Invention and innovation as creative problem solving activities -
A contribution to evolutionary microeconomics

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I. Introduction
The starting point of our paper are some shortcomings of current evolutionary theorizing concerning the microeconomics of novelty creating behaviour (section II). Our suggestion is to get rid of these shortcomings by reassessing the framework of problem solving. We begin the discussion of the concept of problem solving by giving a short introduction into the seminal contribution of Simon and Newell (section III). However, using the concept of problem solving for dealing with the microeconomics of invention and innovation requires an enhancement of that concept. Hints for such an enhancement can be found in modern research on human creativity. The basic elements of this research and the possible integration of problem solving procedures in the realm of creative human action is dealt with in section IV. Finally in section V it is shown, how a synthesis of problem solving methodology and creativity analysis opens up new perspectives for discussing invention and innovation from a micro-perspective and how such a perspective can be linked to a concept of economic agent.

II. Invention and innovation in evolutionary economics
Although analysing the sources of novelty creation is at the core of evolutionary economics there is up to now a somewhat strange neglect of the microeconomic consideration of the process of novelty creation in general.¹ The reason for that seems to be that such an analysis is not in the focus of the dominant approaches of evolutionary economics.

The focus of the neo-austrian approach is on the personal side of entrepreneurship. Here the entrepreneur is postulated as a person who discovers new opportunities of action in an unconscious manner. This implies that these discoveries are not a result of painful strategic search but rather the outcome of a combination of chance and personal qualities of the entrepreneur, especially boldness and imagination (cf. Kirzner 1979; 1997). "...(T)he insight strikes him with a certain epiphany and wonder. This sort of discovery qualifies an entrepreneurial discovery." (Demmert/Klein 2003, 297) Hence the novelty discovering process is qualified as a rather idiosyncratic process almost inaccessible for theoretical analysis.

Contrary to that the focus of the pragmatic technology-oriented approach in evolutionary economics is on the structures and institutions that shape the process of novelty creation and not on this process itself. Here the emphasis is on paradigms in terms of given "technoeconomic problems" and standards for the solution of these problems (cf. Dosi 1988, 1127). Accordingly in national innovation systems the institutions that frame the novelty creation on a national level are the main subject of investigation (cf. Lundvall 1992). Hence the process of novelty discovering is interpreted as being rather predetermined in terms of patterns, routines and institutions. So again there is no need for an extensive microanalysis.

¹ This does not mean that there are no microeconomic investigations at all. To mention a few of these exceptions: Röpke 1977, Witt 1987 and Vromen 2001.
A common denominator of all approaches in evolutionary economics seems to be an "epistemological proviso" against the possibility of a microanalysis of novelty creation. This proviso derives from the paradox that the unknown consequences of novelty creation makes it difficult or impossible to analyse such a process. "In a sense, genuinely new ideas come out of the blue. This merely paraprhrases that they are not predictable." (Vromen 2001, 199)²

All these arguments may be valuable in themselves but they are not convincing in legitimising the impossible or superfluous nature of a microanalysis of novelty creation. Concerning the neo-austrian approaching the entrepreneur's role it may be asked, if the mentioned qualities are a sufficient explanation of the entrepreneur's ability to discover new opportunities. Modern cognitive psychology and especially creativity research shows that more than the mentioned personal qualities are involved if something new is discovered and that this process of discovery normally is not an act of unconscious epiphany (cf. Cszikszentmihalyi 1999a). Concerning the pragmatic approach in evolutionary economics it has to be mentioned, that the generation as well as the dynamics of structures, patterns and routines determining the novelty creating process are not explained sufficiently if no reference to the micro-level is made. Finally according to the methodological proviso one has to deny, that a discovery of a novelty in an economic context does "come out of the blue". Personal inquiries (e.g. Cszikszentmihalyi 1996), case studies (e.g. Hughes 1978; Gorman/Carlson 1990; Israel 2002), experiments (e.g. Guilford/Hoepfner 1971; Kaplan/Simon 1990) and theoretical concepts (e.g. Finke/Ward/Smith 1992) allow for systematizing some features of the underlying processes.

Another shortcoming of the consideration of the novelty creating process in evolutionary economics is the neglect of invention as a specific stage of such a process. This neglect seems to originate in Schumpeter (1961, pp 15, pp 91) and the argument there is twofold: First, invention and innovation are seen as strictly separable phases of the novelty creating process. According to Schumpeter this separability is due to different personal qualities which are required for both operations and a loose causal relationship between the two. The latter means that there are a lot of inventions without leading to innovations and at the same time a lot of innovations without a preceding invention. Second, taken invention separately, it is considered as an activity without economic meaning. A bundle of indicators for that are mentioned: invention is not subject to the usual economic constraints; it is a conjectural, not a planned activity; it produces no results which are meaningful from an economic point of view. Hence from an economic perspective it seems sufficient to assume an exogenously determined supply of inventions which the innovator has to check with respect to their economic exploitability.

This appears to be a somewhat outdated assessment of invention. If the purpose of the separability argument is meant as a device for the first step in an economic

² This view is shared by Popper: "My view of the matter (how it happens that a new idea occurs – FB/MD)…is that there is no such thing as logical method of having new ideas, or a logical reconstruction of this process. My view may be expressed by saying that every discovery contains 'an irrational element', or a 'creative intuition'" (Popper 1959, pp 31)
analysis it is reasonable. But if the purpose of the argument is to identify a sharp borderline between the two stages, it is misleading. Considered empirically there is an increasing importance of institutional contexts in which invention and innovation are mixed: r&d departments in medium and large size firms and an individual inventor-innovator synthesis in small size firms (Nelson/Winter 1982, 263; Parayil 1991, 79, 86). Additionally from the perspective of theory it is now common sense that there are a lot of feedbacks between invention and innovation (Kline/Rosenberg 1986; Grupp 1997). Furthermore, the borderlines are indeed fuzzy in that the exploratory final stage of invention is partly the initial stage of innovation (cf. below section V.3). Correspondingly the invention is becoming increasingly meaningful for an economic analysis. Even if it is still true, that invention by its very nature is in some degree detached from the usual economic constraints it nevertheless becomes a strategically planned search activity the form and output of which are accessible for economic analysis. But apart from this increasingly planned microstructure of invention, the latter is embedded in a social framework which is influencing the direction of this search activity (cf. Hughes 1978; Collyer 1997). This type of 'allocation of scarce inventive resources' should not be ignored by economists!

To resume, there are good reasons (i) for dealing with the process of novelty creation on a micro level without confining this analysis to personality attributes and (ii) to investigate the specificity and the interdependence of invention and innovation in terms of occurring processes, required cognitive resources, personal abilities and environmental conditions. Hence there is the need for an integrative approach to novelty creation on the micro level. What we try to show in the following sections is, that such an approach is problem solving.

III. The core concept of problem solving

In the economy the work of entrepreneurs, of managers, of scientists, of engineers, and of many others can be seen as processes of problem solving. Despite the differences in the corresponding domains, recurrently problems evolve, actions have to be selected and solutions have to be found. Thus, to understand the central features of problem solving can be seen an essential condition for the understanding of economic processes. A seminal contribution to such an understanding has been made by Simon and Newell (Newell/Simon 1972) which we will describe in this section.

The starting point of the problem solving procedure is the perception of a "problem". "A person is confronted with a problem, when he wants something and does not know immediately what series of actions he can perform to get it.....To have a problem implies (at least) that certain information is given to the problem solver: information about what is desired, under what conditions, by means of what tools and operations, starting with what initial information and with access to what resources."(Newell/Simon 1972, pp 72; cf. Cyert/March 1963, 121) Hence the essential feature of a problem is a divergence between the given and the desired state of affairs. The conditions for eliminating this divergence are on one side the well known constraints of the agent (in cognitive as well as economic terms) and the (virtual and real) transformation devices for the given state of
affairs. Yet, the applicability of these transformation devices is uncertain in that there is only a rough idea about the appropriateness of these devices.

"Problem solving" is the process of finding out a sequence of states between the initial and the desired final state under the given constraints (cf. fig. 1). This process is based on a "mental representation, a mental scheme for holding information in memory and operating on it" (Simon 1999, 674; cf. Simon/Newell 1972). The elements of the mental representation are (i) an interpretation of the given situation, (ii) a listing of the transformation devices (called "operators") according to this interpretation and (iii) a test and evaluation mechanism for the results of operator application. Hence activating a cognitive activity which is constrained by the available knowledge and the experience about the problem domain, makes the starting point of the problem solving process. This cognitive activity is influencing the real activities of the agent and is as well influenced by the latter. The listing of the transformation procedures within the mental representation is not complete because not all the procedures contained in the knowledge stock are activated. This would easily lead to a combinatorical explosion of transformation possibilities which, due to cognitive constraints, would have to be dealt with on a trial and error base. Therefore the problem solver has to restrict himself to apply more or less general search procedures (heuristics) to reduce the size of the problem space, i.e. the space which is defined by applying all available transformation possibilities to all possible states.

Such a complexity-reducing process can be illustrated by the heuristics of the "General Problem Solver" (GPS) a programmable problem solving procedure developed by Newell and Simon (Newell/Simon 1972). The first heuristic of the GPS is the "means-ends-analysis". It consists of three operators: the transformation operator (change a given object with undesired qualities into an object with desired qualities), the elimination operator (reduce the difference between the qualities of the given and the desired object e.g. by defining and

3 The kind of mental representation Simon has in mind is different from a rough classification scheme for given situations, which is used in routines. It is also different from the clear-cut identification of a given situation as it assumed in deliberate choices (cf. Beckenbach 2003).
4 These heuristics might be either explicit in that they are explicable and even programmable or they might be implicit in that a given situation includes cues about what to do for the experienced problem solver.
5 Here object can be an object proper, a state or an option.
pursuing sub-goals) and the application operator (transform the given object into another object so that the difference between initial and desired qualities is reduced). The second heuristic is "planning". This denotes the possibility to use a more or less simplified model of the problem solving process and to anticipate the results of each state specific transformation process. Taking these two heuristics together the problem solving becomes a recursive procedure triggered by – at least one of – these heuristics and the corresponding operators, feeding the memory with the virtual or real goal attainment (cf. fig. 2). In such a recursive procedure multiple heuristic and operator sequences might take place until the gap between initial state and goal is filled.

Assuming that the storage of available representations, operators and goals as well as the activation of a selection of these elements in a given situation is the function of the memory (here subdivided in working memory and long term memory) the whole process of problem solving can be summarized as in fig. 3. However, only under ideal conditions problem solving will be a linear sequence of representation, operation and realization. Normally it will be a feedback process between the steps "operation" and "representation" as well as within the "operation"-step. Furthermore: if several attempts to reach a given goal are not successful, the goal itself might be modified (see the dotted line in the figure).

This sketch of the seminal contribution of Simon and Newell to the analysis of the elements and process of problem solving shows, that this is a path breaking alternative to the standard model of the deliberate decision process: (i) In that it focuses an open ended search behaviour divided in the statement of the given

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6 These operators are complementary and activated in a sequential manner.
situation, the figuring out of the problem space and finally the solution of the problem; (ii) in that it integrates the assumption of bounded rationality in terms of knowledge dependent problem representation and in terms of limited capabilities of problem manipulation (e.g. by heuristics). Due to these cognitive constraints the process of problem solving becomes sticky and path-dependent. In the case of the means-ends-heuristic this stickiness is a consequence of the decomposition of the problem (especially by using the application operator), of the serial way to deal with solutions on a given problem level (trying only one solution path until it gets stuck) and of the incremental adaptation of the solution in case of failure (only the last steps of the solution path are skipped).

fig. 3

Nevertheless – at least in its original form – the concept has a rather narrow scope. *First*, it takes only the performance dimension into account which abstracts from basic abilities of the agents as well as from individual specificities. *Second*, according to the computer oriented context in which this concept of problem solving was developed, it had been finally confined to clear cut ("well defined") problems. This means that the goals of the agent as well as the heuristics used for reaching this goal are specified in such a way that the results of the application of theses heuristics can be unambiguously evaluated with respect to their goal-reaching capability. Furthermore it is assumed that this capability is even measurable in terms of a larger or smaller distance to the goal. *Third*, it is assumed that the definition of the problem and the finding of the problem solving devices are two separable elements and that the problem solving devices are merely instrumental for the problem itself. Thus, only these solution advices are varied during the problem solving process. Hence one might be skeptical about the generality of the GPS: "Once activated, the GPS is working straight forward through the maze of problems. All required information is available and accessible. There are no uncertainties about the consequences of applying possible
operators. The search for possible differences (between given and final state – FB/MD) is routinized. In the final analysis, the stage of development of GPS is the same as in a closed model of individual decision behavior under the condition of perfect information about the alternatives' outcome. Hence the GPS – just as the original model of homo oeconomicus – can only be a starting point for further investigation."(Kirsch 1971, 187 – our translation FB/MD)

IV. Enhancing the concept of problem solving: ill-defined problems and "creative problem solving"

IV.1 Ill defined problems and creativity research

Not all problems in the economic world are well defined in the sense of the standard approach of problem solving. Sometimes even the understanding of the initial situation is not in such a way clear that it can be transformed into a mental representation. Consequently it remains vague in which way such a situation can be influenced by any kind of operator and which goals are appropriate for it. However, even if the situation is well understood it might be difficult to solve a problem because there are multiple incommensurate problem spaces and/or a lack of appropriate operators/heuristics making it intricate to find a sequence of reasonable operations. Finally, it is possible that the goal is not defined in an unanimous manner. These caveats are the background for admitting "ill defined problems" (Simon 1977) and thereby broadening the scope of the concept of problem solving.

The inconveniences arising with ill defined problems – which do normally occur in an uncertain world – change the character of the problem solving process. First, it is not any longer 'directed' insofar it successively reduces the gap between initial and final (goal reaching) state; rather it might circle around or even be regressive by broadening the gap. This is due to the lack of appropriate operators/heuristics and/or the goal ambiguity. Second, the instrumental role of problem solving devices does not hold anymore if the problems are ill defined. Under this condition heuristics and operators as emanations of the stock of knowledge are themselves influencing the way the problem is posed at every time step. Problem solving then becomes an iterative and simultaneous exploration of problems and solutions.

Solving ill defined problems makes great demands upon the actors involved. At the core of the individual ability to look for new situations and to deal with them is the human creativity. Therefore it seems reasonable to expect some hints how ill defined problems are solvable by referring to creativity research. 7 This research has a long tradition starting when the ability to create something new is no longer considered as a divine inspiration but rather an individual capacity of the human being. However, even in the professional treatment of creativity in psychology it took some time before single hypothesis approaches (such as the psychodynamic,

7 Simon and his colleagues have dealt with ill defined problems in the context of scientific discovery (cf. Simon 1977, pp 315; Langley et al. 1987, pp 14). Here the concept of problem solving was broadened to include multiple problem spaces, problem finding and problem formulation. But this broadening of the problem solving approach suffers from being restricted to one specific domain and to computable problems.
associationist and gestaltist treatment) to this human ability have been overcome in favour of a broad treatment including all resources and processes known in modern cognitive psychology.  

The modern creativity research defines creativity as "the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)" (Sternberg/Lubart 1999, 3; cf. Amabile 1996, 33). Hence, what is meant by creativity in the sense of modern creativity research are the individual creative traits and processes. Creativity research does not primarily deal with the wide range of everyday creativity. Rather creativity here implies that the individual creative output (product) is being assessed and accepted by the environment. Following this definition three different – although interdependent – aspects of creativity are emphasized in the modern creativity research: the individual qualities, the process analysis and the environment. All these aspects are relevant for solving ill-defined problems and thereby broadening the scope of the original concept of problem solving (cf. Daskalakis 2002).

- The individual qualities can be subdivided in knowledge and skill endowment, motivation and personality features. For being creative knowledge is required about the domain specificities (cf. Weisberg 1999). This knowledge should be well organized giving the possibility for switching flexibly between different levels of generalization. Whereas this kind of knowledge is "declarative", also "procedural" knowledge is required in terms of knowing how to use available heuristics. These different levels of knowledge are accomplished by skills in terms of finding new heuristics and capabilities for recombination and association of given elements of knowledge (cf. Chand/Runco 1992; Policastro/Gardner 1999). However, knowledge and skills are not sufficient for being creative: additionally a strong motivation for fulfilling a task is required. This strong motivation can either come from inside in that an individual views such an engagement as an end in itself (intrinsic motivation) or this motivation comes from outside following from external information or expectations without restricting the autonomy of the person under consideration (informational or enabling extrinsic motivation; cf. Amabile 1996).  

Finally some personal qualities are required for a creative activity. Among the most important ones are curiosity, the steadfastness of purpose, curiosity, and the willingness to leave the known and take risks. The ability to perceive the task as entertaining and the possibility to enjoy the process are essential for creativity.

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8 The starting point for modern creativity research was given by Guilford in his American Psychology Association presidential address (Guilford 1950) where he outlined the impact of creativity research for the economy. Since then, the study of creativity has grown to a small, nevertheless well accepted field of science.

9 This informational and enabling extrinsic motivation is different from an extrinsic motivation (in the proper sense of the word) to fulfil a predefined task. Picking up the metaphor of maze this difference between intrinsic and extrinsic motivated behaviour leads to a different search behaviour: "...(E)xtrinsically motivated individuals, because they are motivated primarily by some task-extrinsic factors, will be more likely to rely on common, well-worked algorithms that they have learned for doing a particular task. In other words they will be more likely to exit the maze as safely and surely as possible, and the result is unlikely to be novel. By contrast, intrinsically motivated individuals, because they enjoy the task itself and the process of searching for a new solution, will be more likely to explore the maze, attempting to find their way to one of the more novel exits." (Amabile 1996, 122)
patience and a fundamental willingness to bear risks (cf. Csikszentmihalyi 1999b). Knowledge, skills, motivation and personality are combined in two overarching features of creativity: deliberate cognitive style and divergent thinking. A deliberate cognitive style is a stable preference for using extensively deliberate (conscious) resources in sorting out the possibilities of action (cf. Kirton 1989). Divergent thinking is a specific way to use these cognitive resources. Convergent thinking has only one direction; one conventionally correct answer is searched for. Contrary to that, divergent thinking proceeds in different directions (cf. Guilford 1959, 359). Hence the approach of creative individuals to problems is original in that they are breaking with traditional formulation and solution of problems and it is flexible in that many ideas about formulation and solution are held for a long time simultaneously in mind until a switch to one of these options occurs (cf. Amabile 1996, 88).

• The process analysis of creativity was initially heavily influenced by the idea that the creation of something new is a rather unexplainable operation in terms of rational process analysis. This gap in explanation was either filled by referring to mysterious abilities of the human genius or it was assumed that creative ideas emerge from a largely uncontrollable Darwinian process of random variation and natural selection. This gap is well documented in one of the first process models of creativity by Wallas (1926/1946). In this model four phases are distinguished: (i) the definition of the issue and the observation of the starting conditions in the phase of preparation, (ii) then the phase of incubation in which the issue is laid aside, (iii) the phase of illumination in which the new idea is born by picking up the issue after a while and finally (iv) the phase of verification. How this illumination can happen remained unexplained at that time. Furthermore it seems dubious to separate this act of illumination from all conscious endeavours to analyse the issue. This lack of explanation was reflected in the process model of Rossman (1931/1964). In this model the preparation phase is composed of observation of need, analysis of need, a survey of all available information and a formulation of all possible solutions. The incubation/illumination phases are replaced with a critical analysis of these possible solutions and a birth of the new idea out of this analysis. The last phase is analogous to Wallas (here based heavily on experimentation). How this "birth" happens still remains mysterious. Meanwhile these traditional conceptions have been challenged by at least two relevant approaches: On the one hand the incubation/illumination paradox is explained as a cognitive processes, relying on cognitive operations and not on mystical insights. Thereby the features of the four-stage model are either updated (Amabile 1996; Csikszentmihalyi 1999b) or rejected (Weisberg 1993, Kaplan/Simon 1990). On the other hand, very promising

10 Meanwhile at least two attempts have been made to explain the incubation/illumination paradox: Simon (1977) suggests that the illumination is due to crystallizing the relevant connections in the time of incubation whereas Amabile (1996, 101) refers to a possible erosion of an extrinsic motivation (in favour of intrinsic motivation) in the course of time. For a further discussion cf. Finke/Ward/Smith (1992, pp 143, pp 179).
endeavours have been made to propose new models to overcome the traditional perspective (Finke/Ward/Smith 1992). Additionally a lot of empirical and experimental work has been done to explain problem solving (and problem finding) processes (Lubbart 2000/1).

- Creative operations do not happen in an empty space, they have an environment. This environment is relevant for the generation of a creative act as well as for the evaluation of the result of this creative act. According to the difference between the outcome of creativity (an idea, a concept, a physical product etc) and the creative person the environment is seen to consist of a "domain" to which the product refers and a "field" to which the person refers (cf. Csikszentmihalyi 1999b). Unresolved problems in the domain as well as the way the experts in the field deal with theses problems determine the act of creativity: on one side by the accessibility to the (incomplete) knowledge of the domain and on the other side by the degree of the open-mindedness of the experts in the field. This is related to the knowledge base and the motivation of the creative person and to the preparatory stage of the creative process mentioned above. But the domain and the field are also important 'testbeds' of the results of a creative act. It will become manifest how much the domain is altered by this creative result (To what degree hitherto unsolved problems are pretended to be solved?) and the experts in the field will have to evaluate this change in the domain (Is the solution accepted? How far reaching is it?)

What conclusion can be drawn from this sketch of creativity research for dealing with ill defined problems? (i) Before problems of this kind can be solved, a creative specification of these problems in preparatory steps is necessary. (ii) Unconscious illumination, imagination and the like are not sufficient for explaining the creative process because a necessary condition for creativity are conscious endeavours. At the core of creating something new there is a twofold process of synthesizing ideas, facts etc. on one side and a transfer and transformation of these ideas, facts etc on the other side. (iii) Insofar as the solution of ill defined problems requires acts of creativity, personal qualities as well as a creativity friendly environment are necessary for the problem solving. Finally (iv) the role of a variety of cognitive elements like knowledge, motivation, and memory is emphasized.

IV.2 Creative cognition and creative problem solving

The separation of personal qualities, environmental conditions and process analysis is a useful starting point for systematizing the insights of creativity research. But from the perspective of modern cognitive psychology this separation seems arbitrary and therefore attempts have been undertaken to broaden the process analysis of creativity to include at least some aspects of personal qualities and environmental conditions. Such an attempt is "creative cognition", developed by T. Ward, S. Smith and R. Finke. In this approach a new model of the cognitive process and structure of creativity is proposed, incorporating thereby the aspects of individual qualities and – though at a different level - aspects of environment (cf. Finke/Ward/Smith 1992, 36, 42). The main feature of this approach to creativity is a heuristic model called "genplore" (cf. ibid., pp 17). According to
this model the creative process is a sequence of generative and exploratory processes (hence the name).

The generative processes take place in the initial phase. Here mental manipulations of knowledge elements (retrieval, association, synthesis, transformation, transfer) lead to new mental representations e.g. to a new interpretation of the initial situation, new operators, new evaluation mechanisms and/or new combinations of these elements. Such new representations may consist of discovered patterns, mental models and the like. These results of the generative processes are not simply novel. Rather they have some inherent ambiguity, incongruity and divergence and therefore encourage the investigation of these results in the second phase, the exploratory processes. Because the problem definition is incomplete in that no definite goal is given, the applicability and usefulness of the new representations are now tested. What kinds of problems can be tackled with such new representations? Are new attributes of a problem at stake accessible? What kind of operators can be used to manipulate the initial context and what will be the result of such a manipulation? Finding answers to these questions might include a modification (focus or expand) of the pre-inventive structures (new mental representations) which are the result of the generative process. Hence, multiple feedback cycles between generative and exploratory processes might be necessary until a useful novelty has been discovered.11

What kind of insights for a problem solving process under the condition of an ill defined problem can be gained from the creative cognition approach? "Attempts to specify whether something constitutes a 'problem' in traditional problem solving studies, without considering the underlying cognitive processes, may be futile. Instead, one needs to examine the subject's background knowledge, how he or she represents the problem, and the cognitive strategies used to explore possible solutions. In creative cognition, we emphasize the importance of trying to identify the cognitive processes and structures that contribute to creative problem solving, as opposed to merely focussing on the nature or features of the problem itself." (Finke/Ward/Smith 1992, 168) Insights from creative cognition for the concept of problem solving are threefold: First, a specification of what means "ill defined" is provided. Bringing in new cognitive devices (like mental models, analogy building, context shifting and divergent thinking; cf. Finke/Ward/Smith 1992, pp 167) it is possible to specify what generative/explorative method is used. Furthermore the following questions can be answered: Is the 'illness' of the definition due to not having a new representation or is it due to the unexplored usefulness of a new representation? Or is it due to both? Second, the generative processes constitute a specific determining stage of the whole problem related process: the problem finding. This is tantamount to finding representations or heuristics by using the "geneplore" approach. Third, the problem solving itself changes character in that it becomes creative. It deals with new heuristics/operators and makes of problem solving proper a temporary operation

11 In such an iterative procedure sophisticated forms of path-dependencies can occur: e.g. sticking to an odd hypothesis ("confirmation bias") or using conventional forms of problem posing ("mental blocks") (cf. Finke/Ward/Smith, 1992, 174)
in an overarching problem finding/problem solving feedback process. Fig. 4 shows the corresponding modifications of the general scheme of problem solving (additional elements are in red).

V. Problem solving and evolutionary theorizing

V.1 Invention as a problem finding/problem solving activity

Invention means the creation of a conceptual novelty. It denotes the creation of an idea or a concept, waiting for being applied in a practical context. Such a new idea or concept might be based on new knowledge which is simultaneously created with the invention ("primary inventions" in the sense of Usher 1971, pp 50) or the invention is the result of new applications of a given set of knowledge ("secondary invention", ibid. pp 54).

Considering invention as an act of creative problem solving means to specify the endowment of the inventor in terms of cognitive resources (cf. above section IV.1). A profound declarative knowledge about the domain, the ability to flexibly combine the elements of this knowledge, and knowing how to search in a given domain for new insights (procedural knowledge) is the first cognitive prerequisite for the creative act of invention. Second, the motivation for inventive activity is strictly intrinsic in that this activity is seen (by the inventor) as an end in itself. Any environmental expectation about the result of the invention is either ignored or transformed in the inventor’s individual motivation. This means that on one side there is no person who is forcing the inventor to follow a predetermined action pattern; on the other side this does not exclude that the inventor has an open mind for scientific, technical, social or economic needs. A third momentum

12 (Scientific) Knowledge is a necessary but not sufficient condition for invention; it may facilitate the latter or even constitute a kind of a "supply push" for invention in that new scientific insights are demanding for practical applications. This is one rationale for r&d laboratories where this knowledge is quickly accessed and focused on the invention at stake (cf. Nelson 1959, pp 105).
of the inventor is including all the personal qualities which have been attributed to the creative personality (cf. section IV.1) with a special emphasis on a deliberate cognitive style and divergent thinking.\textsuperscript{13}

For invention the environment has the double role to be (a more or less) stimulating background and to be an evaluating context. The stimulation is given in terms of scientific, technological, social and economic 'driving forces' (i.e. strategic and/or global needs in these domains). This background for the invention process may be given by identifying "reverse salients" (Hughes 1978, 172, 179) i.e. the bottlenecks of a global system development in the domains mentioned before. The focus on these reverse salients is determined (i) by education and expertise of the inventor, (ii) the prior activities of the inventor in the same or a similar domain and (iii) by anticipating some feasibility constraints in terms of funding, accessible r&d facilities and perhaps by referring to the expectation of an entrepreneur.\textsuperscript{14} The evaluation context for the invention is now specified as the entrepreneur function. This function can be incorporated in a special group of entrepreneurs (as it is often assumed in evolutionary economics: cf. Schumpeter 1964; Röpke 1977) or it may be a temporary feature of actors, which have also other roles to play. One component of this entrepreneur function is assessing the outcome of invention as regards to its economic potential: Is there a possible way to transform this outcome into an innovation and will this innovation be successful in an economic sense? "Invention of a new and useful device is one thing: its production and use are something else again. Invention requires innovation on the part of both producers and consumers before economic change results, and the struggles of countless inventors to get someone to finance or undertake production of their inventions and the often fruitless efforts of producers to market new products are common lore."(Nelson 1959, 102). Hence, this entrepreneurial evaluation process of invented products may be influenced by the hostility of those vested scientific, technological, social and economic interests for which the innovative development of the invention might be a threat (cf. Gilfillan 1970; Hughes 1978; Amabile 1998).

The process of invention can be characterized by referring to the features of an enhanced problem solving concept: (i) It deals with ill defined problems, (ii) it includes a stage of problem finding and (iii) it solves problems in a creative manner.

ad (i): Taking "problem space", "goals", "heuristics" and "operators" as attributes of a problem definition and assuming that all these attributes can be in the state "none", "one", "multiple" and "vague"\textsuperscript{15}, there are $4^4$ possibilities to characterize

\textsuperscript{13} This does not include that invention is completely a deliberative operation. It merely emphasizes that normally a lot of deliberate effort is a necessary though not sufficient condition for generating an invention.

\textsuperscript{14} By taking into account these changing environmental conditions the inventive activity itself becomes a variable. This is one reason why the assumption of a continuous stream of inventions supplying the entrepreneur is meaningless.

\textsuperscript{15} A vague problem space is given if there is a high uncertainty about the dimensions of the problem to deal with. The goals are vague if a goal is not known in a positive sense but only in a negative sense in knowing what is not intended. The heuristics and operators are vague if the appropriateness of both for any given goal is ambiguous.
the problem situation. The problem situation for an inventive activity lies somewhere between a situation which is well-defined (all attributes are in the state "one") and a situation of total ignorance in which all attributes are in the state "none". We suppose that the specific situation of inventive problem solving is typically defined firstly, by a vague problem space and a vague fixing of the goals. This corresponds to the incomplete knowledge of the inventor about possible directions for transforming an initial situation and to a loose binding to the 'driving forces' of the environment mentioned above. Secondly, heuristics are vague and possible operators are unknown (state "none") when the invention process starts. Hence when the invention starts the string of the attributes (problem space, goals, heuristics and operators) is:

\[ I_{\text{vent}} = \{\text{vague, vague, vague, none}\}. \]

This specific type of an ill defined situation is called here a "strong ill defined problem".

ad (ii): Given such a strong ill defined problem, the first stage of the inventive process is the solution of the "problem" of problem-finding. This problem is coped with by the above mentioned generative processes (cf. section IV.2) leading to pre-inventive structures in terms of a specification of the problem space, mental models about this problem space and a discovery of new heuristics and operators for 'walking through' this problem space. Thereby it is specified where this walk could go to, i.e. hopefully the vagueness of the goals is reduced by these generative processes. Ideally at the end of this stage of invention at least the problem space should be specified and a couple of heuristics (e.g. heuristics for decomposing as well as for re-composing a problem space) and operators should wait for being explored.

ad (iii): In the next stage of the inventive process the heuristics and operators are explored. In this process a feedback to the understanding of the problem space as well as to the goals of the whole operation takes place. To specify such a process more closely: The inventor may use one of the available decomposition heuristics to discern the weakest point of a problem at stake, then he/she may solve this weakness by using an heuristic of analogy to a similar (better known) problem and finally this abstract solution is adapted to the real-world problem by using a re-composing heuristic (cf. Hughes 1978, 173).

Invention as an economic activity is confronted with strong uncertainty. This uncertainty is twofold: (i) There is no clear relationship between input and output (cf. Arrow 1971, 172). Hence, there is a high risk of either not finding any new idea or concept at all or to find something which is not applicable, i.e. something that cannot be used as a source of innovation (output uncertainty). This side of the uncertainty can be expressed as the problem of establishing the direction and amount of search activities (cf. Heuss 1965, pp 110). (ii) If the invention is successful, there is no guarantee that those who are not willing to pay for the use of it can be successfully excluded (exclusion uncertainty). Partially this uncertainty can be reduced by juridical protection (e.g. application for patent).\(^\text{16}\)

Especially the output uncertainty confines the applicability of the usual economic

\(^{16}\text{Cf. Arrow's analysis of the difficulties patent laws are facing (Arrow 1971, 173).}\)
calculation framework in terms of costs and (expected) yields. Invention is due to a strategic orientation because only in the long run a pay off can be expected. In the short and medium term the output uncertainty as well as the motivational requirements for the inventors imply the paradox, that inventive activities are the more successful, the more this activity is de-linked from the normal organisation of economic activities and from the efficiency criteria coupled with this normal organisation.\footnote{It is found that, despite talk of close controls, budgetary and otherwise, much industrial research is conducted under very loose control. In general, the greater the technical advance represented by the object of research, the looser the controls. There appears to be recognition in practice of the great uncertainty attached to major inventions and research findings. (Nelson 1959, 101; cf. ibid. pp 121) – This specificity of invention is missed if the necessity to integrate invention in the realm of economic analysis is legitimised by considering invention as subject to "costs and results in revenues like any other business activity" (Solo 1951, 417)}

To resume, dealing with invention in a (broadened) problem solving framework has several specificities: (i) It shows that invention consists of a sequence of knowledge using and knowledge generating stages and their feedbacks. (ii) It integrates modern creativity research by demystifying the "act of insight" in that the latter is seen as a combined effect of cognitive resources, environmental conditions and personality features. Thus, the inventive insight is not a sudden recombination or synthesis of given elements of knowledge; rather it is a result of a – socially shaped – process of finding, defining and treating a problem. (iii) The definition of this problem is influenced by a "supply push" in terms of new knowledge and a "demand pull" in terms of global needs. Hence there is an "….interplay of moving frontiers of knowledge and growing need upon the direction and likelihood of success of individual 'acts of novelty'"(Nelson 1959, 107). (iv) Finally in this approach it is possible to pick up the results of those case studies related to technological inventions which are not part of the creativity research and to interpret them in a problem solving procedure.

V.2 Innovation as a problem solving activity
Innovation means the creation of an instrumental novelty. It is the process of applying and thereby figuring out the result of the invention process. Generally this process has to meet two requirements: The feasibility of applying the inventive idea/concept has to be shown in technical, institutional, and behavioural terms. Furthermore, a path to the marketability of this feasible application has to be demonstrated. To deal with these challenges is at the core of the entrepreneur function.

The cognitive resources involved in innovation as a specific stage in the overarching creative problem solving process are in most parts different from the cognitive prerequisites for invention. Whereas both processes have in common that a profound knowledge of the domain is necessary (declarative knowledge), the requirement for the procedural knowledge shifts in the case of innovation towards knowing how to solve a given problem. Due to an increasing focus on applicability and solution requirements the motivation is no more intrinsic in that the innovation is seen as an end in itself. Rather the innovator is – at least partly –
animated by strong incentives in terms of either "motivational slack" or deficits in realizing some aspiration level as regards to a given goal (cf. Beckenbach 2003). However, because the inventor is not forced by other persons or circumstances to do his job, his autonomy is still unconstrained and therefore his motivation is to a large degree "enabling extrinsic" (Amabile 1996, pp 115). Finally, as inventors the innovators have a deliberate cognitive style but in case of the latter the way of thinking shifts towards being convergent instead of divergent.

The environment of the innovator is set by the ideas/concepts 'offered' by the inventor, the given solutions to past problems in terms of products, processes, organisations and behaviours as well as the competitors. Compared with the inventor, the stimulation for the innovator coming from this environment is more visible (in case it is there) and the driving forces for his activity become less global and less far-reaching. In such an environment the innovator has his role as entrepreneur to play: After assessing the opportunities given by the products of the inventive process he has to focus on one option and implement it as a midrange improvement of his market performance. This implies that there is some acceptance for what he is doing on the side of producers or consumers.

Compared with the process of invention, the process of innovation differs in the way it poses and solves problems: (i) It still deals with ill defined problems, but the 'illness' is weaker than in the case of invention. (ii) There is no stage of problem finding anymore. (iii) Solving the problems at stake requires less creativity.

ad (i): The definition of the problem is shaped by picking up the results of the invention stage. The mental representation of the problem space as well as the goals are to a certain degree specified (turning from the "vague" to the "multiple" state) by the invented option the innovator wants to implement and by the triggering market conditions for such an innovative activity. Hence, the following questions arise: What are the technical feasibility problems of a given concept? What qualities of the product innovation promise what kind of advantage in the market performance of the innovator? Additionally the innovator has to deal with remaining uncertainties as regards to heuristics and even more as regards to operators. Although these heuristics and operators are to a large degree determined by the invented option, at least a multiplicity of these heuristics and operators have to be checked. Furthermore the implementation of the invented option may necessitate to find out and experiment with unknown (sub-)heuristics and unknown (sub-)operators. Hence, the string of attributes (problem space, goals, heuristics and operators) at the beginning of the invention switches now to: $I_{\text{var}} = \{\text{multiple, multiple, multiple, vague}\}$.

This specific type of an ill-defined situation is called here "weak ill defined problem".

ad (ii): Assuming that the initial condition for the innovative process is the application of an outcome of invention for improving the economic performance and given a weak ill defined problem, no problem finding is necessary – the finding problem is solved!

ad (iii): Solving the weak ill defined problem of innovation still requires some creative resources. Even if heuristics and operators are determined by the option
picked up by the inventor, the outcomes of these transformation procedures are uncertain. For example: Which of the heuristics and operators discovered during the invention process may be appropriate for generating a desired product quality? Additionally – as already mentioned – new sub-problems will arise and hence a need for new sub-heuristics and sub-operators. Exploratory processes with respect to the whole problem at stake and generative as well as exploratory processes with respect to the sub-problems are still necessary.

Compared with the invention process the overall degree of uncertainty is reduced: Although the implementation of an idea or a concept may be a source of additional uncertainty, the output uncertainty is reduced because the amount and direction of the search activities is much clearer now. Contrary to that the exclusion uncertainty is increased because competitors may use the same invented option and similar heuristics and operators. Last but not least the great challenge for the innovator is to transpose the figuring out of the invented option into a context which is determined by normal organisational procedures and economic evaluation criteria.

V.3 The novelty creating process as a whole

Invention and innovation are stages of the novelty creating process. They are distinct in terms of general definition, cognitive resources, environmental conditions, process elements and economic character. Table 1 resumes some of these different attributes.

<table>
<thead>
<tr>
<th></th>
<th>Invention</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>general definition</td>
<td>conceptual novelty</td>
<td>instrumental novelty</td>
</tr>
<tr>
<td>ps-definition</td>
<td>(i)solution of strong ill-defined problem</td>
<td>(i)solution of weak ill defined problem</td>
</tr>
<tr>
<td></td>
<td>- vague problem space</td>
<td>- specific problem space</td>
</tr>
<tr>
<td></td>
<td>- vague heuristics</td>
<td>- specific heuristics</td>
</tr>
<tr>
<td></td>
<td>- no operators</td>
<td>- vague operators</td>
</tr>
<tr>
<td></td>
<td>- vague goals</td>
<td>- specific goals</td>
</tr>
<tr>
<td>(ii)solution of problem finding</td>
<td></td>
<td>(ii)problem finding solved</td>
</tr>
<tr>
<td></td>
<td>- specification of problem space</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- specification of heuristics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- generation of operators</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- specification of goals</td>
<td></td>
</tr>
<tr>
<td>(iii)problem solving</td>
<td></td>
<td>(iii)problem solving</td>
</tr>
<tr>
<td></td>
<td>- exploring new heuristics</td>
<td>- exploring known heuristics</td>
</tr>
<tr>
<td></td>
<td>- exploring new operators</td>
<td>- exploring known operators</td>
</tr>
<tr>
<td>motivation</td>
<td>strictly intrinsic</td>
<td>enabling extrinsic</td>
</tr>
<tr>
<td>knowledge</td>
<td>- domain knowledge</td>
<td>- domain knowledge</td>
</tr>
<tr>
<td></td>
<td>- search knowledge</td>
<td>- solution knowledge</td>
</tr>
<tr>
<td>skills</td>
<td>divergent thinking</td>
<td>convergent thinking</td>
</tr>
<tr>
<td>research</td>
<td>size and direction</td>
<td>implementation</td>
</tr>
<tr>
<td>integration</td>
<td>- delinked from efficiency</td>
<td>- linked with efficiency</td>
</tr>
<tr>
<td></td>
<td>- delinked from normal organisation</td>
<td>- linked with normal organisation</td>
</tr>
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<td>orientation</td>
<td>long term</td>
<td>medium term</td>
</tr>
<tr>
<td>risk</td>
<td>high</td>
<td>medium</td>
</tr>
</tbody>
</table>

Table 1

18 This may lead to the often observed case of similar innovations at the same time.
Taking into consideration these differences the whole novelty creating process can be deciphered in a more step-wise (dynamic) fashion (cf. fig. 5). Thus we have a process in which the state of the string of the problem representation (consisting of the components problem space, goal, heuristic and operator) changes according to a process of "generation", "exploration" and "implementation". Starting with a situation slightly on this side of total ignorance in which at least some rough ideas exist about problem space, goals and possible heuristics, the generation process leads to a reduction in the search space. It identifies different dimensions of the problem space and creates a finite number of heuristics and operators. This still very large search space is further reduced in the exploration process in which ideally a unique problem space should be found (being one condition for a switch to a well-defined problem) and possible goals of the process should be specified. The task of the final implementation stage is to find unique states for all the components of the problem representation. This means there should be definite answers to the following questions: What is the novelty about? What is it good for? What are the steps from an initial situation with a problem to be solved and a final situation, where the problem is solved?

The novelty creating process is not unidirectional. Because it is a process of search, discovery, and learning there are feedbacks between the successive stages of this process. Early in the research about inventions it was noticed that inventions produce inventions: "Following the break-through of basic invention, there is at first a rising, than a falling, rate of increase in practical adoptions of the new inventions. In time the new invention is made obsolete by still newer inventions, and its use declines or falls off entirely. A basic invention is usually followed by a number of improvement inventions. The rate at which improvements are made rises as practical experience with the equipment increases, then falls off as improvements reach physically determined limits."(Nelson 1959, 104; cf. Heuss 1965, 26; cf. Usher 1971, 54) In terms of our process analysis this means that the findings of the exploration stage stimulate new generation activities. This may be the case, either if the exploration shows that the generative activities went in the wrong direction (substitutive feedback) or if a further specification of the invention or a complementary invention is necessary (adaptive feedback). Correspondingly it was observed in the research about innovation that "...often an innovation is changed or modified by a user in the process of its adoption and implementation"(Rogers 1995, 174)\(^9\) In terms of our process analysis this is tantamount to a feedback from the implementation stage to the exploration stage. The reasons for this feedback are analogous to the feedback mentioned before.

According to the analysis of the social embeddedness of creative activities given in the systemic approach of creativity research (cf. Csikszentmihalyi 1999b) these different stages of the novelty generating process are influenced by different environmental conditions. The generation phase depends on the socially available knowledge about the domain at stake (apart from the individual tacit knowledge).

\(^9\) Rogers denotes this modification in a misleading way "re-invention" (ibid.)
On the other side, this domain knowledge is influenced by the new knowledge produced during the invention process in case that this new knowledge is communicated. When the generated ideas or concepts are explored and thereby related to existing ideas and concepts in the domain leading to an assessment by the people in the given domain, the influence of a "field" comes in. This is the way the inventor is affected by needs articulated in the public. Furthermore, if the field is dominated by some order parameters, there might even be an influence of the field on the direction of the generating processes of invention. As in the case of the domain the field is be influenced by the results of the inventive exploration. Finally the implementation stage is shaped by the embedding of the innovator in the economic competition which strongly determines his/her goals. If a strategic deficiency in his/her competitive performance is observable for the innovator, this will have an impact on his exploration activities.

Invention and innovation are not disjunctive stages in the novelty creating process. Rather there is a fuzzy border between these two processes in that they overlap. The final stage of the invention process in which an idea or concept is explored thereby reducing the ambiguity of a problem representation (or discovering potential problem representations) may be the first stage of an innovation process. In this process an understanding of the invention is obtained (specifying the problem space) and the range of goals is defined to which the invention can be related.

In evolutionary economics the novelty creating process is normally treated in a meso-economic perspective. The emphasis is then on the patterns and structures for these processes and not on the proceeding of these processes themselves. Taking social embeddedness and strong uncertainty as boundary conditions for
the novelty creating process, it is not surprising that this process normally takes place in a structured environment. Intuitively it seems plausible that social interests (or even social conflicts) are an important factor in establishing the social needs in the above mentioned field. Intuitively it also seems plausible that the reduction of the search space (e.g. reduction of uncertainty) takes place in using the known elements for solving similar problems. Hence it seems reasonable to assume "paradigms", "dominant designs" and the like for the novelty creating process. In the case of the technological domain these structures can be described as follows: "A 'technological paradigm' defines contextually the needs that are meant to be fulfilled, the scientific principles utilized for the task, the material technology to be used. In other words, a technological paradigm can be defined as a 'pattern' of solution of selected technoeconomic problems based on highly selected principles derived from the natural sciences, jointly with specific rules aimed to acquire new knowledge and safeguard it, whenever possible, against rapid diffusion to the competitors…….A crucial implication of the general paradigmatic form of technological knowledge is that innovative activities are strongly selective, finalized in quite precise directions, cumulative in the acquisition of problem-solving capabilities." (Dosi 1988, pp 1127)

In terms of our description of the novelty creating process this can be interpreted either as a strong selective effect of the field on the exploration process or as a strong predetermining effect of the field on the direction of the generative processes of invention. Taking the description of the novelty generating process supposed here, this rather exogenous explanation of structuring and directing can be specified in two respects. First, it misses the structuring and directing factors which are given at the micro level of the novelty generating process itself. These factors are (i) the clustering of inventive activities included in the above mentioned adaptive feedback between exploration and generation leading to a system of interdependent inventions and (ii) the lock-ins as well as the path-dependencies inherent in the invention process the more it advances (e.g. fixing a mental model, learning effects). Second, it does not reflect the tension between the early stages of invention led by divergent thinking on one side and the postulated conformity to the paradigmatic determination of problem space, goals, heuristics and operators on the other side. This tension gives the chance that basic novelties contradicting the paradigm are searched for and in the case of inventive success may be promoted by some parts of the (social) field.

V.4 Integrating invention and innovation in an evolutionary concept of agent

Invention and innovation are two interacting components of the novelty creating process. Taking the perspective of an economic agent this process is a temporary mode of action. This temporary nature of the novelty creating process is independent of the different ways persons are involved in it. Thus it is possible that there is a professional invention agency selling its 'product' to an entrepreneur (e.g. licensing a patent) or that one single person figures as an inventor-innovator. In both cases the process starts with an open search and – if not interrupted before – ends up with figuring out a new option for the agent. Taking the specific and temporary nature of the novelty creating process into account, several questions
arise. What are the conditions triggering an inventive or innovative search? What happens when this search is successfully finished? What other modes of actions is an economic agent equipped with? How are the different modes of actions related to each other?

Answering these questions (even in a sketchy way\textsuperscript{20}) means to broaden the perspective to the economic agent in terms of his modes of action. According to the discussion in evolutionary economics, we suppose the following modes of activities, each characterized by a specific way to determine the possibilities of action, to discriminate between the latter and to select/practise an option:

\begin{itemize}
  \item single routines,
  \item multiple routines,
  \item choice,
  \item invention/innovation, and
  \item imitation.
\end{itemize}

These capabilities of action as well as the experience with them (in terms of pay off) are stored in the long term memory. The long term memory is at the same time the locus, where the levels of aspiration as well as motivational strengths are built. Depending on the state of these evaluations on one side and on the actual situation of the agent on the other side, one of the modes of actions is activated. This might include either proceeding further with the actual mode of action or switching to another one.\textsuperscript{21} The selection of the appropriate mode of action as well as the decoding of required resources from long-term memory for realising this selection (finding the options, routines, heuristics, operators etc.) takes place in the working memory. Then this selected mode of action is prosecuted and the cognitive evaluation procedure takes place again, when results of these activities are observable for the agent (cf. fig. 6).

Inventive and innovative search processes are either triggered in the case of a severe missing of the aspiration level or in the case of a motivation surplus ("motivational slack"). If this search is successful, in the course of time the invented option becomes part of the routine or choice setting of the agent. Therefore, invention and innovation are the bygone sources of what is the usual starting point of microeconomic consideration.

\textsuperscript{20} For a more detailed answering cf. Beckenbach 2003.

\textsuperscript{21} According to the emphasis on personal qualities as a prerequisite for invention and innovation, this may lead to a biased selection between all modes of action if a population of agents is considered in the course of time. Those agents who are not equipped with the personal qualities for invention or innovation will fail if selecting these modes of action and therefore they will select imitation if their situation makes search for new options necessary in the future.
VI. Conclusions

We propose an enriched problem solving framework for bridging over the gap between empirical findings and assessments in case studies as well as experimental research about novelty creating processes on one side and the focus of the main approaches in evolutionary economics on the other side. In such a problem solving framework invention and innovation are distinct as well as interdependent processes embedded in an institutional and social environment. Thus invention and innovation might become a genuine topic of evolutionary microeconomics.

But this is not only a proposal for catching up with empirical observation and assessment in economics. Furthermore it is implicitly an attempt to catch up with the insights of cognitive psychology where a lot of cognitive resources and processes being important for "bounded rational" ways of action in an economic context are investigated. As a first step in this direction we took into account the role of motivation, knowledge, memory, and personal qualities for the problem representation. The invention/innovation process is then understood as a sequence of iteratively specified problem representations.

In such a (broadened) problem solving perspective on novelty creation the latter becomes in principle a temporary specific mode of action in contrast to assuming...
novelty creation as a permanent property of a special group of persons. Nevertheless, due to required personal features and due to an unequal endowment with these features at the different agents, the economic interaction of these agents may lead to situations where the invention/innovation frequency is quite different for the different agents, including the extreme case of agents who never activate the invention/innovation mode.

This mode of action is not blind, it is goal oriented. Furthermore it is intelligent in that a goal inspired search takes place by using and manipulating knowledge (e.g. by defining a problem space, heuristics and operators as well as observing and evaluating experiments). But this does not imply that the process of problem solving consists only of conscious elements: Retrieving elements of knowledge in memory is not controllable by the problem solver. Hence, though our approach is different in emphasizing the conscious and strategic elements in novelty creation, there is still some similarity to the understanding of entrepreneurial discovery in the neo-austrian approach.

References
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