetrix chips are destroyed once tested.

In my opinion we still have the `stone of the wise people'. Just missing the PNA-measurements and the development of the whole thing.

…

`If you have a better mousetrap, the world will beat a path to your door'

so long,

the Biotech Cowboy (Email dated dec 5, 2003, translation by author.)

4. Characteristics of Visionary Entrepreneurs

We can discern the following psychological characteristics, motivations and behaviors of a entrepreneur from the evidence presented above:

1. a vision, which amounts to having a strong opinion on how things should be or will develop which amounts to normative thinking
2. perception of opportunity, i.e. the ability realize when positive circumstances and necessary conditions overlap and when not
3. combination of new (technological) elements, and/or recombination of existing elements, attempted on a massive scale

4. a set of differentiated priorities and conditions for certain actions, i.e. a mental representation of the world containing a differentiated hierarchical ordering of necessary steps and conditions as well as (momentarily) irrelevant issues
5. sampling, evaluation and selecting of masses of data
6. motivation: driven by desire to do science, but in better condition than at university

The problem solution approach of such a personality, at one extreme characterized by the aim of solving an issue of major importance, can also be compared to Schiller's `philosophischem Geist' (versus his `Brotgelehrtem', see Schiller 1789), that tries to connect issues across disciplinary boundaries. It is certainly characterized by a a certain perfectionist stance which makes it hard to put constraints on the ideas and activities of (some of) such persons.

According to Becker and Knudsen the characteristics of our entrepreneur match into a seldomly acknowledged category of the entrepreneurs:

"The 'founder' (promoter), is not commonly considered entrepreneur either, if for completely different reason. The most striking characteristic of the founder is his almost exclusive focus on seeking and carrying out new possibilities. That does not entail any power over means of production, though, which often is a defining characteristic entrepreneurship. From Schumpeter's point of view, however, the founder is the purest expression of the entrepreneur." (Becker and Knudsen 2004 p. 14).

The lack of (the necessary) resources and discretion over resources is certainly correct in our case, but to criticize the lack of consideration of such persons goes too far in my view. It may be hard to easily observe such a category of entrepreneurs until they are reasonably successful, and an exclusive focus on new possibilities may stand in the way of commercialisation, success and recognition (e.g. take the case of Ted Nelson, the hypertext–pioneer). Even if one argues that these are the characteristics of pioneers, if found in the economic realm they are likely to be considered entrepreneurial.

This point hints to a differentiation of entrepreneurial activities according to risk(-aversity) on the one hand and social and/or economic "reach". In terms of risk and economic success, it matters whether entrepreneurs tend to pick low-hanging fruits that present themselves, or whether they aim to build 'systems' (in the sense of Thomas Hughes), such as Edison managed to do. As it seems, successful entrepreneurs are characterized either by focussing on the low-hanging fruits they happen to come across and follow their lead wherever that may be, or by a combination of system-building traits with the ability to focus on / select economically successful plans. Less successful entrepreneurs in contrast choose fruits hanging (too) high (for them), which do not yield sufficient (economic) returns and/or are focussed on specific technological or social questions, which make them possibly persistent pioneers changing the

5. Conclusion

The case study shows how the founding process of a new venture is characterized by many selection decisions prior to the operation of market selection and how these interact in the mind of an entrepreneur. These include and are related to technological approaches, choice of partners, choice of investors by entrepreneurs and investment decisions of investors. Overall decisions about how to present and market the venture are controlled by the expectations about market (selection) decisions. The environment for DNA-Biochips is presently a difficult one since a large number of approaches competes for attention and resources. This is reflected in the shifting argumentation for the technological approach championed by our entrepreneur.

In social systems the generation of change can be conceptualised as follows: Mental representations respectively elements in cognitive maps are moved around, realigned and translated into real-world tests of (hypotheses about) artefacts. In an evolutionary perspective: Variety generation is closely related to hypothesis generation and testing. In terms of the generation of novelty and application of novel approaches to problems, two extreme types of 'archetypical' actors respectively approaches can be discerned:

- The first one is asking: What do we have in terms of resources? What can we do with them? This means, an actor is looking for a problem to solve with his available tools.
- The second one starts out from a problem and asks: Given a problem, what is a good (if not ideal) solution? What do we need (to do) to solve it?

Real, observed behavior will of course lie on a continuum between these cases with differing expectations as to the quality of the outcome.

The example also shows that an evolutionary learning perspective can integrate perspectives from evolutionary biology, psychology, sociology, institutional and evolutionary economics and thus can complement 'standard' economic approaches to economic behavior in the case of entrepreneurship on the micro-level (and in the aggregation of many such actors to economic development on the macro-level). Individual profit motivation a la Penrose, complemented by a motivation to build something and an evolutionary account of economic behavior do not contradict each other neither at the micro-level nor at the aggregate level.

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