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Society, Technology and Region

Contributions from the social study of technology to economic geography

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Abstract

Recent debates in economic geography have emphasized the need for a more explicit analysis of innovation processes at a sectoral or technological level. A great deal of attention has furthermore been devoted to connect the internal disciplinary debate with the wider discourse of the social sciences that deal with economic development in general and the role of innovation in particular. The present paper argues that the field of the Social Study of Technology (SST) can inspire research in economic geography in important respects: SST research has an explicit focus on the genesis of socio-technical configurations, it has developed sector and technology related multilevel theories of socio-technical change, it has a strong emphasis on innovation dynamics and sector transformations, and finally, it has a focus on strategic planning in multi-actor settings and thus favors foresight and participatory planning approaches in science, technology and innovation policy. SST inspired research could thus be an interesting partner for those approaches within economic geography that share some ontological starting positions with regard to actors, the role of institutions and a co-evolutionary and multilevel analysis of socio-technical transformation processes.

1 Society, technology and region in economic geography

Recent debates in economic geography have emphasized the need to more explicitly link up with the wider field of discourses in the social sciences in general and economics in particular (Boschma and Frenken, forthcoming; Peck, 2005; Bathelt and Glückler, 2003; Schamp, 2002; Sjöberg and Sjöholm, 2002; Storper, 1997). A starting point of a substantial part of recent theorizing in economic geography has built on a fundamental critique of neo-classical economics. This surge war reinforced after the recent re-discovery of geographical themes by economists (Krugman, 1991; see also Scott, 2004). Other exchanges and intellectual trading zones have been established with institutional economics (Scott, 1988), the wider field of institutional analysis (Martin, 2001), economic sociology (Peck, 2005) and evolutionary economics (Boschma and Frenken, forthcoming; Boschma and Lambooy, 1999; Cooke et al, 1998; Storper, 1997). In critical

assessments of current economic geography research, a number of theoretical, empirical and methodological laboring fields have been identified, which still need further exchange and collaboration with other social science disciplines (Scott, 2004; Cumbers et al, 2003; Markusen, 1999). The present paper aims at reconstructing recent development in the academic field of the Social Study of Technology (SST).This research offers a number of substantial insights, some new theoretical concepts and specific methods that might be instrumental for tackling the identified laboring fields.

It is fair to say, that economic geography has had a long history of contention with neo-classical economics (Scott, 2004). The discipline stood divided in one of two interpretations regarding its relationship with this big and powerful neighboring discipline. One part of the scholars accept a role as being mainly a field of spatialized economics (as exemplified in the work of Krugmann 1991), whereas others see its role as having an independent methodological core that fundamentally challenges core assumptions of neo-classical economics (see for instance Peck 2005). We will not recount here the long and ardent arguments that have been exchanged over this issue. For the present purpose it is however important to see that SST related research is part of a social science research community that has evolved in rather critical distance to the dominant school in economics and will therefore more be in line with institutional or evolutionary strands of economic geography (Boschma and Frenken, forthcoming) than with its neo-classical variants.

A commonly shared starting point on which all strands of modern economic geography and SST research agree is related to the importance of innovations in modern societies. The traditional economic analysis of factors of production, being focused on capital, land and labor, does not represent the key factors for international competition any more. Rather, a fourth factor has to be considered, namely the ability to generate, apply and contextualize new knowledge in the form of new technologies, products and organizations (Chang and Chen, 2004; Storper, 1997; Lundvall, 1992). The ability to contribute to and participate in these change processes becomes a crucial factor for economic success in an increasingly globalized economy. Therefore, structures and processes of knowledge production, learning and communication have gained increasing attention.

The disagreements are rather with regard to the key processes and resources which are necessary for knowledge production, the actor structures which are preserving and developing the knowledge

stocks and also the policy implications that result from this analysis. Institutional and evolutionary inspired approaches strongly argue for non-atomistic actor concepts. They criticize the rationalistic model of "economic man", which assumes that actors are in control of all relevant information about the alternatives he or she has to evaluate in order to optimize either profits or utilities (rational actor paradigm). The counterargument states that knowledge processing capacity of real world actors is limited and that not all relevant resources for economic success may be either attributed to characteristics of individual decision makers (preferences) or the material artefacts of the options in their choice set (technologies, products, etc.). Rather a number of essential resources (institutions, cultures, trust, etc.) are constructed through the interaction of different actors and no single actor may produce and control these resources by his or her own (critique of methodological individualism). As a consequence, no single objective optimal development path may be identified. Rather there are several alternatives, which determine the landscape on which actual development paths unfold (multiple or punctuated equilibria). Path dependencies leading to lock in of specific development trajectories play an important role and may hinder the achievement of globally pareto-optimal solutions. Dynamic processes are likely to exhibit strong historic and local specificities and therefore local starting conditions may matter decisively for the fate of a development path (path dependencies and lock-in). Finally, mechanistic forecasting and evaluation of different development alternatives as well as linear steering attempts by policy makers are in general doomed to failure. The co-evolutionary quality of socio-technical transformation processes demands a more procedural and open-ended management approach. Policies therefore have to create and support conditions for envisioning, learning and coordination.

A large number of scholars within economic geography share these criticisms. From this shared starting points however, a broad variety of schools and approaches have developed over the past few years and successes of developing an integrated research agenda have been few (Scott, 2004 and 2000). There have been quite heated internal debates about the theoretical basis, methodological preferences and the kind of empirical foci that should be part of the core agenda of economic geography. From these discussions, a number of open fields of inquiry may be derived, which would allow to integrate several of the sub-orientations within economic geography. First, there are recurrent claims that the core object of transformation namely innovation and technology are not adequately addressed (Bathelt and Glückler, 2003; Storper 1997). Furthermore, there seems

to be often too much emphasis to the spatial characteristics of innovation processes. As a consequence, processes related to the emergence and transformation of technologies, products (Storper, 1997) or entire sectors (Breschi and Malerba, 1997) tend to often not receive enough attention (Cumbers et al, 2003). Second, and partly as a consequence of this lack of attention, there is a need for more explicitly elaborating multilevel analyses of socio-technical transformations and combining them with multilevel spatial developments (Simmie, 2003; Bunnel and Coe, 2001). Third, and at a more theoretical level there is a need for broadening the trading zones with other social science disciplines (Peck, 2005). And finally, one might add the recent call of Scott (2004) that economic geography should reclaim its tradition as a discipline favoring critical analysis and progressive social change.

In the present paper, we contend that a potentially inspiring search area that offers inroads for dealing with these problems may be found in Social Studies of Technology (SST) within the wider field of Science and Technology studies (STS). SST shares the above basic assumptions with institutional and evolutionary economic geography but has a different perspective on innovation processes and the interaction between technology and society. By taking into account this kind of research, economic geography might reap the following benefits: SST research has an explicit focus on the genesis of socio-technical configurations, it has developed sector and technology related multilevel theories of socio-technical change, it has a strong emphasis on innovation dynamics and sector transformations, and finally, it has a focus on strategic planning in multi-actor settings and thus favors foresight and participatory planning approaches in science, technology and innovation policy.

We will develop this argument as follows: First, a short reconstruction of major lines of debate within institutional and evolutionary approaches to economic geography will be endeavored that will highlight core concepts of actors, technology, institutions, multilevel structures, dynamics and policy approaches. In chapter three, the recent developments in the field of SST will be presented elaborating the same core concepts. Chapter four spells out the commonalities and complementarities between SST research and economic geography. The final chapter will elaborate in more detail a number of promising research areas that might be profitable for future economic geography research, namely early gestation processes of radical technologies, combined socio-technical and spatial multilevel concepts for analyzing development trajectories, procedural policy

approaches in the realm of innovation and regional policy and finally, a shared reformatory agenda in the context of long term transformation processes as in the context of the sustainable development debate.

2 Economic geography from an institutional and evolutionary point of view

In the following we want to identify a number of key lines of inquiry in economic geography of the recent past that have been developed as more or less open critiques of neo-classical economics. Our intention is not to give a new synthesis of this debate. This has been done more proficiently many times before (e.g. Scott, 2004 and 2000). Rather, we will highlight these elements in order to identify promising exchange points between economic geography and the Social Study of Technology. The main thrust of the chapter follows the tracks of the "assumption debate", i.e. we will analyze the actor concepts, the role of institutions, the availability of multilevel concepts as structural elements of these debates. Furthermore, we will present the major dynamic processes, the concepts of development phases and finally the policy implications that are favored in these accounts.

Actors, technology, institutions and multilevel concepts

One of the most basic criticisms relates to the *actor concept*, which forms the very heart of formal neo-classical theorizing. Perfectly rational actors have to be fully aware of their options, their preferences and the long term implications of their actions. Technology is mostly treated in these accounts as an externally given parameter. Technological alternatives are more or less readily available and will be chosen according to their relative advantages over their alternatives as soon as market conditions allow for it. Especially the assumptions on the information processing capacities of real-world actors have come under attack since long (see e.g. Dosi, 1982). Already Simon (1956) challenged the economic optimizer model and substituted it with a behaviorally more realistic satisfier principle. In economic geography, the concepts had been taken up already in the 1970s (Hägerstrand, 1970; see also Scott, 2000).

In modern economies the decision problem of economic actors is increasingly complicated by not only having limited information about the decision alternatives (a mere problem of ignorance) but also being confronted with fundamental uncertainties (Ravetz and Funtowitz, 1999). Real world

actors compensate for these uncertainties by basing their decisions on rules, habits and routines (i.e. on generalized precedents) that had proven to be effective in the past. This was one of the major starting points of the work in evolutionary economics (Dosi, 1988; Nelson and Winter, 1982) which found immediate resonance in economic geography (Scott, 2000; Storper, 1997). Development, evaluation and transformation of these rules depend on an active management of knowledge stocks in firms and regions through processes of learning and interacting. As a consequence, different forms of knowledge, as well as conditions of their production, storage and proliferation gained increasingly attention in the literature. A major distinction was the differentiation between codified forms of knowledge and tacit knowledge (Gertler, 2003; Malmberg and Maskell, 2002; Nonaka and Takeuchi, 1995; Lundvall, 1992; Nelson and Winter, 1982). Codified knowledge is in general well covered in conventional innovation economics research (e.g. with regard to the role of patent laws for innovation). Tacit knowledge, however, depends on experience and trust building, which in turn may depend on cultural proximity and co-presence in space and time of actors (Morgan, 2004). As a consequence, there has been an increased interest in the production and diffusion conditions of tacit knowledge both in economic geography and the knowledge management literature (Gertler, 2003).

In situations where tacit knowledge is important, *institutions* (in their broadest sense as recurrent patterns of rules, behavior, habits, conventions and routines, see Morgan, 1997) are more than mere aggregate results of conscious decisions of individual actors. Institutions are able to stabilize, transmit and contain tacit knowledge in communities of actors (be it sectors or regions). Institutions may therefore be interpreted as relational assets that are essentially "untraded interdependencies" between the actors (Storper, 1997). They render the behavior of other actors more predictable and may increase flexibility of the same actors. Flexibility may therefore be seen as a socially co-produced (or socially constructed) characteristic of networks of producers. Maskell (2001) for instance expects a high probability of occurrence of producer networks in situations in which a diversity of strategies is necessary for coping with uncertain market situations. Producers can gain stability in following their own strategy but by also observing attentively their competitors. These key functions that have been attributed to institutions explain in some sense the emergence of an "institutional turn" in economic geography research in the 1980ies (Martin, 2000). A major tenet of

this kind of research is the explanation of differences in regional economic performance by the specific institutional set-up of the regions (Schamp, 2002).

Much research has been devoted to identify *actor constellations,* which are able co-produce and sustain institutions to maintain a high level of innovation activity: national systems of innovation (Lundvall, 1992), regional systems of innovation (Chang and Chen, 2004; Cooke et al 1998), industrial districts (Scott, 1988), clusters (Porter, 1990), innovative milieux (Crevoisier, 2004; Camagni, 1991), technopoles (Castells and Hall, 1994) or learning regions (Morgan, 1997) have been introduced in order to better conceptualized institutional structures and processes at a regional level (for an overview see Moulaert and Sekia, 2003).

A major problem of many institutional studies has been their focus on specific spatial levels. Only few attempts have been made to elaborate *multilevel concepts* (Bunnel and Coe, 2001). An exception is again Stroper (1997) who claims that nexuses of actor networks, institutions, products and technologies may co-evolve in a way to create more or less coherent "worlds of production". These worlds of production may be embedded in a more general socio-economico-political environment, which has its own coherence characteristics (see Peck 2005). An example of the latter is the Fordism period as debated in the regulation school, which gained a strong position in the literature of economic geography in the 1980s (Scott, 2000). There may be historical phases in which a certain regional nexus of institutions is well aligned within the overall structure of the global economy, whereas others may be in constant disarray with the wider environment. At a regional level, we may have coherent socio-economic milieus, which form a basis for sustained innovative activity. Institutions and conventions may therefore form nested hierarchies from the local to the international level and form multilevel socio-political regimes of regulation.

Dynamics and Policies

In a dynamic view, institutional structures may lead to highly non-linear development trajectories of regional economies. Increasing returns to scale, the existence of non-tradable resources, a mismatch of institutions and the like may create substantial barriers for development and path dependencies. In the life cycle of regional economies, different *phases* have to be distinguished. In situations of emerging new technologies, dependence on specific institutional environments may be rather unspecific. Therefore the starting conditions are relatively open. A "window of locational opportunity" may open up (Storper and Walker, 1989). Later on, when production systems have

built up their competence base, local labor markets are formed and (tacit) knowledge stocks have been built up, agglomeration economies increase and could lock-in a production system in specific places. Once a production system is anchored in place, it will in general perpetuate its own conditions for existence (Scott and Storper, 2003; Storper, 1997).

Given the need to integrate large quantities of codified and tacit knowledge and a high level of uncertainties in the market, the essential productive capacity of economic actors is the ability to learn, to be creative and to adapt flexibly to new situations. Concepts like the learning region (Morgan, 1997) have therefore been proposed to focus on these key processes of resource building for regional competitiveness. Storper (1997) proposes the key processes of "talk" and "confidence" that drive resource build-up in this kind of networks. Talk means the recreation and dissolution of network ties by getting into direct contact between the actors and relates more to the codified dimension of knowledge. Confidence rather relates to the tacit dimension. "Relational assets" are therefore a kind of capital stock which is co-produced in actor networks and transcends the conventional notion of "externalities" prominent in much of the neo-classical literature. Relational assets constitute one of the major anchoring points for innovation systems in "space". They are historically and spatially contingent and cannot easily be transported from one place of the world to another. Here lies one of the major reasons why the announced "death of geography" is still waiting for its completion (Morgan, 2004).

From these dynamic characteristics flow a number of specific implications for *regional economic policy*. By drawing from insights of evolutionary economics Lambooy and Boschma (2001) state that regional policy has to be oriented in a way to navigate between two contradictory tendencies: on the one hand side, socio-technical and regional development depends on "chance events" and on the other side, they are strongly conditioned by historically developed institutional structures and "path dependencies". A narrow planning approach would therefore be doomed to failure. Multiple equilibria, lock-in and path dependencies are the rule rather than the exception. Attention of policy makers should not only be focused on investments in "hard" infrastructure or assure the proper working of markets by setting appropriate framework conditions. These policies may be appropriate under specific conditions. Additionally, "soft infrastructure" policies may be as important in order to support an active and or receptive social structure, which could allow regional actors to take up the impulses and to position themselves on the national and international markets (Morgan, 1997)..

Therefore, a key task is to support processes of learning and networking among the relevant actors in a region in order to increase their innovative capacity.

Open issues

So far, we have tried to reconstruct some essential traits of recent economic geography research as if it was a unified body of theoretical propositions, methodological principles and convergent research styles. It is certainly fair to say that this is not the case (Peck, 2005; Scott, 2000). There have been heated debates and recurring changes of the research focus over the past twenty years. Because of their common criticism of neo-classical approaches they have often been treated as belonging to one and the same "alternative" tradition. However, it is obvious that different schools relate to different theoretical backgrounds and formulate different goals for research.

First, many scholars have claimed that a more explicit treatment of innovation processes focusing on technologies (Storper, 1997), products (Bathelt and Glückler, 2003) and sectors (Breschi and Malerba, 1997) would be necessary. In this context, institutional economic geography research is often accused of spatial fetishism, i.e. an over-emphasis on small scale local networks and a recurring risk to loose sight of the more powerful non-spatialized processes for instance those in control of multi-national companies or structural conditions lying beyond the reach of a specific region (Cumbers et al, 2003; Markusen, 1999). As a consequence, the need for developing multilevel concepts of spatial transformation processes has been expressed in order to recombine local production networks with sectoral interaction structures (Bunnel and Coe, 2001). In particular, there is need for a more explicit treatment of power relations and structural conditions for underdevelopment. Institutional approaches often tend to be over-optimistic with regard to assessing the innovative capacity of actors (Cumbers et al, 2003; Scott and Storper, 2003), especially in peripheral and deprived regions. Third, in order to reach more internal coherence of the discipline, commentators have time and again demanded that intra-disciplinary discourses should be related to kindred discussions in other disciplines. By this, the theoretical basis could be solidified and exchange with other related fields could be increased. And finally, one possible way to revivify the common core and identity of economic geography could be found in its common roots as a tradition of critical analysis and progressive social change (Scott, 2004). This outer reference could help to close the ranks and overcome the high fragmentation into many small sub-

orientations within economic geography. In the following chapters, we contend that SST related research might inspire the quest for some solutions to these identified laboring fields.

3 The Social Study of Technology

The Social Study of Technology (SST) has in the past few years developed into an interdisciplinary field in the social sciences dealing with the explanation of social pre-conditions for the development of socio-technical systems as well as their impact on society. Its theoretical underpinnings draw very much from sociology but encompass additionally an important number of concepts from history, philosophy, economics and the engineering sciences. SST may be seen as constituting "one half" of the wider field of Science and Technology Studies (STS) (see Pinch and Bijker 1984). We will first describe the core object of analysis of this field and present different research strands that have developed over the past few years. Then we will present key concepts of this field along the same lines as those chosen for economic geography, namely actors, technology, institutions, multilevel concepts, dynamics and policy approaches.

Tenets and strands of research

At about the same time as evolutionary economics was developed on the axiomatic lines introduced above, other social scientists turned to more explicitly analyze the dynamics of technology development. A common motivation to deal with material artifacts from an explicit social science point of view was the critique of technological determinism, a view that technologies developed out of an inner logic to which society could nothing but adapt (Smith and Marx, 1994). Against this "dualist" conception of the relationship between technology and society, historians of technology, historical economists and sociologists contended that the two parts were intricately interwoven and the question whether technology determined social conditions or *vice versa* was treated as an open research question and not as an a priori setting. A wide array of theoretical and empirical studies showed that the direction and form of a specific technological development integrated and mirrored its social and cultural context. Therefore, the appropriate unit of analysis was not technology per se but rather "socio-technical systems".

As a disciplinary field, SST research may not be considered as a monolithic research tradition. Rather different schools and approaches have developed over the past thirty years with specific

emphases and methodological preferences. Following Weber (2006), we may distinguish the following four "schools" in SST research:

- MacKenzie and Wajcman (1999, first edition published 1985) published one of the first collections of papers that focused on the importance of social, economic and political interests and values, which influence the course of technology development. Their approach had been labeled according to the book title "Social Shaping of Technology".

- As a joint endeavour between the SST and the sociology of scientific knowledge, Pinch and Bijker (1984) formulated the "Social Construction of Technology (SCOT)" approach. They emphasize the decisive role of social processes in determining the actual shape of technology, the multiple construction processes happening between users, producers and regulators in order to ultimately generate the socio-technical configurations which make up a technology.

- An even stronger focus on social processes for technology development has been formulated in the context of the Actor Network Theory (ANT) (Latour, 1991, Callon, 1987). In ANT it is claimed that no clear dividing line between technologies, users, producers or institutions exists. Instead Actor Networks are constituted by human and non-human elements (actants) which mutually co-determine each other in order to lead to identifiable and temporarily stabilized configurations.

- Finally, relating to a more system oriented analysis, the approach of Large Technical Systems (LTS) (Coutard, 1999; Summerton, 1994; Hughes, 1987) focused on the systemic interaction between social and technological processes, especially in the realm of large infrastructures.

An important dimension of differentiation between these four approaches is the relative autonomy of social processes compared to the material characteristics of a technology. The LTS-school emphasizes the strength of path dependencies, which are a consequence of the material characteristics of a technology. These are mirrored by strongly stabilized social structures which may be as hard to change as the material infrastructures. The social shaping approach maintains that technological trajectories are strongly influenced by prevailing values, norms and power relations. The actual configuration of a technology has therefore to be understood as a sequence of explicit "social choices" and should not be seen as an inevitable outcome of scientific laws. The SCOT approach emphasizes the autonomy of the social over the technological even stronger. It focuses on

the "interpretative flexibility" of different actor groups when dealing with material artifacts. These actor groups project different images and meanings onto one and the same material configuration, which then shape and constrain the future development characteristics of this technology. The development of socio-technical configurations has therefore to be understood as an actual "social construction" process, i.e. an active determination and combination of social and material elements by social processes. The ANT approach goes even one step further in that it denies the sensibility of any dualistic distinction between technology and society. Instead they propose monadic concepts to analyze the mutual determination of different kinds of human and non-human elements (Latour, 1999). Despite these differences, however, there have been some decisive signs of convergence between these different approaches.

Actors, technology, institutions and multilevel concepts

SST research did not start in the first place with an explicit critique of atomistic *actor concepts*. Rather it criticized the "linear" conception of technological progress and the strict separation of technological dynamics from social processes, which was prevalent in many former technology studies. These suggested a linear logic in the production and transfer of knowledge: new ideas are discovered in scientific research and trickle slowly down through technology departments of firms and research institutes into marketable products. Technology is in this view conceptualized as an external parameter, and is therefore treated as a "black box" (Rosenberg, 1994) or as "manna from heaven". SST research proved the empirical inadequacy of this linear model in many historical case studies. The emergence and diffusion of new ideas and technologies follows often a much more recursive and messy process where a multitude of actors contribute in different roles. Users for instance were found to not only work as "adopters" of new technologies but also as important sources for innovative activity or even as "co-inventors" (Leonard-Barton 1988; von Hippel, 1988). Engineers were often at the forefront to suggest solutions to basic research. As a consequence a clear-cut distinction between invention, innovation and diffusion phases, as the classical innovation theorists claimed (Rogers, 1995) is often not possible. Technologies, preferences and products co-evolve in a process of mutual determination (Rip, 2002).

This view of technology resonated well in the emerging field of evolutionary economics (Dosi et al, 1988; Nelson and Winter, 1982) and was compatible with their actor concept. Rule based behavior under conditions of uncertainty, path dependencies and innovation management by consecutive

phases of variation and selection represent important inroads for social mechanisms. Values, norms and power relations may influence substantially the direction of technology development. "Interpretative flexibility" of different actor groups will for instance be decisive for variation and selection behaviors of innovating firms (Pinch and Bijker, 1984). More or less socially shared expectations, visions and *Leitbilder* (guiding visions) (Grin and Grunwald, 2000; van Lente and Rip, 1998; van Lente, 1993; Dierkes et al, 1992) may shape investment behavior of firms and priorities in technology policy. By this the actual trajectory of specific technologies may be influenced substantially and this all the more if path dependencies will lead to an early lock-in of specific technological designs.

But not only decision rules of firms are subject to social influences. Preferences of users and patterns of use of a new technology will in general also be conditioned by former use contexts and socio-cultural contexts. Preferences and use patterns are in general considered as being externally given in conventional economic approaches (Stagl, 2003). SST studies showed that they often co-evolve concomitantly with new technological configurations (Truffer, 2003; Kline and Pinch 1996; Leonard-Barton, 1988). The analysis of social construction processes has even to consider broader actor groups than producers and users of technology. An important field of inquiry in SST research has been the interaction between different formation processes in heterogeneous actor networks or constituencies (Molina, 1993) encompassing innovating firms, users, NGOs and government departments.

These processes of mutual co-determination lead to the emergence of stabilized *networks, institutions* and material artifacts and finally lead to the emergence socio-technical systems or "configurations that work" (Rip and Kemp, 1998). Several concepts have been proposed in the literature to identify such coherent configurations. Among the first was Dosi (1982) who developed the notion of "technological paradigms". These are sets of rules which inform and constrain the variation and selection behavior of firms and lead to the emergence of distinctive "technological trajectories". The notion of a technological paradigm was criticized by SST scholars for its strong cognitive connotation. They proposed alternative concepts like "framing" (Callon, 1998a), "technological frames" (Bijker, 1995) or "guideposts" (Sahal, 1985) as more socially enriched versions of these meso-level structures.

Actor Network Theory (Callon, 1987) goes even a step further and treats material artifacts and actors as essentially symmetric elements (actants), which are bound together by necessary relations. Neither the technologies nor the actors exist without explicit reference to each other. Institutions and rules form the context, without which no technology could ever exist. These rules however do not fully determine action but let room for interpretation by specific actor groups (Callon, 1998a, 6). He states that "overflows" (in the sense of dependencies or unintended consequences) are the rule rather than an exception in socio-technical configurations. In particular, one has to distinguished "hot" from "cold" situations. The former denotes situations where everything is contentious, the distribution of source and target agents, the nature and valuation of overflows, the list of actors that have to be taken into account in order to settle disputes, etc. An example may be seen in the early days of the BSE crisis, where the connection between responsible agents and potentially impacted people, the actual causation mechanisms and therefore liabilities and risks were highly fluctuating. These uncertainties had a substantial impact on production technologies in cattle farming, eating habits of consumers, public perception of agriculture, import regulations etc. In cold situations, framings are stable and so responsibilities may be settled and institutions may be built up that deal with liability claims in a peaceful way (Callon, 1998b). Overflows are in this view a much richer concept for analyzing the mutual dependencies than the notion of "externalities" used in neo-classical economics (Callon, 1998b). Networks, technologies and specific actor identities are as a consequence only different emanations of the same process of "cooling down". Lock in and path dependencies are furthermore an essential necessity for socio-technical configurations to work and not a mere unintended consequence or even a mere hindrance to rationally optimizing actors.

Recently, *multilevel concepts* for the analysis of socio-technical configurations have been developed in the SST literature (Geels, 2002). The core concept is the one of "socio-technical regimes". These are defined as "the coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures" (Rip and Kemp, 1998). Socio-technical regimes are embedded in broader contexts (the so-called socio-technical landscapes), which determine the macro-institutional environment, the consumption patterns and the cultural codifications in which regimes have to operate. Alongside dominant regimes, newly emerging technologies may exist, which are not in line with many or most of the regimes

institutional structures. These are, as a rule, still in a "hot" phase, i.e. most of the framing elements are not yet fixed. Actors wanting to promote these alternatives have therefore to set up protected spaces (so called technological niches) in which the different framing elements may specify and stabilize. Out of technological niches, new socio-technical configurations or nuclei of future regimes may develop (Hoogma et al, 2002). Take as an example the emerging solar power technology which is badly aligned with the dominant regime in the electricity sector that is based on central power production and high voltage transmission over long distances.

Dynamics and policy

SST research is strongly focusing on *dynamic* aspects in the structuring and development of new socio-technical configurations. A considerable part of empirical SST research has concentrated on the historical reconstruction and reinterpretation of transformation processes in technology fields and sectors. Among the first are a number of studies about typewriters (David, 1985), ship building and navigation (Law, 1987), Bicycles and lighting (Bijker, 1995), medical instruments (Pickstone, 2000) or the automobile (Hard and Knie, 2001) to only name a few. Besides producer oriented reconstructions, a number of research lines have dealt with the emergence of new use practices and the transformation of activity fields (such as household work) in interaction with emergent new (household) technology (Schwartz Cowan, 1983). At a sectoral level, research has been carried out to analyze for instance the transformation of the electricity system (Granovetter and MacGuire, 1998; Hughes, 1983) or the automobile sector (Hoogma, 2002). These studies have clearly emphasized the co-evolutionary development of technologies and social institutions. A central conclusion is that the ultimately chosen paths where not necessarily the optimal ones from a societal point of view -- or at least -- that the question of optimality is far from obvious (Granovetter and MacGuire, 1998).

At the level of regime dynamics, *early phases* have been in the focus. In particular, conditions for breaking out from conventional technological trajectories and conditions to develop radically new designs are of interest here. In this vein, the role of outsiders has been considered explicitly (van den Poel, 2002). The main argument being, that incumbent industry was constraint in its variation behavior and had a tendency to engage in incremental innovation and therefore to reproduce successful designs of the past. Outsiders from other industries (Tushman and Anderson, 1986), outsider networks (van de Poel, 2000; Truffer and Dürrenberger, 1997) or even networks of users

(Truffer, 2003) had a higher propensity and chance for success to overcome taken for granted worldviews. Conservative attitudes for maintaining existing regimes are not only relevant for producers of technology. Users, as well, tend to favor established technologies because of their current practices and preferences. When confronted with new products, users have to actively integrate them into their daily routines, to establish corresponding preferences and cost-quality equivalencies. Lie and Sörensen (1996) have epitomized this process as one of "domestication" of a new technology. In the SST traditions, user practices and demand articulation (Rip and Schot, 2002) is considered much broader than mere user-producer relationships prevalent in conventional innovation studies. They encompass active participation of users in the innovation processes (Russel and Williams, 2002).

In early phases of innovation processes the role of expectation formation is of key importance (van Lente and Rip, 1998; van Lente, 1993). Expectations and visions form coordination devices for the innovation strategies of different actors (even users and policy makers). In order to cool down, expectations have to be aligned in a coherent way. Here early head start advantages may be created that may make a specific socio-technical design win over its competitors irrespective of actual performance advantages. This may be a precondition for a specific socio-technical system to mature (cool down) and to reap external economies and penetrate markets.

The emergence of a new regime will gradually lead to the replacement of a former dominant one. This transformation may be characterized as a multilevel process where changes in the socio-technical landscape weaken the dominance of an established regime. The dominant regime is in general constraint in its reactions to these outside pressures by its internal coherence characteristics. At the same time these changes may open-up windows of opportunity for new socio-technical configurations that have matured in specific niches. Under certain circumstances, these niches can then replace the old regime and establish a new one with its own specific coherence characteristics. As an example one could see a potential future regime change happening in the context of individual mobility. The vehicle concept of the "automobile" including in particular the internal combustion engine, specific manufacturing technologies associated with an increasingly globalized automobile industry, but also specific use patterns and preferences, supporting infrastructures, and regulatory systems have given rise to a highly coherent socio-technical regime that is more and more conditioning the dominant form for individual mobility at a global scale. Future changes at

the landscape level such as a shortage of fossil fuels, exhaust limitations due to climate change or air pollution, space regulations in metropolitan areas etc. are likely to put this dominant regime under increasing pressure. Alternatives, such as integrated mobility forms, hydrogen based fuel cell drive trains, light weight vehicle concepts etc. are today mainly existing within specific technological niches or small market niches. A break-through in fuel cell technology, an emergent provision structure for hydrogen and/or an increased openness of users for non proprietary use forms of individual mobility could give rise to a substantially different socio-technical regimes in the future. Historical examples that have been analyzed along these lines are the advent of the steam ship regime, which ultimately supplanted the sailing ship regime (Geels, 2002) in marine freight transport, or the regime transition in personal mobility from horse-drawn carriages to automobiles (Geels, 2005). Regimes shifts that may be observed today are the transformations in voice communication from a fixed line telephony to a mobile phone based regime leading ultimately to a fundamentally transformed technological structure in the sector as well as a new understanding of personal communication and co-presence in space and time (on the latter see Callon and Law, 2004).

These dynamic concepts have also given rise to new approaches in the realm of technology and innovation policy (Rip and Schot, 2002). As no single actor, in general, is able to control the co-evolutionary dynamic of technology development, coordination with other actors, real world experiments, reflexive market introduction strategies etc. are essential to find out which kinds of configurations will actually work. As a consequence, co-evolutionary modes of governance have been proposed in recent years. An early precursor has been Metcalfe (1994). A later line of research was developed in the context of technology assessment and foresight studies (e.g. Grin and Grunwald, 2000). The original idea of Technology Assessment to predict societal impacts and of attributing a simple steering role for technology policy has been given up for more constructive, participative and co-evolutionary approaches. Constructive Technology Assessment (Rip et al, 1995; Schot, 1992) is a case in point, which draws extensively from the SST tradition. Central to this approach is the organization of learning processes in the context of socio-technical transformations and the embedding of a new technology in its larger socio-economic environment. Particular emphasis is given to “real-world” experiments with new technologies that aim at simulating and enabling co-evolutionary processes on a smaller scale. This approach has been

spelled out under the label of Strategic Niche Management (Hoogma et al, 2002) and deals with the conscious and reflexive development of technologies at the level of niches in order to transform socio-technical regimes and thus might improve success of radical innovation processes. Related to the need to more reflexively deal with expectations and visions of different actor groups, foresight methodologies have gained increased attention over the past few years. Related to the multilevel concept of socio-technical transformations, a number of encompassing policy approaches have been developed. Here, the Dutch Transition Management approach (Kemp and Rotmans, 2004) or the Sustainability Foresight methodology (Voss et al, 2005) may be mentioned.

4 Commonalities and Complementarities

Before the background elaborated in the former two chapters, we may now work out the commonalities and complementarities between these fields. We had described the two fields with regard to their actor concepts and their understanding of technology. Furthermore, we emphasized the fundamental importance attributed to meso-level concepts such as institutions and networks. These lead to multilevel descriptions of causation mechanisms and corresponding dynamics of socio-technical transformations. Finally we have presented their specific approaches to policy. Taken together, these dimensions demarcate a possible trading zone between economic geography and SST research.

The *actor concept* of SST (which is often more implicit than explicit) is shared with evolutionary and institutional approaches in economic geography by seeing actors essentially as boundedly rational, following routines, habits and rules. However, these habitual patterns are not given exogenously (as in some over-socialized accounts of certain institutional approaches, see Granovetter, 1985) but have to be constantly created and reconstructed by the actors in their daily practice. In this, they have considerable "interpretative flexibility", which may by itself be a source of transformation and a force that influences the trajectory of a specific socio-technical configuration. Conditions of knowledge production and knowledge transfer, particularly in their tacit form of conventions, practices and cultures, play an essential role in both approaches.

From its specific perspective SST research has developed a highly elaborate concept of *technology* which emphasizes the co-determination between technological and social, political and economic

aspects. It shows in what respects specific technological trajectories have been subject to conscious (or also hidden) choices of different actor groups and that a given historical trajectory was not the only optimal, let alone the only possible trajectory. Economic geography has as a tendency used a more generic understanding of technology and may therefore profit from considering the SST concept. As a counterpart economic geography has developed a much more elaborate concept of *space and place*. Recently, SST scholars have proposed a monadic conceptualization of space (e.g. see a late special issue of Environment and Planning D. Callon and Law, 2004). However, it is fair to say that SST research had until recently a rather generic notion of space and could thus profit from economic geography.

Meso-level concepts such as *institutions* and networks are seen socially constructed (or co-produced) resources by both traditions. They explicitly criticize the notion of externalities by emphasizing the co-production of interdependencies (Storper, 1997) or the contingent way in which the overflows in an economic transaction are socially handled (Callon 1998b). SST research concentrates on the role of expectations, shared interpretations (technological paradigms, framings, etc.) and networks of heterogeneous actors. It focuses on the micro-dynamics of social construction processes but tries increasingly to elaborate multilevel concepts for technology development. Institutional and evolutionary economics perhaps have focused more strongly on incumbent actor networks in specific regions or urban areas and conditions for maintaining their capacity to innovate. SST research has emphasized the role of outsiders and new actor configurations that would support radical innovations or even regime transitions. This difference should however be seen as being one of complementarity. It represents the respective preferential focus on different maturing phases of production systems res. of socio-technical configurations.

In economic geography there has been a recurrent claim (especially for institutional approaches) to loose sight of *multilevel* causation forces, i.e. neglecting processes that happen at different spatial levels. An example may be found in the assessment of the relative importance of globalization versus regionalization processes when discussing the development potentials of a specific regional economy. In SST research multilevel concepts have been developed with a sector or technology connotation as socio-technical landscapes, regimes and niches. We will shortly elaborate in the next chapter how a combination of these two multilevel concepts could be fruitfully combined in future research.

Dynamic concepts used in the two traditions show considerable overlap. Learning and transmission of tacit knowledge stocks are key processes for successful innovation processes. Furthermore, both traditions state that lock-in and path dependencies are a crucial empirical phenomenon both in technology dynamics as well as in regional development. With regard to the phasing and maturing of socio-technical configurations res. regional production systems strong similarities exist. The distinction between "hot" and "cold" socio-technical configurations could be fruitfully brought into the analysis of early phases of sector development, especially those where windows of locational opportunity still exist (Storper and Walker, 1989). Later phases of regime stabilization will in general go hand in hand with an anchoring in space of the corresponding production systems. By combining the two perspectives a more complete analysis of technical-cum-spatial transformation processes could be developed.

Finally there seems to be a high similarity with regard to policy implications that may be derived from these two traditions. Both seem to be aware of the basic dilemma in evolutionary policy advice of being at on the one hand confronted with strong path dependencies and on the other hand taking into account the possibility of social construction processes and strategic action (Lambooy and Boschma, 2001). SST researchers have recently elaborated encompassing governance approaches for technology policy that include more process oriented and deliberative methods. The same seems to be true also for economic geography. The two approaches could therefore join forces rather easily. This is all the more the case as their "classical" policy domains, regional res. science, technology and innovation policy, show quite considerable overlap in many real-world contexts.

5 Exemplary domains of joint research

In the present paper, we have argued that economic geography could benefit from explicitly considering research developed in the tradition of Social Study of Technology. We have retraced key concepts on which substantial parts of both fields of inquiry build and have worked out a number of complementarities and potential trading zones. In this last chapter, we want to sketch out four fields of exchange in some more detail, which might be of interest to economic geographers and SST researchers.

First a promising field of joint inquiry could be the analysis of socio-technical systems "in the making". Storper's (1997) claim for focusing more strongly on the analysis of products and sectors could therefore be reformulated as analyzing the conditions for emergence and transformation of socio-technical regimes. SST research delivers a rich background of development histories of different sectors and technologies, especially in the domain of infrastructures, chemistry, transport, bio-science and medicine. The tight interaction between technical characteristics, consumer preferences and institutions could set the stage for an analysis that retraces the institutional, spatial and technological formation processes in their dynamic of mutual determination. An important difference is however, that SST preferentially focuses on situations which are not yet fixed in all their aspects. Radical and system innovations have therefore gained more attention than the capacity to generate long sequences of incremental innovations. Economic geography as a rule has been more occupied with actor constellations that are able to maintain innovative capacities over longer time spans and therefore incremental innovations have been more important. The combination of the two perspectives could however bring about a more encompassing view on the development cycle of new socio-technical systems in their coupling with territorialized production systems.

Second the spatial and socio-technical multilevel concepts could be combined in order to reformulate a life cycle of technologies and territories. The economic geography literature has been criticized time and again for its strong focus on territorialized processes and a potential neglect of non-localized networks (Cumbers et al, 2003; Amin and Cohendet, 1999; Markusen, 1999). Bunnel and Coe (2001) therefore demand a reconsideration of global production systems as a nexus of interlinked sub-national clusters and a renewed focus on the couplings between these clusters. These inter-linkages are dominated by non territorialized relationships enacted by firms and individuals and therefore enable research of innovation across different spatial scales. Or as Storper (1997, 268) put it "The challenge to policy is thus to establish not one but two economic dynamics: the technological trajectory (the mastery of specific spaces in the economy characterized by technological spill-over and complementarities) and the trajectory of conventions, which link and re-link agents to each other in a coordinated fashion". The SST multilevel concept of socio-technical landscapes, regimes and niches could be brought in here for an operationalization of sectoral and/or technological dynamics (Geels, 2004). An additional interface could be seen in the

analysis of the couplings between national /regional systems of innovation with sectoral/technological innovation systems (Chang and Chen, 2004; Carlsson et al, 2002). We propose to view the spatial and socio-technical multilevel concepts as two independent dimensions of analysis, i.e. landscape, regime and niche characteristics may be each specified at global, national and regional scales.

As an illustration, we may use the automobile production system for delimiting the corner stones of a combined spatial-cum-technical multilevel analysis. This could for instance be carried out for analyzing potential innovation paths that are available to a specific region active in automobile production: New technological variants may be developed in socio-technical niches like those created by the Californian zero emission vehicles act (e.g. see Scott, 1995) or in outsider networks in Switzerland, Norway and Southern Germany (Truffer and Dürrenberger, 1997). These protected niches may form the basis from which new socio-technical configurations could develop. A first nucleus of a new regime structure could emerge on a regional (or national) level. The scaling-up of these experiments will have to actively take the dominant socio-technical regime of automobile based transportation into account, which is structured at a national and increasingly also at a global level. Furthermore, these regimes are embedded in socio-technical landscapes that are in strong resonance with national modes of regulation. An integrated multilevel analysis could then be used in a prospective sense in order to sketch potential development paths of new socio-technical configurations and to reflect specific regional and sectoral policies.

Third, benefits could be expected by analyzing innovation, technology and regional policy in an integrated way. Although there is already often a strong connection between technology and regional policies, a more explicit analysis of the technological and regional precondition would be necessary. An important role has recently been attributed to envisioning exercises (in the sense of foresighting and scenario planning), which may improve joint strategy development in contexts of heterogeneous actor constellations (Koschatzky, 2005; Gertler 2004; Morgan, 1997). These developments resonate quite well with Storpers (1997) proposal for a more reflexive regional policy or Lambooy and Boschmas evolutionary policy approach. Storper (1997) proposes a four step procedure to develop heterodox policy frameworks: (i) Strategic Assessment, (ii) definition of capacities that have to be assisted, (iii) implementation of heterodox meso-economic policies to be implemented, (iv) adaptation of framework conditions. He furthermore explicitly supports

experiments as an important means for policy development. Methodological approaches developed in the context of SST research such as Strategic Niche Management, Constructive Technology Assessment or more recently Transition Management could potentially improve the effectiveness of these governance arrangements.

Fourth and finally, SST might also be an ally in the quest for a more critical and socially reformative agenda in economic geography as demanded by Scott (2004). Some strands of SST research have recently focused on developing more pro-active modes of technology modulation, especially in the quest for more environmentally benign products and technologies (Kemp and Rotmans, 2004). In the broader field of sustainable development research, economic geography and SST could find common fields of application (Braun et al, 2003; White, 2002; Sneddon, 2000; Angel, 2000; Truffer et al, 1998). They aim both at contributing to an identification of long term balanced growth of global society, which should not impair options for development of present day and future generations (Rammel and van den Bergh, 2003). Here economic geography may contribute by its focus on regional distribution at the interface of economic and social development (Braun et al, 2003, Störmer, 2001; Angel, 2000). SST more strongly focuses on the interface between economic and ecological aspects. Sustainable development may only be realized if all three aspects are conciliated in a balanced way. This implies action on a regional, national but increasingly also on a global level. New institutions have to be built up, which have to work in an increasingly globally competitive setting. Here, envisioning procedures, technology development, equity consideration and procedural policies combine to achieve the overall goal of sustainable development to which both fields could substantially contribute at a theoretical, methodological and empirical level (de Graaf et al, 2005).

Concluding, it may be fair to say that even if economic geography and SST research become more attentive to each other, still a number of blind spots would remain. For instance the recent claim for more methodological diversity and a broader competence base (Scott, 2004; Sjöberg and Sjöholm, 2002; Markusen, 1999) will not be immediately remedied by incorporating SST oriented research. However, also here some promising initiatives are in the making, which aim at a more formalized treatment of socio-technical dynamics (Pyka and Küppers, 2002). With regard to the contribution to the wider project of social science research, economic geography could profit from the interaction with SST as a member of the broader Science and Technology Studies community. Although there

have been some tentative interactions between STS research and economic geography (see Callon and Law 2004 or Hinchliffe 1996), there is considerable potential for fruitful exchange at the level of new modes of knowledge production and the geography of knowledge and science (Grabher, 2004; Rammert, 2004). By this, economic geography could contribute to the emergent field of social constructivist theories in STS and the Economic Sociology tradition (Peck, 2005). Summarizing the relationship between SST and economic geography, we might say that it looks as if they were stemming from related families. Until recently they have ignored each other largely. It would be profitable for both however to get introduced to each other in order to develop new and more synergistic cooperation.

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