Innovation Systems and Paradigms in Public Policy

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1. Introduction and Key Objective

The paper provides an eclectic approach to understand and structure the different policy paradigms within an Innovation System and the trade-offs involved. It is based on a comprehensive and integrative overview on literature-based theory on research and innovation as well as corresponding public policy. The literature is highly interdisciplinary and heterogeneous. While some of the authors focus on microeconomic approaches on entrepreneurial behaviour or individual decisions within a diffusion system, others analyse the relationship between innovation and economic growth and their consequences for a policy approach within a regional/national/multinational innovation system. While some of the studies use econometric methods, others are based on qualitative methods and case studies.

Key objective of the paper is to define, compare and contrast different theoretical frameworks in order to derive at policy conclusions within the framework of a market economy which bears an inherent potential conflict between technology and competition policy. The character of research and innovation, which is focused on in this paper, is mainly general purpose technology and their spillover effects.

The paper concludes that with increasing technological catch-up, constitutional elements of a market economy and the conformity of state interventions with these constitutional principles are required in order to keep a country on its technologically determined growth path without losing its ability to break away from path dependency if necessary.

2. Innovation Systems and Public Policy: Theoretical Background

The interest in innovation activities is driven by the fact that investment in technology can influence economic growth. This does not only include an improved performance at a microeconomic but also at aggregated levels like the industrial or macroeconomic one. But before we proceed to discussing growth factors and the role of the state, let us define technological progress and performance indicators.

While technology is conceptualized as the physical representation of knowledge (embodied technology) as well as its non-physical representation (disembodied technology), the way towards technological progress is described through research and development (R&D) activities. Like Bozeman and Link (1983: 4) put it in a short version: "Invention is the creation of something new. An invention becomes an innovation when it is put in use."

Thus, R&D activities include the procedural way to innovations, i.e. from basic and applied research towards experimental development and finally the commercialization of inventions.

The innovation itself can be classified (Schumpeter 1934: 66) into „(1) The introduction of a new good ... (2) The introduction of a new method of production ... [but also] (3) The opening of a new market ... (4) The opening of a new source of supply ...[as well as] (5) The carrying out of the new organization of any industry ...". It is essential to note that this definition goes well beyond orthodox approaches and creates an early link between innovative activities and diffusion processes because it is diffusion which creates the link between innovation and economic growth.

Diffusion starts with the successful adoption of an innovation within the technological core user group. Once core users are convinced of the innovation's net utility, imitators are attracted if there are no market entry barriers like patents. And as soon as the critical mass allows for economies of scale and low prices, adoption can cross industrial borders to be finally implemented in a society's institutions, organisations and everyday life.

Accompanied by the establishment of a new paradigm, the growth effect of general purpose innovations like the steam engine, the electro-dynamic principle or the computer technology would then have reached its maximum like discussed in the Kondratieff-cycle literature (like Perez 1997: 47). Thus, diffusion proceeds in innumerable small steps in multiple markets within a complex setting of communication skills, product characteristics, adopter needs and environmental conditions (Rogers 2003: 221 ff.). And each step includes the microeconomic decision on whether to invest in technology or not.

There is a vast interdisciplinary body of literature which reflects all forms of technology investment by firms including research partnerships and their performance (for an overview comp. Link/ Siegel 2006: 48 ff.). Although the indicators on the input side like R&D expenditure and the indicators on the output side like total factor productivity do not allow an exact picture, studies have shown according to Link and Siegel (2006: 51) that "private returns to R&D investment appear to be positive and statistically significant across nations and during most time periods [but also that] ... firms are under investing in R&D from a social perspective."

These so-called social returns are benefits that a society gets from private activities. If e.g. an innovator invested in the creation of knowledge that is accessible to other firms without adequate payment, the social returns exceed the private ones and the firm will under invest in R&D. One objective of the new growth theory was therefore to model the existence of externalities or technological spillovers. This was made possible due to fruitful discussions of the old growth theory (like Harrod: 1946; Domar: 1947, Solow: 1957) which led to more realistic assumptions in new growth models. Conditions of imperfect competition, increasing returns to scale and endogenous technological change leave substantial room for entrepreneurial investment into R&D and knowledge as well as for their being the source for technological or knowledge spillovers. These spillovers can arise e.g.

- from technical progress embodied in investment goods which are diffused e.g. through foreign trade and are only imperfectly protected through intellectual property rights;
- from experience effects or professional training which lead to higher productivity and are spread through labour mobility;
- from a company's networking with its suppliers and customers and which in an agglomeration setting can also stem from its competitors

The risk of spillovers after a cost-intensive and time-consuming R&D process often goes along with the risk of opportunistic behaviour when it comes to willingly sharing information about a specific technology. This increases the probability that, as a result of their overall strategic planning, firms invest less in R&D than would be socially desirable - a gap which is usually filled by the state because the market seems to fail. The concept of market failure has become a widely accepted theoretical basis for state intervention in the area of research and innovation. The discussion not only focuses on externalities but also on public goods or information asymmetries (Fritsch/ Wein/ Ewers 1999). Other factors which are also linked to the role of state but stem from new growth discussion (like Romer 1986, DeLong/ Summers 1991, Barro/ Sala-i-Martin 1998) are the provision of infrastructural resources or institutional rules.

The following table (Table 1) gives a short overview on orthodox channels for spillovers:

Table 1: Potential sources of technological or knowledge spillovers

Author(s)	Potential source of spillovers
Arrow (1962)	Learning by doing
Romer (1990), Aghion and Howitt (1992), Caballero and Jaffe (1993)	R&D investment
Grossman and Helpman (1991a, 1991b), Coe and Helpman (1995)	International trade involving R&D intensive firms
Lucas (1988)	Human capital
DeLong and Summers (1991, 1992)	Equipment investment
Caballero and Lyons (1990, 1992), Bartelsman, Caballero and Lyons (1994), Paul and Siegel (1999)	Supplier and customer-driven agglomeration effects
Helpman (1998)	General purpose technology

Link/ Siegel (2006: 82)

The scientific progress described above is an extract. It is rather that explanatory approaches are broadly facetted and still in flux. As Nelson (2007: 8 f.) puts it: "The new evolutionary growth theory that is emerging sees economic growth as the result of the co-evolution of technologies, firm and industry structures, and supporting and governing institutions. I propose that a satisfactory theory of the processes involved in economic growth must consider all three of these aspects, and that the driving dynamics involves their interaction."

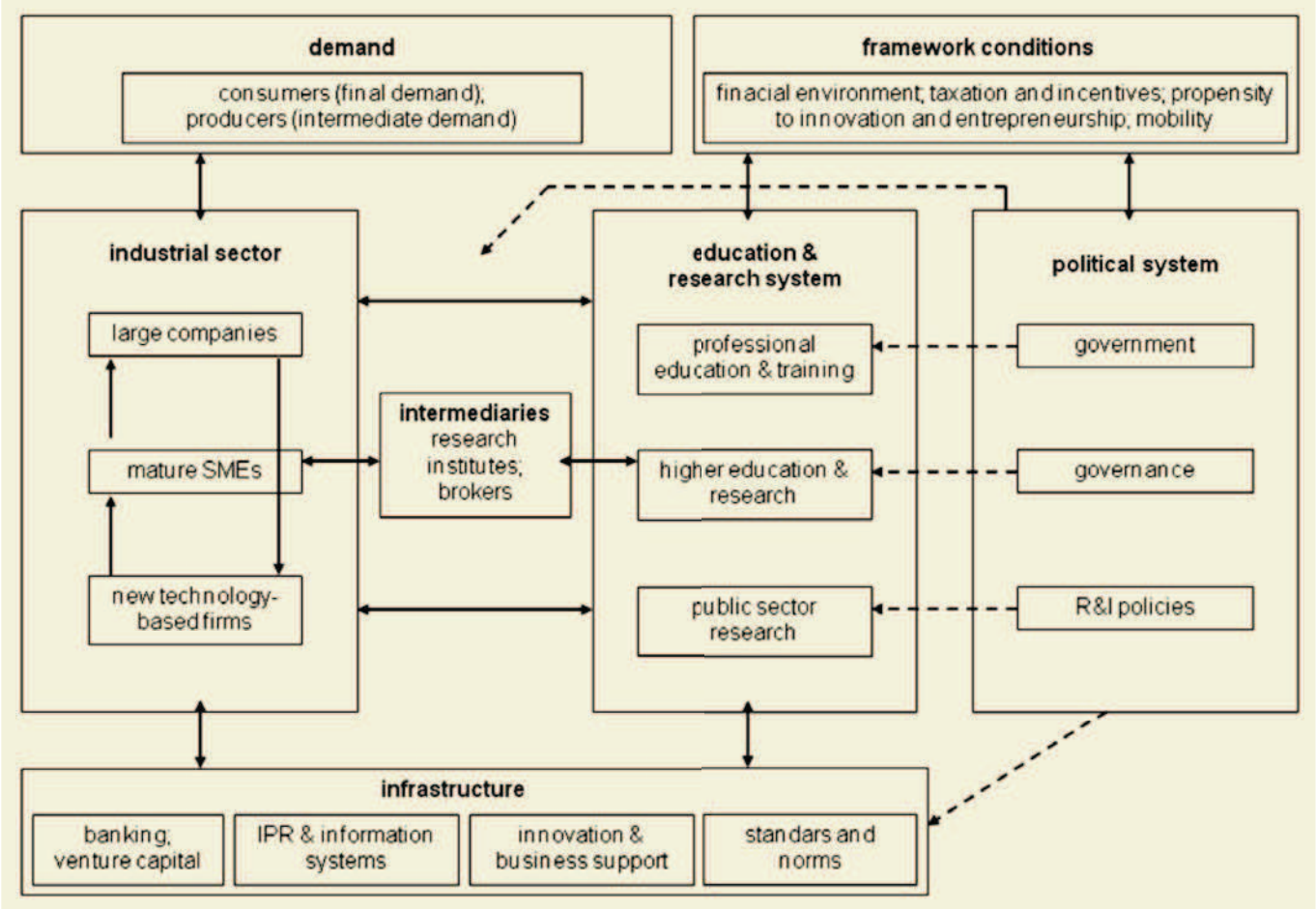
The practice of state action reflects the still open discussion which is led in science. One example (Freeman/ Soete 2004: 414) is the 'old' mission-oriented technology policy of the 50s and 60s which "developed radically new technologies through government procurement that were largely isolated from the rest of the economy … [while] the pervasive character of new mission-oriented projects [in the 70s and 80s] … calls for a more systematic approach to policy." Thus, politics has followed the same shift in perspective that happened in science – from a non-diffusion based approach to one which allows a large number of actors to participate based on the assumption that there are high social returns to innovation especially in the case of general purpose technologies and that this underinvestment might involve the need for state action. The following paragraph sketches the role of government as a player within the current framework of innovation systems.

3. Innovation Systems and Public Policy: Practical Approaches

On a territorial basis, systemic approaches concentrate on industrial districts/innovative milieus/local production systems, new industrial spaces, learning regions, collective efficiency or spatial cluster of innovation (like Porter 1998). The largest territorial conception is a so-called national innovation system (NIS) which Metcalf (1995: 212) defines as "…a system of interconnected institutions to create, store, and transfer the knowledge, skills, and artifacts which define new technologies." Thus, the range of government activities includes among others the provision of technology and research infrastructure (like adoption of standards, tradition of open public science), training through universities and the dissemination of ideas from science that can be used by multiple sectors to advance applied R&D. The figure (Figure 1) gives a short overview.

In recent years, the systemic approach has been complemented by a relaxation of antitrust

Figure 1: Elements of a National Innovation System (NIS)



Kuhlmann (2001) in BMBF (2004: 88)

enforcement related to collaborative research or to new forms of pooling intellectual property rights if based on rule of reason it can be concluded that that competition is not lessened (Schmidt/ Schmidt 2006: 61; Scotchmer 2004: 172 ff.). It is assumed that it is the interaction between explicit/codified and tacit knowledge that allows for the accumulation of new knowledge and its expansion from an individual to an organizational level in a multi-actor context (Kim 2002). Through this process, the efficient selection of new technologies, their subsequent adaptation, improvement and finally the generation of innovations is supported (Lall 2004).

Recent research highlights that there is a shift from a geographical to a virtual context, driven by digital innovations (Passiante et al., 2002), thus, the interaction among clusters is more and more determined by an electronically linked world that has broad applications for general purpose technologies. Especially the internet is characterised through a high share of information with limited appropriability, especially in the case of open source software where a cooperative group of developers dispersed worldwide works over the internet to create software which can be used for commercial purpose (Burger-Menzel/ Cabero Tapia 2007).

Evidence suggests that also in the virtual context social returns to innovation are high, but we once again still need further exploration of the relationship among technological change, organizational change and performance.

Fact is, that systemic approaches are based on decentralized control mechanisms in a large community of players including local, regional and national governments as well as international organisations. This leads to a complex policy mix combining several policy fields which might even be conflicting or including governance gaps (Schmidt/ Schmidt 2006: 163 ff.; BMBF 2004: 91). Policies which have typically been associated with the

state like providing the infrastructure for science and training are now accompanied by issues like the enforcement of knowledge dissemination, the reduction of user ignorance through information policy or the technological openness also of governments as a political means against lock-in technological development.

Although the adoption, mastering and improving of technology is driven by a company's own needs, it is clear that innovation management approaches are an element of a larger whole as locational and infrastructural advantages as well as a country's endowment in scientific and technical personnel and skills do not fall from heaven. They stem from a context of natural resources, historical development and social, cultural and political factors. Yet, during the last decades conditions for policy-makers have become less stabile as a speeding up of technological progress as well as globalisation has made policy outcomes less predictable, thus, increasing the risk for state failure.

The following table (Table 2) gives an overview on some policy instruments with regard to technological externalities and the technical problems associated

Table 2: Judging state policies in the case of technological spillovers

Instrument	Static efficiency	Dynamic efficiency	Target group reached	Total effect
Moral appeals	?	+	?	Significant effect only in small groups
Public procurement	-	-	-	Only if no other option is given due to bureaucracy problem
Merger/ collective supply	+	+	+	Only of use in specific situations; merger might imply power concentration; collective supply only works if exclusion is possible and useful
Rules, bans and requirements	- -	- -	-	High inefficiency because of information and incentive problems
Taxes and fees	++	++	-	Adequate approach; but problem of adequate unit of reference
Subsidies to reduce negative externalities	++	?	-	Limited approach; problem of adequate unit of reference; questionable distribution effect
Subsidies to stimulate positive externalities	++	++	-	Adequate approach; but problem of adequate unit of reference
Negotiations with liability for damage	++	++	+	Theoretically good approach; but problem of unequally distributed transaction costs, information problem
Negotiations without liability for damage	++	?	+	
Tradable rights (certificates)	+++	++	++	Adequate approach; but problems of practical use
Law on liability (endangerment case)	++	+	-	Principally appropriate; but problem of only partially possible internalisation
Law on liability (damage case)	- -	- -	-	

? hardly foreseeable; --- very bad; -- bad; - restricted; 0 neutral; + weakly positive; ++ good; +++ very good
Adopted from Fritsch/ Wein/ Ewers (1999: 149)

with their use:

How can government safeguard that policy incentives reach the right target group and make this group act accordingly now (static efficiency) and in the future (dynamic efficiency), i.e. as long as the measure is scheduled to run? Basically they are two groups of reasons which may cause inefficient state action. According to normative theory (Burger-Menzel 2005: 53f.), state action can be inefficient due to the fact that politicians and bureaucrats face an information disadvantage when it comes e.g. to diagnosing which technology has a big potential in the future, to assess the right means to adequately reach the target group or to forecast policy effects. And state action also has substantial time-lags from the moment of diagnosing the need for an intervention until the measure gets implemented, checked and possibly corrected. Within the context of positive theory (Behrends 2001: 46 ff.), problems may arise because politicians and bureaucrats act selfishly with a tendency to support well-organised groups.

Given the technical problems which accompany public policy, it seems challenging to design and implement a public policy which matches the specific sources of underinvestment in research and innovation.

The call for a 'right' research and innovation policy (technology policy) is additionally made difficult if policy makers have to check their instruments for conformity with the economic constitution given. Focus of this paper is on the market economy in the Western tradition whose intellectual descent can be traced back from Smith through Schumpeter to the modern representatives of institutional economics. This tradition has very much turned the individual into the authority whose desires and needs is the main concern of political action (Kirsch 1997: 18) while "... to some extent government is a form of voluntary cooperation, a way in which people choose to achieve some of their objectives through governmental entities because they believe that is the most effective means of achieving them" (Friedman/ Friedman 1990: 27).

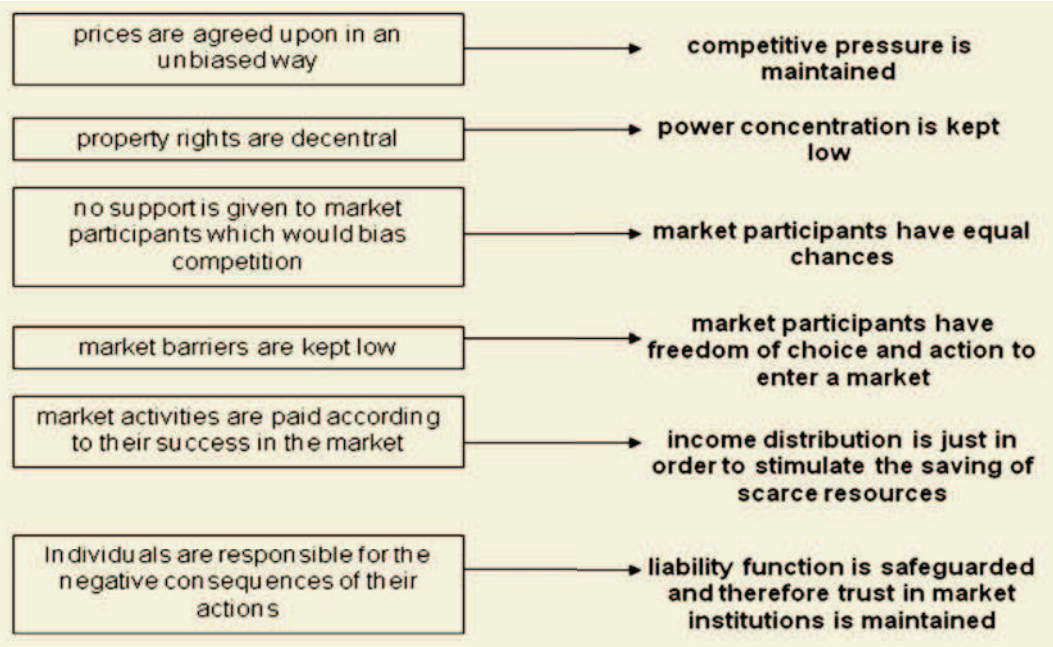
A market economy in its extreme form does not go along with the existence of an intervening state and a pure planned economy is based on an omnipotent government. In reality, there is no pure form but a mix of voluntary agreements (market) and command structure (state) and the constitutional form is defined by the dominating principle (Friedman/ Friedman 1990: 11). Market economies have empirically proved to be technologically more progressive than non-market economies (Hemmer 2002:117). The answer could lie in the incentive structure for innovative behaviour. Market principles go well along with the so-called intrinsic motivation to be creative. Therefore, apart from technical and incentive problems of state action there is need for an additional focus on the conformity of state action with market principles.

Innovative behaviour is interlinked actions that start with an uncontrollable drive to understand the world we live in and result in initiatives to put a new idea into practice. Usually, these initiatives are directed against common sense. Therefore the process of developing and diffusing these new ideas is time-consuming and accompanied by intense conflicts. Creative people tend to endure these hardships because they feel intrinsically driven to move on. As von Mises (1927: 48) puts it: "All progress of mankind always took place because a small minority started to move away from the ideas and costumes of the majority. …If you give to the majority the right to dominate the minority in questions of what the minority should think, read and do, progress is being prevented forever."

This intrinsic motivation still remains a 'hidden' factor in standard microeconomics even if impressive efforts are being made by scientist like Frey. Economic models are not yet adapted to integrate psychological insights. This intrinsic motivation is like a flame that cannot be set on fire by someone from the outside but according to Frey (1997: 25 ff.) intrinsic motivation can be reinforced through positive incentives from the outside if self-determination is not restricted, self-estimation is not reduced, and opportunities to express intrinsic motivation are not limited. If interventions are seen as control measures, intrinsic motivation is usually crowded out.

Thus, one can conclude that intrinsic motivation goes well along with an economic constitution that stresses individualism as a norm, that transforms individualism into civil rights and liabilities including conflict-solving mechanism and that has an openness towards new values and norms. These characteristics are well reflected in the so-called

Figure 2: Functions immanent to market economy systems



Own figure

system immanent functions of market processes described by von Eucken (1952: 255):

The highest conformity of NIS policies with these functions is given if state action provides general law and order conditions for economic activities (like legal property rights) or for safeguarding competition in markets (like law on antitrust). Specific law and order conditions are already less conform because they usually create exemptions from rules for groups, sectors or regions and they tend to lower competitive pressure if they do not only focus on supporting factor mobility (Meißner/ Fassing 1989: 161ff.). Even less conform with the system immanent functions of market processes are discretionary policies where governments influence the individual optimisation calculus. Examples are public procurement, subsidies and other interventions that directly or indirectly influence individual decisions and, thus, potentially also intrinsic motivation.

Empirical research shows that economic constitutions temporarily tolerate to a certain extent non-conformist state intervention (Peters 1996: 137). Yet, shaping a steady culture of non-conformist state action will bring a market economy system down and create a state dominated economy. Technology policy knows both forms of state actions – law and order policy as well as discretionary policy - with a tendency towards the latter which can also be observed on a global scale as more active governments build up pressure for less active ones. One cannot ignore that in recent years discretionary industrial policy interventions within the NIS framework have increased substantially like e.g. demonstrated by extensive EU programs such as ESPRIT, FLAIR, ERASMUS or SPRINT (Schmidt/ Schmidt 2006: 9 ff., 185). These programs are driven by the state's aspiration to control market processes also via substantial extrinsic incentives. Therefore substantial crowding-out effects might be given. One example is the aggressive exercise of intellectual property rights by universities which contradicts the long-standing tradition of open science and training. Blumenthal et al. (1997) found out that university scientists engaged in technology transfer-related activities are less likely to share their data with fellow scientists and are, in general, more 'secretive' than comparable university scientists who are not involved in technology transfer.

As an acceptance of non-conformity problems of state action, the German Commission on Deregulation (Hotz-Hart 2001: 210) provides a practical checklist in order to decide if and how state action should take place in a more conform way. If all questions are answered with 'yes', the probability increases that there could be net utility of state action:

- Does market really fail in the case concerned?
- Is there an arrangement to prevent government from failing?
- Is it possible for new participants to enter the market?
- Does price mechanism still work effectively?
- Does the state refrain from entrepreneurial activities?
- Is regulation restricted to a minimum?
- Are governmental activities quickly and effectively implemented?

If these aspects are compared to the conditions which enhance intrinsic motivation for innovative behaviour, one has to conclude that the checklist criteria can also strengthen intrinsic motivation if market principles like individual liberty, civil rights and liabilities, conflict-solving mechanisms as well as an open-minded environment are provided.

To the background of recent insights from new growth theory and network approaches this checklist can be completed by adding the following aspects which should create a sensitivity for trade-offs within hierarchies and knowledge networks (Hotz-Hart 2001: 218):

- Exploitation-exploration trade-off: Do company structures allow for profitable use of strategic innovation strategies? Yet, how big is the risk of lock-in effects?
- Integration-flexibility trade-off: Are knowledge networks big and differentiated enough to make use of synergies? Yet, has integration proceeded to a degree that lowers the chance for other options which are outside of the knowledge network?
- Diversity-harmonising trade-off: Do standards encourage effective communication and the use of economies of scale? Yet, how much do standards reduce variety and dynamic progress?

These considerations imply that a lock-in effect within a company or knowledge network can be enhanced through state action which artificially prolongs the life-cycle of a technology. Therefore the new paradigm for state action must be directed towards encouraging and educating the self-responsible individual and the normative discussion going along with it.

As the economic system is only part of a societal whole, economic policy does not only reflect changes in objective conditions but also shifts in values or understanding. Such values might be environmental protection or social security. In addition to that, there is the political process itself with its actors which Nelson and Winter (1982: 372) describe as such: "Change over time in the relative power of different interests and groups within society likely will pull changes in policy in their wake. ... Sometimes the institutional machinery for making policy seems to take on a life of its own."

As a result, practical approaches in economic policy vary from state to state and from situation to situation. This makes discussions on technology policy extremely challenging, also because one has always to be aware of the fact that normative judgment is so close at hand. Technology policies might even be consistently designed but conflicting with other policy fields because rent-seeking of actor groups outside of the NIS is relatively successful.

A final remark is on the situation in industrialising latecomer countries. As in these countries the constitutional perception of their economic system has still to be developed, the risk of policy inconsistencies is even bigger there. The specific conditions in late-industrializing countries create a need for own solutions in technology policy approaches which even include bargaining processes with multinational companies. As Nelson (2007: 15 f.) puts it: "... in today's world, countries seeking to catch up technologically will be operating under a much more restrictive regulatory regime defined by international treaties than was the case earlier. … TRIPs makes copying, or appearing to copy, much more hazardous in terms of generating lawsuits and diplomatic pressure than used to be the case. And at the same time, treaties enforced through the WTO significantly narrow the range of government policies of protection and subsidy that can be undertaken in support of infant industry. It is interesting, and I think highly relevant, that these treaties do leave room for support of training, and certain kinds of research and development. But to take advantage of this opening poses a major institutional challenge."

4. Conclusion

There is an institutional and organisational environment which can be positively, neutrally or negatively linked with the intrinsic motivation for innovative behaviour. This is also true for conditions set by an organisation like the state. As described above, the biggest approach of state action are (inter-)national innovation systems. Given the assumption that an economic constitution which is based on individualism is an adequate approach for safeguarding intrinsic motivation, state action has to check for the conformity of NIS policies with market principles.

State action in the field of research and innovation therefore requires among others:

- Government should concentrate on actions that are not market transactions which is especially the case with basic research whose results should be made available to the public. Subsidized private applied researchers should be obliged to diffuse this knowledge e.g. through licensing.
- Government should enable a favourable institutional environment for educational and professional training as well as for self-responsible action and lifelong learning; this means e.g. that authorities quickly adapt educational and professional standards to new requirements.
- Government should enable the mobility in factor markets and assure corresponding information transparency; this means e.g. that regulation should be flexible and procedures should be transaction cost minimal.

Yet, conditions for technology policy makers are difficult. Due to dynamic technical progress, structural change and globalisation, due to pressure from interest groups and from policy races among governments, there is more and more need for finding answers to the following still open research questions:

- How are intrinsic and extrinsic motivation for innovative behaviour interlinked? Which state action has a positive, neutral or crowding-out effect in this respect?
- How are these motivational factors reflected in the economic constitution given?
- How conscious are policy makers about the nature of their economic constitution and how is the consistency of economic constitution affected in the course of time?
- Is the economic constitution reflected in the design of innovation systems? How do different types of technology policies interact with each other? And do they conflict with other policy fields especially competition policy?
- How do country conditions shape the design of the constitutional framework and of the innovation systems?
- How can the risk of technical problems of state action be reduced? How to analyse governance gaps which are driven by technical progress and globalisation?
- How can the risk of lacking welfare-orientation of politicians and bureaucrats be coped with?

Evidence seems to indicate that government initiatives can stimulate innovative behaviour. Yet, there is still further need to explore the relationship among market and state failures to the background of systemically interlinked (inter)national actor groups.

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