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Competition, Innovation, and Maintaining Diversity through Competition Law

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Abstract: Competition can be analyzed as an evolutionary (Schumpeterian or Hayekian) process of parallel experimentation and mutual learning (or variation and selection of new problem solutions), which allows to apply arguments and models of evolutionary innovations economics. From this perspective, the number and diversity of independently experimenting competitors can have a positive effect on the knowledge-generating function of competition. This is supported by the general advantages of diversity: A more diverse pool of problem solutions (as technologies) can increase the probability of being capable of responding quickly to exogenous shocks and of developing superior innovations. Therefore mergers and R&D agreements might also have a negative effect on the effectiveness of competition as process of parallel experimentation (problem of parallel research). A number of positive and negative effects of a larger or smaller number of parallel experimenting firms are shown (trade off problems; optimal number of parallel experimenting firms or parallel research projects). Whether and how competition law should and can protect competition as a process of parallel experimentation?. Although the Innovation Market Analysis developed interesting criteria for maintaining parallel research projects and protecting diversity, they used no appropriate theoretical reasoning about the benefits of protecting parallel research. An evolutionary approach to competition might be much better suited. At the end of the paper some ideas are discussed how competition law might be able to take better into account diversity and parallel experimentation in competition cases.

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1. Introduction

Market competition is a very complex phenomenon, which has many dimensions. Modern game-theoretic industrial economics is a powerful analytical tool for studying important aspects of markets and competition. However, modern industrial economics does not deal with all essential dimensions of competition processes in dynamic market economies. Rather a multitude of different theoretical approaches might be necessary to understand and explain the complexities of what happens in market competition. One of the least understood dimension of competition is its dynamic character - both in regard to the pure dynamics of competition itself and in regard to the relation between competition and innovation. In this paper, I want to focus primarily on one specific dimension of competition, which is not dealt with by current mainstream competition economics, namely competition as a process of parallel search of (competing) firms for new and better problem solutions (innovations). It was Hayek

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(1948, 1978) who emphasized this dimension with his concept of "competition as a discovery procedure". Starting with the assumption that the best solutions are often not known yet, competition is viewed as an evolutionary trial and error-process, in which the firms try out different problem solutions and can learn from the feedback of the market, which of their specific products and technological solutions are the superior ones. Two conclusions follow: (1) Competition is a process, in which previously unknown knowledge is generated, and (2) the multiplicity and diversity of the (parallel trials of the) firms might be important for the effectiveness of competition as a discovery procedure. From a competition policy perspective, then the question arises, how the application of competition law should take this dimension of competition into account.

This paper intends to fulfill three tasks, carried out step by step in the next three main sections:
(1) In section 2, the basic concept of competition as a dynamic process of parallel search for and experimentation with new problem solutions is being presented. It will be demonstrated that this view of competition as a knowledge-generating process fits well with wellknown basic ideas of Schumpeterian and Hayekian approaches to competition but also with the basic tenets of modern evolutionary innovation economics. Therefore we will see that competition as a process of experimentation can be theoretically analyzed as an evolutionary process with variation and selection as crucial mechanisms. It will also be emphasized that competition and innovation processes should be analyzed within an integrated theoretical framework, implying that also the broad theoretical and empirical insights of the multi-disciplinary field of innovation research should be used in addition to traditional industrial economics for applying competition law.
(2) In section 3, we focus on the specific economics of parallel processes of search and experimentation and therefore on the merits (and problems) of diversity. In a brief summary of general arguments about the advantages of diversity, partly stemming from the biodiversity debate, it will be demonstrated that a more diverse pool of resources (products, technologies) might increase the probability of being capable of responding quickly to non-anticipated exogenous shocks as well as enhance the endogenous capability to develop better problem solutions to existing problems. This will provide important arguments why a multiplicity of independent sources of innovations might be so important for rendering the market effective as a selection device. In evolutionary (innovation) economics a number of mathematical models exist which analyze the knowledge generation effect of such variation-selection processes in competition. These studies suggest that in situations of large uncertainty about the optimal solutions, the number and diversity of parallel research projects can have a positive impact on the effectiveness of competition as a knowledge-generating process. This preliminary result will then be confronted with a brief review of the usual arguments about the advantages and disadvantages of parallel research, leading to a trade off problem in regard to the benefits and costs of carrying out parallel research projects, both on the firm and the industry level.
(3) A crucial consequence of this analysis of the merits of competition as a decentralised process of parallel experimentation is the suggestion that it might be an important task of competition policy to ensure a competitive market structure in order to maintain a minimum number of firms as independent sources of searching new problem solutions and safeguarding the effectivenes of competition as a

process of parallel experimentation and mutual learning (section 4). This conclusion will be confronted with the Innovation Market Analysis in US antitrust law, which already used the concept of maintaining several parallel research paths as a competition assessment criterion, both in the Antitrust Guidelines for the Licensing of Intellectual Property (1995) as well as in a number of merger cases. It will be argued that an evolutionary innovation economics approach might provide a better theoretical basis for such a policy of maintaining parallel research than the arguments provided by Innovation Market Analysis. This theoretical discussion will be followed by a brief analysis how this idea of maintaining multiplicity of independent research and diversity might be applied to competition laws. However, it also will emphasize our lack of knowledge in this respect, stressing the need for more (economic) research in regard to this dimension of competition as well as using more the existing insights from modern (evolutionary) innovation economics

2. Competition as an Evolutionary Process of Parallel Search for New Problem Solutions

What are the benefits of competition? Competition is a complex phenomenon. Even from the perspective of a consumer welfare standard, we expect a number of different benefits. For example, the EU Horizontal Merger Guidelines state that the EU competition rules intend to protect "effective competition", which "brings benefits to consumers, such as low prices, high quality products, a wide selection of goods and services, and innovation". Therefore benefits of competition can be anything, which increases the welfare of consumers, either by reducing prices through cost reductions and/or a reduction of the price/cost margin or through improving the utility derived from the characteristics of the products and services or through a faster / cheaper (transaction cost diminishing) distribution. Ultimately, the decisive question is to what extent the products and services offered by the firms solve problems of the customers as well and/or cheaply as possible. This is the reason why there is broad consensus that competition is not only about driving prices down to the cost level and bringing about allocative (static) efficiency. It is also about the developing and spreading of new problem solutions (innovations), i.e. about finding out what the current problems of consumers are and how they can be solved better than before (dynamic efficiency). The core problem is that in a changing world most often there is no objective knowledge what the best products for the current preferences of consumers are and how to produce and distribute them with the least possible cost. The basic presumption of a market economy is that competition between firms is usually the best way to ensure that the consumers get their problems solved as good and cheap as possible.

How is this search for new and better problem solutions done in competition? In a recent small article with the title "Complexity, diversity, and antitrust" Farrell (2006) asks whether antitrust should protect diversity in situations, where the complexity is too high for having reliable information about the right solutions. As an example, he uses the decision of a drug company after a merger to pursue only one of the previously two research projects of the two merging companies. Would not be the higher diversity of pursuing both approaches be one of the benefits of competition? Farrell insists on the impor-

tance of a variety of experiments and claims that this "econodiversity" is another crucial benefit of competition, which he calls the "dark matter of competition", because it is hard to pin down and prove (Farrell 2006, 168-169). The problem is that this dimension of competition, i.e. that firms experiment with different research approaches, make mistakes, and learn from each other's experiences is not tackled with in modern game-theoretic industrial economics. There is a large industrial economics literature on innovation, even in regard to the interrelationship between competition and innovation, but in this literature it is usually assumed that the firms know the best products and technologies or what the current preferences are. In this section, we want to focus on theoretical approaches, which can be used for analyzing competition as an evolutionary process of searching for better products and technologies under the condition of large uncertainty and limited knowledge / bounded rationality of the firms.[1]

Although Schumpeterian competition is a wellknown concept in antitrust law discussions, its theoretical background is much broader and more fundamental. In his famous book "Theory of Economic Development" Schumpeter (1934) sketched an alternative paradigm to mainstream equilibrium economics, which views technological progress as the central endogenous driving-force for economic development, propelled by pioneering entrepreneurs and imitators, who introduce and spread new products and production methods. From that Schumpeterian perspective, competition as an innovation-imitation process is seen as more important than price competition for the long-term growth of wealth. This Schumpeterian view of competition was the starting-point for concepts of dynamic competition, which attempted to analyze competition as a rivalrous process of innovation and imitation between competing firms, consisting of advancing, following, and overtaking action and reactions (Clark 1961, Arndt 1952, Heuss 1965, Ellig / Lin 2001). This notion of dynamic competition was very successful in Germany, and influenced also the European concept of effective competition. Whereas this specific German concept of dynamic competition has lost its impact in competition economics, Schumpeterian competition as a general claim about the importance of innovation for revolutionizing entire markets and erasing established market power positions is still a powerful argument. However, the Schumpeterian approach has become much more important in innovation economics, where the above-mentioned basic ideas of Schumpeter are the starting-point for nearly all of the rather diverse approaches in this interdisciplinary field of innovation research. Schumpeter's idea of an alternative economic paradigm is also the basis for the broad and thriving approach of modern evolutionary innovation economics.

Hayek's concept of competition as a discovery procedure can be understood as an indirect way of how to integrate innovation into competition (Hayek 1948, 1978). Hayek's approach starts with the knowledge problem, i.e. that individuals and firms have only a limited and subjective knowledge about the preferences of consumers, which products satisfy these preferences best, and what the most cost-efficient production technologies are. Therefore, from the Hayekian perspective, it is the main function

[1] For the following, see also Kerber (1997) and Kerber / Schwalbe (2008, 226-230).

of competition to find out in a trial and error process what the best products and production technologies are. As a consequence, competition is a method for solving knowledge problems. From that perspective, also Hayek's main critique of the traditional neoclassical concept of competition (as used in the model of perfect competition and still present in modern industrial economics) can be understood best: This concept of competition is seriously flawed, because it already assumes the existence of the knowledge which from an Hayekian point of view can only be generated through the competitive process. Hayek's position is an epistemological one: Nobody has perfect knowledge about the current preferences and the best products and production technologies. Only through the feedback from the market can be determined what the best products for the current preferences of the most cost-efficient technologies are (market test). In that respect, competition can be seen as a process of experimentation, in which firms make experiences, from which they can learn. Therefore it is Hayek who - based upon his analyses of knowledge problems in society - has drawn our attention to the function of competition as a process, in which firms search for better problem solutions and therefore new knowledge is being generated and spread.[2]

Although Hayek's notion of competition as a discovery procedure is a famous catchword, known by all economists, there is nearly no serious theoretical and empirical economic research about this dimension of competition. In the following, some basic tenets of a more elaborated approach will be presented. A first crucial point is the already mentioned epistemological dimension of competition as a process, in which previously unknown knowledge is being generated and spread. In that respect, competition can be seen as a research process, whose results cannot be known before. This impossibility of predicting the specific outcomes of competition as a process of trial and error reflects both the openness of market competition, but also the uncertainty, with which the firms have to deal with. Since human beings (as entrepreneurs) are creative and their ideas and visions about profitable business plans cannot be predicted, and also scientists and engineers do not know the optimal ways to technological inventions in advance, firms are often confronted with situations of Knightian "true uncertainty", in which firms have to make decisions without knowing either the set of all possible states of the future world nor objective probability distributions (Knight 1920). It is this kind of uncertainty (also called structural uncertainty) and the non-predictability of future innovations, which have led economists to the question, whether an evolutionary approach (with a variation-selection-framework suggested by the biological analogy) might be a promising one for analyzing certain aspects of competition and innovation processes.

From such a perspective the Hayekian dimension of competition could be seen as a process of parallel search, in which a number of firms strive for improving their products (or cutting their costs through technological or organizational innovations) through trying out new problem solutions. These new problem solutions can be seen as hypotheses, whose relative quality is being tested in the market (in particular, through the decisions of the customers on the demand side and, ultimately, the consumers)

[2] Hayek's concept of competition is also closely connected to Austrian market process theory (Kirzner 1973).

(Kerber 1997; Kerber / Saam 2001).[3] Since in competitive markets, the profits and losses of firms reflect the relative performance of the firms, this profit/loss feedback of the market also can be interpreted as an information feedback, whose hypotheses have been the superior ones. In such a process of parallel experimentation with new hypotheses, the superior problem solutions can be identified through the market test, leading to the possibility of mutual learning through imitation.[4] Through the generation and testing of new hypotheses about appropriate problem solutions competition has the function of generating and spreading new knowledge about how to fulfill best the preferences of the consumers. Such a concept is able to integrate both the Hayekian notion of competition as a discovery procedure and the Schumpeterian idea of competition as an innovation-imitation process. Firms would compete not only in regard to prices but also in regard to their search for better problem solutions for the other market side. Since it is a process of parallel search, experimentation, and mutual learning, the multiplicity and diversity of experimenting firms can be expected to have an important impact on the working of this dimension of competition. In the next section 3, we will see that in this theoretical approach a higher number of firms and a larger diversity can lead to a more rapid accumulation of knowledge through more parallel experimentation (see section 3).

Such a process of generating and testing of new problem solutions can also be analyzed as an evolutionary process of variation and selection. In his broad survey article about "Recent Evolutionary Theorizing about Economic Change" Nelson (1995) explains the main characteristics of an evolutionary theory: It analyzes the dynamics of a population of elements (here: products, technologies etc.) over time through the mechanisms of a variation of their traits and a systematic selection process. With a number of different examples Nelson demonstrates the evolutionary character of learning in trial and error processes. Since (1) the innovation of new problem solutions cannot be anticipated in detail (leading to a kind of random element and therefore some "blind" variation) and (2) the market can be seen as a device for the systematic selection of new problem solutions, the Hayekian dimension of competition as a process of parallel experimentation can be analyzed as such an evolutionary process of variation and selection of problem solutions. It should be noted that in competition economics the selection character of market competition has always been emphasized. However, it has been rarely analyzed explicitly; the same is true for the interplay between the variation and selection mechanism in market competition.[5] Therefore it is necessary to use more the broad theoretical and empirical insights of the evolutionary approaches to innovation research for analyzing more deeply the determinants of the variation and selection processes in competition. Beyond that, the interdisciplinary field of innovation research can provide a large number of other results from theoretical and empirical studies, which

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[3] For a broader presentation of this concept of competition as a test of hypotheses see also Kerber (1994) and Linge (2008, 185-210); this concept is also closely related to research done by Harper (1996) and Mantzavinos (2001) as well as to the Darwinian "growth of knowledge" concept of Popper (1972).

[4] Please note that in this respect also many "market failure" problems can arise, which can lead to serious errors in the selection of new problem solutions and a lot of ensuing problems.

[5] For example, it was one of the most powerful arguments of the Chicago School in the U.S. antitrust discussion to emphasize that in a competitive market only efficient business practices and firm sizes can survive, leading to an indirect efficiency explanation. However, it is the lack of serious evolutionary analysis that leads to such misleading conclusions as the Chicago claim that only efficient behavior can survive in markets.

can be used for a better analysis of the dynamics of competition as well as for a better integration of competition and innovation economics.[6] In the following, our analysis will focus on the specific impact of multiplicity and diversity of firms for the effectiveness of competition as a process of parallel experimentation.

3. Advantages of Parallel Decentralised Search and Diversity in Competition

3.1 Value of Decentralised Search and Diversity: An Overview

The question of diversity has been discussed most prominently in regard to biodiversity.[7] For decades there are well-founded, serious concerns about a irretrievable loss of biodiversity through endangered species (animals, plants). Despite the question of an intrinsic value of species, it has also been asked what the value of biodiversity is for the global ecosystem and human mankind. In empirical studies, a positive correlation between biodiversity and biomass productivity has been shown. This can be explained by the probability effect, i.e. among a more diverse population the probability is higher "that traits of some species or technologies match those that lead to maximal efficiency and productivity" on average (Tilman et al. 2005, 412). Another strand of arguments emphasize that biodiversity als increases the stability of ecosystems. Since a higher degree of biodiversity implies a larger pool of species with their different characteristics, an ecosystem can react faster to exogenous shocks, because the probability increases that some of the species are well-adapted to the new circumstances. However, also a more direct benefit for human beings are being discussed. One of the most direct economic values stems from the pharmaceutical use of plants and animals, which is increasingly explored by international pharmaceutical companies (Nunes / van den Bergh 2001). Within this biodiversity debate, also the economic argument was used that specific genes or species within the global pool of existing life forms can have an option value, because due to high uncertainty it cannot be known whether these genes or species might have a crucial value in the future, either for the ecosystem or as resources for developing valuable pharmaceuticals. In that respect, maintaining biodiversity can have an insurance function against unanticipated changes.

Of course, the last paragraph could only give a very brief idea of the complexity and sophistication of the biodiversity debate. In the meantime, there is also a large literature about a wide range of policy measures how to maintain biodiversity on very different levels. Interesting for us is that there are both very important parallels but also differences to the problem of parallel search and diversity in market competition. One of the most important differences is that lost genes and species in biological evolution cannot be retrieved in the same way as products, technologies, and knowledge that did not sur-

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6 For overviews about evolutionary innovation economics see, e.g., Dosi (1988, 2000), Saviotti (1996), Freeman / Soete (1997), and Metcalfe (1998)

7 For the discussion on biodiversity, see Lister (1998), Mc Cann (2000), Tilman et al (2005), and as overview Linge (2008, 122-126).

vive market selection. This also leads - in combination with a normative element - to the strong tendency in the biodiversity debate to conserve already existing genes and species and analyse the adaptive ability of ecosystems to future shocks, whereas in innovation economics it is the creation of new innovations and therefore the evolutionary capabilities which are most focussed on. Despite these important differences we can use some of the arguments also for the analysis of potential advantages of diversity in economic settings and especially in market competition, as we will see below.

From an economic perspective, we can distinguish two groups of arguments about the value of diversity, (1) a faster adaptation to exogenous shocks, and (2) a greater evolutionary capability for the development of new problem solutions. The basic idea of the first group starts with the notion of a given pool of products, technologies, skills, capabilities, and knowledge (human resources). It can easily be shown that a larger and more diverse pool, e.g. of technologies, leads to a higher probability that in the case of an exogenous shock, one of these technologies will provide an appropriate solution (Cohen / Malerba 2001). This can be called probability effect or pool effect. It should be clear that the extent of this pool effect depends both on the number and the heterogeneity of the technological solutions within this pool. In that respect, diversity has a quantitative and a qualitative dimension. Maintaining a pool of different technologies can be interpreted from an economic perspective as a pool of options, which can be chosen at some future date, if through changed circumstances or new information these technologies prove to be the right choice. By using economic option theory, today's value of holding specific options can be calculated (Kreps 1979). In the strategic management literature, this argument about creating and holding options has been widely used for rationalizing the building up of large portfolios of technologies and patents or for committing to R&D joint ventures, which can give access to new technology that previously not existed in the firm. In that respect, building up and maintaining a pool of diverse resources or technological solutions can be seen as investing into the technological flexibility or as insuring oneself against the unanticipated consequences of future change (Vives 1989, Thomke 2003). These arguments about the economic value of diversity emphasize again the crucial importance of uncertainty.

The second group of arguments about advantages of diversity refer to its contribution to the development of new innovations. There is an interesting small literature on the specific impact of diversity on the innovativeness of teams (for an overview: Van der Vegt/Janssen 2003; Milliken/Martins 1996). Here a clear trade off emerges: Differences in the knowledge, experiences, attitudes (perhaps also caused by different cultural backgrounds) leads to cognitive diversity of the team members. On the one hand, this stimulates innovativeness through more discussion between different perspectives and the potential use of a broader pool of knowledge, ideas, and experiences (and the possibility of recombining them); however, on the other hand, a too large degree of diversity can also lead to too much conflicts and communication problems. More important for diversity in competition are arguments about a larger exploration of search space, mutual learning, and cross-fertilization. Similar to the above-mentioned probability effect, a quantitatively and qualitatively more diverse set of firms will explore the search space for new solutions of a problem much more extensively than a smaller num-

ber of more homogeneous firms (Cohen/Malerba 2001). This argument will be analyzed much more in the next section about the advantages and disadvantages of parallel research. But the basic idea is that a multiplicity of firms with different knowledge, skills, and experiences (and therefore cognitive diversity) will in situations of large uncertainty tend to explore a broader set of research paths, which will lead to a broader range of feedback, to better solutions, but also to more potential for learning about the merits and problems of different ways to solve a problem. This emphasizes the important role of feedback from the market and the possibilities for firms to learn both from the successes and failures of their competitors. Firms can learn both from the failures of competitors and also from cross-fertilization between the experiments of diverse firms. Therefore the argument about positive effects of diversity in market competition relies also on mutual learning, cross-fertilization, and knowledge spill-overs between firms, and not only on the impact of a larger number of independent and different trials on the probability of finding appropriate new problem solutions; however, in the following we will primarily focus on the latter argument.

3.2 Modelling Evolutionary Search Processes in Competition

In evolutionary innovation economics a number of models have been developed which analyze the searching for innovations in market competition settings under the conditions of bounded rationality and large uncertainty. Since these models have been developed for different objectives, both their analytical design as well as their specific assumptions vary widely. They have in common, however, that they try to analyze at least parts of evolutionary processes of variation and selection of populations of products or technologies, and can be used for a better understanding of processes of the parallel search of competing firms for new problem solutions.

An interesting group of models are so-called fitness landscape models, which analyze trial and error search processes of agents with bounded rationality.[8] In these simulation models, agents are randomly distributed on a n-dimensional fitness landscape with valleys and mountains. These agents only know the fitness value of their location on the landscape but do not know the landscape (bounded rationality). However, they can change their location within this n-dimensional landscape in search of higher fitness values. In the simulation of these search processes, the agents can change their location for a certain number of steps into a specific direction. If the fitness increases (hill-climbing), they will relocate, otherwise they will search into a different direction. With these fitness landscape models trial and error search processes can be analyzed in regard to their determinants and problems. One of the typical problems is that deciding on taking only small steps helps finding peaks on the landscape but increases the danger that only local maxima are found. A particular difficult problem is, if the relations between the different dimensions of the landscape are very complex, because in this case the

8 For an overview about fitness landscape models see Frenken (2001, 2006) and Frenken/Windrum (2000); NK-models were introduced in biology by Kauffman (1993).

landscape is getting very rugged, leading to large difficulties for a step-by-step search (NK-models). An example for applying fitness landscape models for market competition would be the search of a firm for improving the utility of their product without having a detailed knowledge of the (landscape of) consumer preferences. By changing specific features of the product step-by-step and getting the market feedback from the consumers, the firms can try to improve their product. If in these fitness landscape models also the mutual observation (and imitation) of searching agents can be integrated, then they could be used for analyzing the parallel search processes of competing firms.

Metcalfe (1989, 1998) presented replicator dynamics models, which allow the modelling of progress through a pure selection process. Metcalfe starts with an initial diversity of the productivity of firms in an industry and assumes that competition would induce the growth of firms with a productivity above average, whereas firms with a productivity below average will lose market shares. The resulting pattern of differential growth of heterogeneous firms leads to a path of increasing average productivity in the industry (pure selection effect of competition). Particularly important is the conclusion of Metcalfe that continued economic progress is only possible, if constantly new variety is created. "While innovation enhances variety, imitation and competition consume variety so that continued economic progress depends on there being a balance between the different mechanisms ..." (Metcalfe 1989, 55). The importance of generating diversity or heterogeneity in competition for providing the selection process of competition with material that can be selected has also been emphasized by other authors.[9] However, it is only a logical consequence of the evolutionary process of variation and selection, because only the combination of both mechanisms leads to the emergence of a path of technological development and progress.

Such a path of technological and economic growth, which encompasses both variation and selection, is the result of the evolutionary simulation models of Nelson / Winter (1982). They combined for the first time basic Schumpeterian ideas about economic development and competition with the behavioral approach to the firm of Cyert / March (routine concept) and an explicit evolutionary model consisting of variation and selection. In these very complex growth models the basic driving force for economic growth is an evolutionary model of variation and selection of the routines of the firms, which represent the knowledge of the firms. The path of growth is the result of a series of innovation processes, which are modelled as the stochastically drawing of new routines (e.g. technologies) from a set of possible new problem solutions (variation), and ensueing imitation processes through other firms, leading to a variation and selection process of the population of routines in the industry. Although the aim of Nelson and Winter was not the explanation of competition but providing an evolutionary theory of economic growth, their models entail the simulation of processes of parallel search for better technologies and mutual learning through imitation under the conditions of uncertainty and bounded rationality. Therefore the generation of diversity through stochastic innovation processes is crucial for the endogeneously created technological progress, implying that - in contrast to Metcalfe's model - the

[9] See, e.g., Alfred Marshall (1920, 355): "tendency to variation is a chief source of progress".

variation and the selection mechanism are included in the model. After these Nelson / Winter models, a large number of other evolutionary models have been developed, which analyze a broad array of questions in regard to innovation processes; however, most of these evolutionary models do not explicitly refer to competition issues.

An exception is a small simulation model of Kerber / Saam (2001), which tries to analyse directly the positive knowledge-generating effect of parallel experimentation and mutual learning within a Hayekian notion of market competition. In this model a number of firms compete with a set of activities, whose quality is measured in fitness values. In each period, all firms innovate by drawing stochastically from a set of ways how to carry out these activities; after determining the best overall firm (by calculating the average fitness of all activities), the less successful imitate to a certain extent the activities of the most successful firm. This very simple model of parallel experimentation and learning is used for analyzing how the number of competitors, the number of activities, and the imitability of activities influence the growth rate of the average fitness of the industry. This model is Hayekian in the sense that the firms do not know the fitness values of their innovations ex ante; only through the carrying out of the innovation, i.e. through experimentation, do they get informational feedback (from the market) about the relative quality of their activities (compared to their competitors) and therefore about the question, whose new knowledge is the most successful and should be imitated by the other competitors. The results of this simulation of processes of parallel experimentation and mutual learning demonstrate that the growth rate of the fitness of the industry increases with an increasing number of parallel experimenting competitors and therefore is negatively correlated with firm concentration. However, the positive effect of an additional experimenting firm is getting smaller with the number of firms. It is true that the growth rate depends on a number of other determinants (as, e.g., the ease of imitation, and the variance of stochastic innovation processes, which represent the extent of endogenously created diversity), and the model ignores a lot of other important aspects of markets. Despite these caveats, the results of this model can be used for substantiating the claim that the knowledge-generating effects of competition as a process of parallel search and experimentation might be positively correlated with the number and diversity of the firms in the market. Whether it really might be a powerful argument against an increasing firm concentration, will be analyzed in the next section about the economics of parallel research in market competition.

3.3 Competition, Parallel Research, and Diversity

Hayek (1945) emphasized that in a market economy the price system is capable of using the dispersed knowledge of all members of society, which cannot be centralised in one agency leading to his main argument against the feasibility of a planned economy. This argument can be extended: In the decentralised system of a market economy, the potential of creativity, ideas, and heterogeneous skills and capabilities, which are dispersed in society, has a greater chance of being used, because the individual agents can decide on the basis of their own knowledge whether and how to utilize their spe-

cific capabilities and ideas. From this perspective, it is the decentralised character of the market economy, which leads not only to greater allocative efficiency but also to a much larger innovativeness of the entire market system, because more independent sources of diversity exist. The importance of decentralisation for innovation has also been emphasized in the economic theory of federalism. In a decentralised federal system lower-level jurisdictions can experiment with new and different policies, which leads to new policy experiences and the possibility of mutual learning of these jurisdictions from each other. Therefore a decentralised federal system can work as a kind of laboratory for trial and error processes with new policies (laboratory federalism). This can be combined with interjurisdictional competition, in which also jurisdictions can compete with the innovation and imitation of more successful economic policies (competitive federalism). An important implication is that diversity of policies on lower-level jurisdictions (as the Member States of the EU) might be of crucial importance for the effectiveness of the decentralised trial and error processes in federal systems. This also implies that all harmonisation efforts tend to reduce or even eliminate these positive innovation effects through decentralised experimentation.[10]

On markets the degree of decentralisation means the number of independent decision-makers, which usually corresponds to the number of competing firms. Evolutionary models of competition as a process of parallel experimentation would suggest that a higher number of independently innovating firms would try out more different new problem solutions and therefore cover a larger search space for finding good solutions. This increases the probability that better problem solutions are found, which can be imitated by others, which again increases the growth rate of knowledge accumulation in this market. Although from an Hayekian perspective, competition as a process of parallel experimentation is not confined to the problem of R&D (in regard to new product and technologies), it is clear that this question is most relevant for the wellknown issue of parallel research.[11] If such an effect exists, it would clearly be relevant for the competitive assessment of mergers and all kinds of R&D joint ventures, in which previously independently deciding firms are now either merged or coordinating their search efforts ex ante. This raises the question whether mergers and R&D joint ventures might have a negative effect on the effectiveness of competition as a process of parallel experimentation and mutual learning. In regard to this problem, the following questions will be briefly discussed: (1) What are the most important advantages and disadvantages of parallel research and which trade off problems emerge in this regard? (2) To what extent do mergers and R&D joint ventures lead to a reduction of parallel research, and what do we know about their positive or negative effects on innovation and dynamic efficiency?

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[10] For models that analyze the potential positive innovation effects of decentralised experimentation and mutual learning in federal systems, see Kollman/Miller/Page (2000) and Saam/Kerber (2008); for the concept of laboratory federalism, see Oates (1999), and with an explicit link to evolutionary economics and competition, see Kerber (2005).

[11] For the definition of parallel research and experimentation, see Abernathy/Rosenbloom (1969, B-486): "the simultaneous pursuit of two or more distinct approaches to a single task, when successful completion of any one would satisfy the task requirements"

In the strategic management literature a distinction is made between two different strategies for searching for better problem solutions, namely the exploitation and the exploration strategy (March 1991). The exploitation strategy focusses on a better exploitation of already existing research trajectories leading to a further specialization, combination and bundling of existing knowledge. The exploration strategy implies the search of new research paths with more risky experimentation and the use of more diverse knowledge bases (including the pooling of complementary knowledge). It depends on a number of conditions, whether an exploitation or an exploration strategy might be the more profitable strategy for a firm in competition. In situations with high uncertainty, as, e.g., at the beginning of a technological life cycle, it might be better for a firm to carry our parallel research projects, because this increases the probability of finding faster a proper solution than its competitors. In later stages of a technological life cycle an exploitation strategy might be superior. Similarly, also mergers and R&D joint ventures can be the result of an exploitation or an exploration strategy, which also would influence the choice of the participating firms. In the case of an exploitation strategy, the partners for joint research activities would have pursued similar research trajectories, and the joint research would focus more on further specialisation / deepening of the already existing knowledge bases and aim primarily at incremental innovation. The partners of joint research in an explorative strategy, however, would have different (often complementary) knowledge bases, and would intend to explore different research trajectories and aim at more radical innovations (Linge 2008, 223). This differentiation will help us in answering our two questions.

Our general discussion about advantages of diversity in sections 3.1 and 3.2 already provides us with the main advantages of parallel and diverse research paths. The argument that a higher number of competitors and more diversity can increase the probability of finding new and better problem solutions (as products or technologies) has been brought forward by a number of authors. Here also an important distinction can be made: Cohen / Klepper (1992) emphasize the advantages of diversity and of an industry with many small firms for increasing the probability that a particular approach of innovation in this industry is pursued, they do assume that these research paths are not competing, because they do not aim at the same technological objective. This is diversity, which can lead to a better covering of a technological search space, but ultimately leading to a broader range of technological solutions for different purposes (and therefore also to different products and markets). This is one crucial argument about the advantages of diversity, but it is not really about the advantages of parallel research in the narrow sense, which aims at the same technological objective. In contrast to that, many other authors as Evenson / Kisley (1976), Nelson (1982), Kerber (1997), Kerber / Saam (2001), Frenken et al (2004), Carlton / Perloff (2005, 540), Farrell (2006), Linge (2008) as well as a number of authors from the strategic management literature (March 1991, Thomke 2003) emphasize the advantages of parallel research in increasing the probability of finding a proper solution for a problem. In the evolutionary models of Nelson / Winter (1982) and Kerber / Saam (2001) this higher probability is combined with a mechanism of mutual learning between the competing firms through imitation, leading to an endogenously driven path of technological evolution. As already mentioned, the model of Kerber / Saam (2001) leads to the conclusion that a higher number of parallel experimenting firms

would lead to an acceleration of the rate of knowledge accumulation through innovation. In strategic management literature, it was demonstrated that also within a firm parallel experimentation with different research paths can accelerate innovation processes; this might be especially important in early phases of innovation (or technological life cycles) with still very large uncertainty. Here the pursuit of additional research paths can have a high positive option value, until better information is available, or allow for more flexibility in case of exogenous shocks (insurance value of parallel experimentation).[12] To some extent, both the pool argument as well as the insurance argument for advantages of parallel research can be derived from one of the above probability arguments, but they might also contribute additional insights. Already this brief discussion shows that there might be a wide array of different ways in which the multiplicity and diversity of (parallel) experimentation can have positive effects on innovation.

Although parallel research might lead to positive innovation effects on the basis of these arguments, there are a number of counter arguments and other effects that have to be considered. One important assumption of this argument about the advantages of parallel experimentation is that different firms would also pursue different research paths (and therefore creating the necessary diversity)? From an evolutionary economics perspective (and also from the perspective of the resource-based view of the firm), firms usually have different resources (skills, capabilities, knowledge), leading them to a different assessment what the most promising research paths would be (cognitive diversity).[13] The other (at least as important) argument refers to the large uncertainty about the best way to do research for solving a particular problem. In such a situation, there is no clear rational answer what the optimal research project will be; therefore different firms will identify different research projects as the optimal ones. This is exactly, what Farrell (2006) has in mind, when he speaks of the advantages of diversity in situations of high complexity. In such situations with large uncertainty he does not trust the experts that they are able to identify which of previously two competing research projects should be discarded and which continued after the merger of two firms. This is confirmed by the history of inventions, which is full of examples, where later very successful inventions have been rejected by (the experts) of established firms (Scherer/Ross 1990, 652-654). An important conclusion is that the larger the uncertainty and ignorance about the best research paths, the more valuable parallel research might be.[14]

A large group of counter arguments refer to the manifold advantages of large firm sizes and high firm concentration, especially in regard to innovation. Although the Schumpeter hypotheses about the positive effects of firm size and firm concentration on innovation could not be confirmed, both the theorei-

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12 See Nelson (1961), Abernathy/Rosenbloom (1969), Stephan (2003), Thomke (2003), Linge (2008, 223-229).

13 In evolutionary innovation economics the heterogeneity of firms is seen as the normal case, whereas in industrial economics often the representative firm is used leading to the notion of identical firms as the normal case. The heterogeneity of firms is entirely compatible with the resource-based theory of the firm, which views the firm as a set of heterogeneous resources and is well-established in the strategic management literature (see Barney 1991; Montgomery 1995).

14 In their model about the advantages of decentralisation in a federal system Kollman/Miller/Page (2000) show that the relative merits of a centralised or decentralised federal system also depends on the complexity of the policy questions that have to be solved.

cal and empirical studies about this issue has boiled down to a very differentiated set of insights about the specific conditions, under which small or large firms might have advantages for different kinds of innovation, in different industries, in different stages of an innovation process, as well as in regard to measures of innovation input or innovation output (Scherer / Ross 1990, 630-660). In any case, there are a number of theoretically and empirically well-founded arguments, why the optimal solution cannot be the maximization of parallel experimenting firms or the maximization of diversity. This is also the broad consensus among all scholars who claim that diversity and parallel experimentation is important for competition and innovation. In particular, Nelson / Winter (1982) and Cohen / Klepper (1992) have attempted to include the advantages of firm size and firm concentration in their evolutionary approaches, leading them to a "trade off between firm size and diversity in the pursuit of technological progress" (title of Cohen / Klepper 1992). Usually the following potential advantages of larger firm size and firm concentration are mentioned, which also can be efficiency rationales for mergers and R&D agreements: economies of scale and/or scope in regard to production and/or R&D; avoidance of cost duplication; better appropriability of innovation advantages, e.g. through less spillover effects; R&D costs can be spread over more sales; better access to financial resources; better risk diversification; combining complementary resources (for overviews, see Katz / Ordover 1990; Kerber / Schwalbe 2008, 304-305).

A part of these potential advantages are independent from the problem of parallel research, and are only relevant for the overall trade off analysis in regard to the advantages and disadvantages of larger or smaller firm concentration.[15] However, other advantages might also directly improve the effectiveness of competition as a process of parallel search and experimentation. In the model of Kerber / Saam (2001), it has been assumed that the innovation capabilities of firms are independent from the number (and therefore implicitly the size) of the competing firms. If there are some advantages of a larger firm size in regard to the rapidness and quality of innovation processes, then a smaller number of parallel experimenting firms might lead to a larger growth rate of knowledge accumulation in such a Hayekian model of competition as parallel experimentation and mutual learning. Then also in this model a trade off would emerge between the number of parallel trials and the quality of these trials or "between reduced experimentation and improved experimentation quality" (Linge 2008, 214). This can also be characterized as a tradeoff between higher efficiency / improved learning on the firm level and less mutual learning opportunities on the industry level.[16]

However, this only means that multiplicity and diversity in competition has always both a quantitative and a qualitative dimension, which both influence the effectiveness of competition as a process of

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15 Then also other potential anticompetitive effects of a higher firm concentration (and mergers and R&D agreements) have to be taken into account, as, e.g., less investment in R&D through less competitive pressure; larger danger of unilateral and coordinated effects on prices; extension of the anticompetitive effects of R&D agreements other stages of the value chain or other markets (multi-market problems); see Katz / Ordover 1990; Kerber / Schwalbe 2008, 305-306.

16 See more generall Linge 2008, 212-216; see also Aigner / Kerber (2006) especially for R&D partnerships; here also a direct comparison can be found between an industrial economics perspective and an evolutionary economics perspective on R&D partnerships.

parallel search and experimentation. All these arguments suggest that although such a positive Hayekian innovation effect of parallel experimentation exists (with decreasing returns of additional experiments, Weitzman 1992), there might be some kind of optimal number of parallel experiments, beyond which the growth rate of knowledge accumulation through experimentation might decrease again (due to disadvantages of small firms). This also would suggest the notion of an optimal extent of diversity. The relevance of such a notion for competition assessments of mergers and R&D agreements is evident. However, the theoretical and empirical insights of the innovation research literature also suggest: Such an optimal number of parallel experiments will depend on a large number of determinants and conditions, leading to a perhaps large range of possible optimal numbers in different industries and in regard to different technologies and specific conditions. Therefore serious doubts can be raised, whether we have enough reliable knowledge for using such a rationale for deciding on competition cases. This will be discussed again in our last section 5.[17]

After this general discussion of the advantages and disadvantages of parallel research and experimentation, we turn to our second question about the effects of mergers and R&D joint ventures on the effectiveness of competition as a process of parallel experimentation. In the foregoing discussion, we implicitly assumed that the number of parallel research paths is identical with the number of independently deciding firms, i.e. that a merger or R&D joint venture would automatically lead to a reduction of parallel experimentation. However, this does not take sufficiently into account that also individual firms might find it worthwhile to pursue (and even maintain after a merger etc.) parallel research paths, i.e. we have to consider both inter-firm diversity and intra-firm diversity.

Frenken / Hekkert / Godfroij (2004) is the only empirical case study that analyzes both the impact of inter-firm and intra-firm diversity of technologies in competition with the explicit policy objective how to find the appropriate long-term technology. Starting-point is the diagnosis that so far we do not know which of several low-emission technologies (electric vehicle, hybrid electric vehicle, fuel cell vehicle) might turn out as the best in the long-term. Their concern is that a too early decision for one of these technologies would lead to a lock in effect into the perhaps wrong technology (due to increasing returns to adoption). Therefore the maintaining of a variety of current R&D activities is necessary. They analyze the development of the variety of technologies in regard to low-emission vehicles (by using U.S. patent data and entropy statistics for measuring variety). Their main result is that in the period 1980 - 2001 the technological variety has increased both within firms and on the industry level, leading them to the conclusion that premature lock-ins are unlikely to occur. Beyond that, their study is interesting in several ways. With the problem of possible lock-ins due to path dependencies, they emphasize another important reason for maintaining diversity. This is also important for all kinds of standard-setting, where the dilemma between competing standards and the premature decision for one (perhaps in the long run) inefficient standard is wellknown. For us more important is the insistence of the

[17] However, it should be noted that we have largely the same knowledge problems about the specific design of intellectual property rights (optimal length and breadth etc.).

authors that not only technological variety but due to the dominance of few firms also organizational variety and therefore competition between these firms is important.

Both from this case study as well as from the strategic management literature we know that a firm might find it profitable to pursue an exploration strategy with several parallel research paths within the firm (Thomke 2003). What can we learn from empirical studies, whether after a merger (or a R&D agreement) parallel research projects of the merging (collaborating) firms will be continued or whether they will focus only on one of them? (for a broad overview, see Linge 2008, 233-241). One of the few studies is Cassiman et al. (2005) who asked for the impact of M&A on the R&D expenditures and R&D strategies. Their results show a positive post-merger effect on R&D efforts in the case of complementary technological partners but a negative effects for partners from identical technological fields. When rival firms with similar technological knowledge merged, they were significantly more likely to discontinue R&D projects and to reduce the number of researchers than non-rival firms. Also the merger objectives "elimination of competing product standards" and "decrease of the danger of being imitated" were much more important for managers of technological related firms than in cases of complementary mergers. These results fit into a broader picture about the overwhelmingly negative effects of mergers on innovation. Hitt et al. (1990) and Hall et al. (1990) find that leverage financing of mergers leads to an increase of capital costs with less incentives and resources left for innovation and R&D efforts. In a recent study Grimpe/Hussinger (2007) find empirical evidence that for target firms with patents to block competitors higher prices are paid, if these patents are closely related with the patent portfolio of the acquiring firm. In his review article about the literature on the impact of mergers on the innovativeness of merged firms, de Man / Duysters (2005) finds not one study which could show positive effects on the innovation output. It is not clear whether these negative effects are a consequence of a market power effect of the merging firms, which allows to reduce the incentives to innovate (due to less competitive pressure), or whether part of these negative effects stem from the often difficult problems of integrating the emerging firms. The latter are a larger problem, if the technologies are complementary than closely related (Gerpott 1995). From that perspective, it might not be surprising that mergers are often the result of an exploitation strategy, which implies that the merging firms are technologically closely related, with the consequence of a reduction of innovation incentives and innovation output. Firms which want to pursue an exploratory strategy choose much more R&D joint ventures instead of mergers.

The innovation effects of R&D joint ventures are much more positive. Partly this is not surprising, because mergers can be carried out because of a number of different reasons, whereas R&D agreements alwas focus on the innovation activities. However, an important determinant is also that many R&D joint ventures are carried out because an exploratory strategy is poursued by the participating firms. This brings together firms with different knowledge bases and complementary technologies, which increases the probability that parallel experimentation will be sustained. However, if R&D partnerships aim at reducing research costs, then a decline of R&D investments is likely, while skill-sharing partnerships lead to an increase of R&D investments (Sakakibara 1997). de Man / Duysters

(2005) finds in his review of the literature that the majority of studies finds evidence for a positive correlation between cooperation and innovation. There are a number of studies who emphasize that the partners in a R&D joint venture may benefit from pooling their R&D resources and learning from each other (Ahuja / Katila 2001). This can lead increase the capabilities of the firms to innovate, but also increase the absorptive capacity to integrate external knowledge into the firm (which also might alleviate imitation).

All in all, the empirical studies tend to confirm the hypothesis that R&D joint ventures are more likely to sustain parallel experimentation than mergers. This is partly also a consequence of the often more exploratory character of R&D partnerships in comparison to mergers, which tend to be much more exploitative. The degree of uncertainty and the exploitative or explorative strategy of the firms seem to be the most important determinants for the question whether parallel research projects will be pursued or not. Most important, however, is that so far no empirical studies exist about the effects of mergers on the diversity of their technology portfolio and the question whether parallel research projects are further pursued or stopped, which would lead to a reduction of parallel experimentation on the industry level. Here much more empirical studies are necessary. Another entirely unsolved problem is whether possible increases of innovation capabilities through mergers and R&D joint ventures can compensate for the negative effects on knowledge-generation through less parallel experimentation and mutual learning on the market (Linge 2008, 239). This leads back to our above-mentioned problem of determining the optimal number of parallel experimenting firms. From that perspective the economics of parallel research and experimentation is still in its infancy with many questions still unresolved.

4. Competition Policy Implications: Should Diversity and Parallel Experimentation Be Protected?

4.1 Innovation and Diversity in Competition Policy

The "more economic approach" in European competition policy has led to an increasing tendency for focussing primarily on short-term economic effects of mergers and other business practices on prices and quantities (as indicators for consumer welfare). Long-term effects and, in particular, effects on innovation do play a role only in a small number of cases, primarily in high technology markets. In many merger cases, it is not even discussed whether such mergers might have negative effects on the long-term development of new products or technologies. Also the entire EU Horizontal Merger Guidelines devote only one paragraph to the problem that mergers might restrict innovation competition. From the perspective of Schumpeterian or Hayekian competition, which view innovation and imitation as part of the competition process, as well as from the perspective of innovation economics, this neglect of the assessment of innovation effects in competition law practice is a severe problem. Therefore one important claim is that the assessment of innovation effects should be much more important in the application of competition and antitrust law, and that the results of theoretical and empirical

studies in innovation economics should be used much more than they have been done previously (Katz / Shelanski 2007).

In this regard, it should be emphasized that the current notion in the U.S. discussion that Schumpeterian competition would lead to a more permissive competition policy with less enforcement does not necessarily follow from the perspective of an evolutionary concept of competition as a knowledge-generating process of parallel experimentation with innovations (as it is presented here).[18] It rather shifts the focus from merely short-term static (price) effects to more long-term dynamic innovation effects, which undisputedly are much more important for long-term wealth. Therefore it can be expected that a more innovation-focused competition law practice, which takes into account Schumpeterian and Hayekian notions of evolutionary competition, would both lead to groups of cases, where less enforcement of competition law is recommended, whereas in other groups of cases a more restrictive application of competition law might seem preferable. Therefore, I agree entirely with Katz / Shelanski's statement (2007, 47): "The principal competitive effects of a merger under Schumpeterian competition would be the effects that it has on the pace and direction of innovation." This also would entail to give up the still dominating notion of a conflict between competition and innovation. If the innovation dimension is viewed as part of competition (as in the notion of "effective competition"), then there might be tradeoffs between static and dynamic efficiency (as this was always claimed by Schumpeterian economists) but there would be no systematic conflict betwen competition and innovation. Such a perspective would also entail the claim that all relevant theoretical and empirical insights should be used for analyzing the innovation effects of mergers and other business practices. Besides industrial economics, this also would include research results from the broad field of theoretical and empirical innovation research (including evolutionary innovation economics), and the strategic management literature (including the resource-based theories of the firm).

In the remainder of this article we want to ask the more narrow question, whether and how this additional Hayekian dimension of competition as a process of parallel search, experimentation and mutual learning should be taken into account in the application of competition law. In section 3, we have seen that there might be a negative effect of the reduction of the number (and/or the diversity) of independently experimenting firms on the effectiveness of competition as a knowledge-generating process, because less parallel experimenting might lead to fewer experiences and therefore to a slower process of learning about better problem solutions. However, it was also demonstrated that both the existence and the extent of such a negative innovation effect might depend on a number of conditions as well as be subjected to a trade off analysis due to other advantages of less parallel experimentation. It also was clear that our knowledge about both the advantages and costs of parallel experimentation is still very limited and much further research is needed.

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[18] It should also be noted that the German tradition of dynamic Schumpeterian competition did not develop a negative attitude to competition policy; however, they tried to take into account the dynamic effects of competition.

It must be emphasized that this discussion on the problems and merits of the number of competing firms (or firm concentration) is at an entirely different theoretical level than in the current industrial economics discussion. In the latter, mergers and the increase of firm concentration is nearly exclusively analyzed in regard to its non-coordinated (unilateral) or coordinated effects on prices; and we argue that mergers should be prohibited, if their effects would lead to an increase on price (and therefore decrease consuemr welfare). Here the problem of less decentralisation are the negative effects of the loss of independent sources of innovation and of fewer experiences through less experiments on the evolution of the pool of knowledge in the entire industry, from which all can learn. Such negative effects on dynamic efficiency would also be detrimental for consumer welfare, and therefore might also constitute a "significant impediment to effective competition" (in merger cases). The question, therefore, is whether competition law should try to protect a kind of minimum degree of multiplicity and diversity, in order to maintain the knowledge-generating Hayekian function of competition as a process of experimentation and mutual learning. My contention is that we should try to do this, and the main questions are more, whether we are able to do this and how we can do this. In the following, we will discuss briefly a first attempt for developing and implementing such a policy, the Innovation Market Analysis in US antitrust policy.

4.2 Maintaining Diversity in the Innovation Market Analysis

The Innovation Market Analysis (IMA) was developed in the 1990s for the analysis of innovation effects, both to mergers and to joint ventures. The basic idea was to take into account also their effects on innovation competition through the analysis of their impact on the incentives to invest in R&D activities (Gilbert / Sunshine 1995; Gilbert / Tom 2001). The analysis requires four steps: (1) For the definition of socalled innovation markets, it is assessed whether the firms' R&D activities overlap, and to what extent there are alternative sources of innovation (requiring a test for the need of specialised assets as laboratory equipment or intellectual property rights). (2) and (3) In the next steps, it is asked whether the merged firms are able and have incentives for reducing their R&D activities through unilateral or coordinated behavior, or whether the threat of other innovating competitors does not makes this a possible or profitable strategy. (4) The last step assesses whether an expected reduction of R&D investments through the merger would be defended through innovation-related efficiencies. This step-wise procedure is designed very close to the usual merger review on product markets, although here the analysis is focussed on the activity "innovation" and not on a real market. Although the IMA was used in Guidelines and applied in a number of cases, it was heavily criticized for a number of reasons, e.g., its lack of theoretical foundation and practical implementation problems. The IMA was not used in EU competition law, where the same competition problems were tried to solve through the analysis of potential competition for the product markets.[19]

[19] For the general critical discussion of the IMA, see Widnell (1996), Orth (2000), and Davis (2003).

The interesting aspect of the IMA for our topic is that in the "Antitrust Guidelines for the Licensing of Intellectual Property" a safe harbour rule was introduced that a licensing agreement will normally not be challenged, if at least four independent, substitutable technologies exist (DoJ / FTC 1995, Sec. 4.3). Although the Guidelines insist that also a smaller number of independent technologies need not lead to the illegality of such an agreement, this provision can be interpreted as an explicit attempt to establish a kind of minimum number of parallel existing research paths for antitrust law purposes. In a similar way, there have been a number of merger cases, in which the US antitrust authorities had great concerns about the danger of reducing research diversity and therefore impeding dynamic efficiency. *General Motor's Allison Division / ZF Friedrichshafen* (1993), *Montedison / Shell* (1995), *Lockheed Martin / Northtrop Grumman* (1998), *Halliburton / Dresser* (1999), *Amgen / Immunex* (2002), and a number of other mergers in the pharmaceutical industry were such cases, which often have led to divestiture remedies in settlements. Whereas the US antitrust authorities were regularly interested in the question of the effects of merger on research diversity and investigated this issue in a number of cases, the EU Commission did largely ignore this question in comparable mergers. As far as R&D issues are concerned, the EU Commission was more willing to accept arguments about increasing efficiencies in R&D (economies of scale, less cost-duplication etc.), which led to a more merger-friendly attitude.

From the perspective of our argumentation about the potential positive effects of research diversity on the Hayekian dimension of competition as a process of experimentation, the policy implications of the IMA of establishing criteria of a minimum number of competing research paths, which should only be violated, if there are considerable efficiencies through mergers and agreements, seems to be very interesting. However, the main problem is that the theoretical foundations of IMA, which is primarily the famous (but also very old) model of Arrow (1962) is not very suitable for deriving such conclusions. Arrow presents a simple model about the incentives to invest in R&D, which shows that incumbent firms have less incentives than new firms, because the latter need not take into account that a new innovation will reduce the profits of their old products. Due to its many specific assumptions, this model of Arrow does neither reflect properly the "state of the art" about the analysis of innovation incentives nor does it take into account the knowledge and uncertainty problems (discussed in section 2) or any of the advantages of diversity (presented in section 3). Although the IMA propagates policy solutions which protect the maintaining of diverse research paths, it lacks the proper theoretical reasonings for doing so. Therefore it is not surprising that it was criticized heavily in regard to its lacking a sound theoretical underpinning. However, from the perspective of an evolutionary concept of competition as a process of experimentation, such a theoretical foundation might be developed.[20] Therefore, a theoretically and empirically better founded analysis of the advantages and costs of parallel research (as it was indicated in the last section 3.4) might be better able to provide an appropriate basis for policies that protect a minimum of parallel research and experimentation against anticompetitive re-

[20] Particularly valuable, however, is the attempt of the IMA to identify competitors by asking for resources and specialised assets, because this resource-based approach is compatible with the view of evolutionary innovation economics (see also Katz / Shelanski 2007, 43).

strictions and mergers. This also would allow a more concrete discussion of the specific assessment of the restriction of parallel research in particular merger cases as well as the question, under what conditions which minimum number of parallel research paths should be protected.

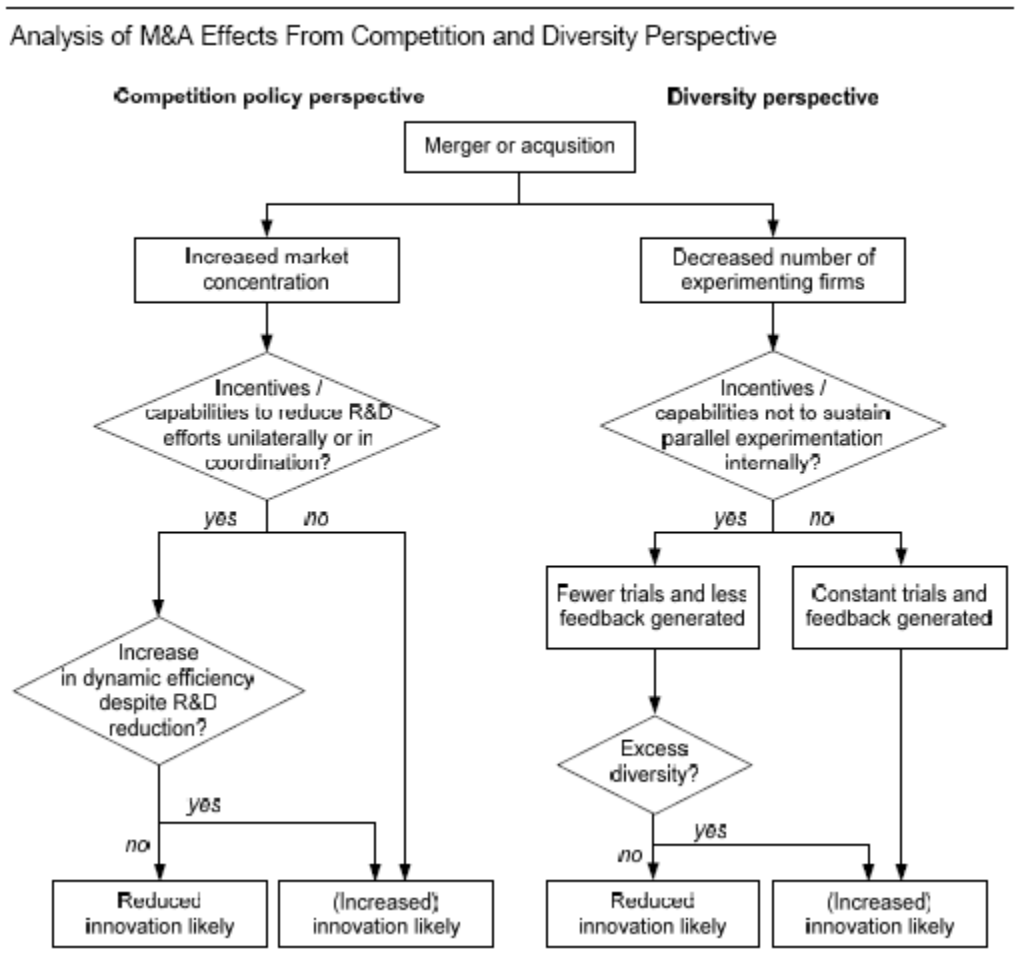
4.3 How Diversity Might Be Taken More into Account in the Application of Competition Laws: Some Suggestions

In her dissertation "Competition Policy, Innovation, and Diversity" Gisela Linge (2008, 263-286) presents a brief outline how a diversity approach in competition policy might look like, which is based upon such a notion of competition as an evolutionary process of parallel experimentation using the insights of industrial economics, evolutionary and innovation economics as well as strategic management literature and the resource-based theories of the firm. Linge does not claim to provide a fully-elaborated and direct applicable procedure and list of relevant assessment criteria how to take into account diversity in competition cases. In the following, a rough summary is given about her basic ideas how an innovation-enhancing competition policy can be supported from an diversity perspective. Her theoretical background corresponds to a large extent to the theories and research results that have been presented in the sections 2 and 3.

After emphasizing the general need for taken innovation effects more into account in competition law practive, Linge turns to the specific diversity perspective of competition as an open-ended trial and error process which benefits from diverse, parallel experimentation. The first important point is her distinction between quantitative diversity (number of firms and their activities) and qualitative diversity (differences among firms and in regard to their activities). From a Hayekian perspective, she is right to emphasize that the knowledge-generating process of parallel experimentation with new problem solutions in competition is not confined to the activity "R&D", but is also important for other activities of the firms as marketing, organization, financing, or production. Therefore a diversity-oriented perspective is broader than what our discussion on parallel research in section 3.4 might have suggested. For competition law practice she views diversity as an additional criterion which should be assessed in addition to other assessments of the competitive effects of a merger or an agreement etc. The following figure 1 gives a broad overview about her ideas, how the traditonal competition policy approach (which largely corresponds to the IMA; on the left side of figure 1) can be supplemented by an additional test on diversity. After asking whether a merger etc. leads to a decreased number of experimenting firms, a first assessment is necessary, whether it might be not possible or not profitable to sustain parallel experimentation internally. If we can expect that parallel exerperimentation will be maintained than it is likely that no problem emerges from a diversity perspective. If, however, we must assume that after a merger parallel experimentation will be reduced, then the fewer trials will lead to less feedback from the market. If, however, we can show that in the initial situation, we already have too many parallel experiments (e.g., in comparison to some reference standard of an optimal number of experiments, implying excess diversity), then such a reduction might not harm consumer welfare. Otherwise, our

diversity test would lead to the conclusion that the reduction of parallel experimentation through this merger or R&D agreement etc. has negative effects on the effectiveness of competition as a process of parallel search and experimentation, is therefore detrimental to consumer welfare and might be prohibited.

Figure 1:



(Source: Linge 2008, 266)

Both in addition to this test but also in order to carry it out, Linge offers an additional list of criteria for assessing mergers or a joint venture in regard to their impact on dynamic innovation processes (figure 2). They should be applied, if after a first assessment of a merger (or joint venture) it seems at least likely that the innovation output might be harmed. On this second stage, the following questions should be addressed (Linge 2008, 274-281): (1) What is the current status of R&D competition? (2) Are the merging or cooperating firms able to innovate and do they possess incentives to do so? (3) Are the merging or cooperating firms able to reduce R&D investments on their own or in coordination with the remaining firms and do they possess incentives to do so? (4) Which efficiency implications are likely to arise from the merger or the cooperation? In regard to R&D agreements Linge also ponders about appropriate criteria for a Block Exemption for R&D agreements, without presenting a defi-

nite proposal. Possible criteria could be: the thresholds of 20% percent are not exceeded; at least three independently researching firms or R&D coalitions remain in the market; appropriability conditions for innovation benefits are insufficient to provide R&D investment incentives, i.e. through high spillover effects; entry barriers into competition for innovation are low; intra-cooperation arrangements do not harm competition for innovation and in product markets (Linge 2008, 283).

Figure 2: Assessment Criteria for Innovation Effects (Linge 2008, 267)

Market conditions:
- High technology market characteristics
- Specialized assets and entry barriers to product / R&D competition
- Appropriability level and character of spillovers
- degree of technological market uncertainty reflected in industry / technological life cycle
- Interdependencies with product market competition

Form or cooperation characteristics:
- Complementary / substituting knowledge resources / specialized assets needed
- Exploration / exploitation strategy
- Time pressure vs. cost pressure

Research properties:
- Cumulative / independent research trajectories
- Incremental / radical innovations
- Economies of scale / scope in experimentation and R&D cost structure
- Marginal costs / benefits of parallel experimentation

It is not possible here to discuss these suggestions how to take into account the diversity criterion in competition law practice. However, these considerations show that from evolutionary innovation economics, strategic management literature, and the resource-based theories of the firm a wide range of criteria can be used, which in addition to the already well-established criteria on the basis of industrial economics rationales might help to assess better the effects of mergers, R&D agreements and other business practices on innovation and, in particular, the effectiveness of competition as a process of parallel experimentation. It must be admitted that we do not know yet, how such a diversity test should be made best and whether we already have sufficient knowledge for designing such a test. However, the opinion that we should ignore long-term innovation effects in competition law practice because of our ignorance about the dynamics of competition and the determinants of innovation and technological progress cannot be held up due to the plethora of theoretical and empirical insights about innovation processes. The appropriate answer rather is that we need much more research both in regard to innovation processes in competition itself but also how appropriate tests for competition law practice can be designed. The suggestions of Linge are one valuable contribution to this necessary discussion.

5. Conclusions

In this paper we have dealt with a dimension of competition, which so far has not drawn much attention in competition economics, namely the task of competition as a process of parallel experimentation and mutual learning, through which new and better problem solutions are generated and spread (competition as Schumpeterian innovation-imitation process or as Hayekian discovery procedure). Competition as a trial and error-process can be analyzed as an evolutionary process of variation and selection of new problem solutions, which allows to apply arguments and models of evolutionary innovations economics to the analysis of competition processes. From this perspective, it could be demonstrated that the number and diversity of independently experimenting competitors can have a positive effect on the knowledge-generating function of competition through the larger possibilities of mutual learning through experiences. The resulting basic idea of advantages could be further supported by the analysis of general advantages of diversity. A more diverse pool of problem solutions (as technologies) can increase the probability of being capable of responding quickly to exogenous shocks and can also increase the capability to develop superior innovations. This led to the hypothesis that mergers and R&D agreements might have also a negative effect on the effectiveness of competition as process of parallel experimentation. In the next step, this basic analysis of the benefits of parallel experimentation was applied to the more specific problem of parallel research. It could be shown that there are a number of conflicting positive and negative effects of a larger or smaller number of parallel experimenting firms, implying trade off problems and the notion of an optimal number of parallel experimenting firms or parallel research projects. In the last section the question was discussed whether and how competition law should and can protect competition as a process of parallel experimentation. It was shown that the Innovation Market Analysis developed interesting criteria for maintaining parallel research projects and protecting diversity but without an appropriate theoretical reasoning about the benefits of protecting parallel research. This was followed by sketching some ideas about how competition law might be able to take both innovation effects and especially diversity and parallel experimentation better into account in competition cases.

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