STI Studies

Science, Technology & Innovation Studies
Vol. 6 (2010), No 1 (August)

Content

ISSN: 1861-3675

www.sti-studies.de

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI Studies
www.sti-studies.de

Editorial
Interaction of Science and Society

The last issue of STI-Studies (vol. 5, no. 2) contained two articles on mode 2 issues, written by Janus Hansen and Monika Kurath, addressing the theoretical basis as well as the empirical foundation of this concept.

The editors of STI-Studies received a substantial number of comments on these two articles indicating that the mode 2 debate is still vivid – and that relevant issues still are contested such as the de-differentiation thesis or the question of legitimacy of public participation.

Following the two main articles of this issue, readers will find a discussion section with contributions of *Laurens Hessels* and *Harro van Lente*, *Arie Rip*, *Peter Wehling*, and finally two comments of *Janus Hansen* and *Monika Kurath* on each other's article. All of them point to the value and the additional insights of the current debate, but also to some weaknesses of Hansen's proposal to include systems theory as well as of Kurath's attempt to measure social robustness.

The two main articles also refer to the interaction of science and society. In his paper "*Emerging Technologies and Waiting Games*", Haico te Kulve presents a case study of institutional entrepreneurship and the evolution of rules and practices of using emergent technologies, such as nanotechnology, in the food packaging sector.

In their paper *"Strategies for the Scientific Progress of the Developing Countries in the New Millennium"*, Vuk Uskoković, Milica Ševkušić and Dragan P. Uskoković put forward the question, how developing countries can catch up or even leap-frog the leading states by mobilizing science – and at the same time avoid the pitfalls and risks of modernization which have shown up in many developed countries.

Many thanks to Franziska Perlick for language assistance, Fabian Lücke for layout editing, and Jens Kroniger for web publishing.

Ingo Schulz-Schaeffer

Raymund Werle

Johannes Weyer

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI
Studies
www.sti-studies.de

Articles

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI
Studies
www.sti-studies.de

Emerging technologies and waiting games:

Institutional entrepreneurs around nanotechnology in the food packaging sector

Haico te Kulve (University of Twente, The Netherlands)

received 25 November 2009, received in revised form 13 April 2010, accepted 25 May 2010

Abstract

While nanotechnologies are expected to generate wonderful benefits for food packaging, there is reluctance in the uptake of these promises. Still, things are changing and there are dedicated attempts – by institutional entrepreneurs – to shape future embedding of these new technologies. Thus one can examine the evolution of sectoral changes before the actual introduction of new and emerging technologies, which is relevant for studies on emerging technologies and industrial change processes. The main question of this paper is how institutional entrepreneurship linking up with emerging nanotechnologies in the food packaging sector has evolved and contributed to changes at the sectoral level. To do so, I mapped instances of institutional entrepreneurship and constructed a narrative of the evolution of these initiatives, taking a broad view of institutional entrepreneurship-in-context. I found a pattern of a succession of waves of initiatives which contributed to an evolving patchwork of rules and practices. This patchwork will, eventually, shape societal embedding of nanotechnologies in the food packaging sector.

1 Introduction

While the improvement of food packaging materials through nanotechnologies may seem straightforward as an innovation, fueled by the promises about nanotechnology since the late 1990s, it appears not to work out that way. A journalist who attended a nanotechnology and food conference in 2006 observed: "The food industry is hooked on nano-tech's promises, but it is also very nervous" (Renton 2006). Of course, the food sector is known to be conservative with respect to new and emerging technologies, having had their setbacks and disappointments. Packaging might be considered as relatively safe, and has actually been identified as the most promising application area for nanotechnologies as to scale (Chaudhry et al. 2008). But even in this area, actors are cautious.

One factor might be the structure of the food packaging sector, which introduces complexities for the introduction of nanotechnologies. The sector is the intersection of food product-value chains and packaging product-value chains. This intersection increases the variety of actor interests and dependencies, and thus the occasions where actors wait for others to take initiatives. Definitely, the reluctance will be related to the uncertain uptake and societal embedding (Deuten et al. 1997) of nanotechnologies by firms and other stakeholders in the food packaging sector. The association with food introduces substantial challenges for embedding nanotechnologies for packaging, not just in terms of performance requirements, but also with regard to regulatory compliance and broader societal acceptance at the level of a sector.

Still, things are happening. At the same time when the US National Nanotechnology Initiative emerged, Kraft Foods Inc., one of the largest food and beverage firms in the world, established the Nanotek consortium. This consortium aimed to link the development of food and food packaging products with nanotechnology research. According to the director of the consortium, Manuel Marquez, Kraft wanted "to keep a leadership position in food science" (Gardner 2002a). Through its high visibility, Kraft's Nanotek provided a model and legitimation for the combination of nanotechnologies and food packaging.

However, Kraft's initiative faded away for contingent reasons – but not the notion of promising nano food packaging technologies. Other initiatives emerged that took up the concrete promotion of the combination of nanotechnologies and food packaging. This continued as issues of broader societal impacts and risks became important, attracting a wider variety of actors who attempted to promote rules and practices in order to shape the embedding of nanotechnologies in the food packaging sector. While the application of nanotechnologies in the food sector is still at an early stage and with only a few food & food packaging products on the market (Chaudhry et al. 2008), the overall situation at the sectoral level has changed through the promotion of these 'proto' rules and practices. Thus, sectoral changes can occur before structural changes in terms of product/firm entries or shifts in size and distribution of firms associated with particular products. How can we understand such sectoral developments in the food packaging sector?

Clearly, we have to include an institutional dimension. As Aldrich/Fiol (1994) emphasized, the development of new activities often faces a lack of legitimacy, resulting from 'unfamiliarity among stakeholders with the new activity and disputed conformity to existing institutional rules'. Embedding new technologies in the sector then does not occur automatically, but requires the dedicated creation of legitimate new rules, which support development and introduction of new technologies, through reducing uncertainties.

The dedicated creation of new rules and practices is what institutional entrepreneurs try to do. The concept, originally introduced by DiMaggio (1988), refers to actors who mobilize resources in order to create new institutions or transform existing institutions, especially through tying disparate institutions together (Garud et al. 2002; Maguire et al. 2004). As Garud *et al.* (2007) phrase it: institutions are patterns 'specifying and justifying social arrangements and behavior, both formal and informal'. When taken up, these patterns become 'the rules of the game' in a sector.

The concept of institutional entrepreneurship is useful to understand dedicated attempts at creating new patterns. However, it should be expanded to take into account the broad variety of actors that are likely to play a role in shaping the embedding of emerging technologies. Institutional entrepreneurship, in the case of emerging technologies, will thus be distributed across a number of actors. In general, innovation processes have become complex and diffuse with a variety of actors interested in shaping development and introduction of new technologies. For emerging technologies, such as nanotechnologies, in an early phase of development and with a strong open-ended character, processes and effects of dedicated initiatives will be even more diffuse.

This paper aims to contribute to the understanding of sector-level developments during an early phase of development of nanotechnology engineered food packaging materials. The main question is: How does institutional entrepreneurship, linking up with emerging nanotechnologies in the food packaging sector, evolve and contribute to changes at the sectoral level?

To answer this question, I will first review institutional entrepreneurship literature relevant for my theme and expand on it for the purpose of my paper. In addition, I need to develop an approach for identifying and analyzing real time instances of institutional entrepreneurship, when it is not yet clear what the outcomes might be.

2 Distributed institutional entrepreneurship and sectoral changes

It is necessary to expand on the notion of institutional entrepreneurship, as discussed and studied in the literature, in order to capture the variety of actors involved in newly emerging technologies and their embedding in society, and the importance of anticipation and prospective coordination. This, then also allows me to indicate how to study such broader dynamics as real time developments.

2.1 Distribution of institutional entrepreneurship in a sector

The concept of institutional entrepreneurship builds on the concept of entrepreneurship, but foregrounds different types of change. Battilana *et al.* define institutional entrepreneurs as change agents, individuals or groups of individuals "who, whether or not they initially intended to change their institutional environment, initiate, and actively participate in the implementation of changes that diverge from existing institutions."(2009, p. 70) They add that the institutional entrepreneurs do not have to be successful in order to be classified as institutional entrepreneurs. They also argue that business entrepreneurs can act as institutional entrepreneurs, when they create new models diverging from the dominant business models, rather than follow these existing models. However, creating new business ventures is not an essential element of institutional entrepreneurship.

Studies in the literature have analyzed institutional entrepreneurship as a phenomenon in its own right, rather than as part of dynamics at the sectoral level. Institutional entrepreneurship studies associated with technologies mainly focused on single instances of entrepreneurship (Hargadon/Douglas 2001; Garud et al. 2002; Munir/Philips 2005; Jain/George 2007). But to understand what is happening, we need to take into account a broad variety of actors in a sector that have an interest in promotion and/or control of such technologies – all of whom may act as institutional entrepreneurs.

Actors in a sector, including institutional entrepreneurs, cannot move freely with respect to emerging technologies. They need to take into account the promises, and are subject to sectoral developments. Institutional entrepreneurs are enabled and constrained by sectoral structures (Garud et al. 2007). Garud and Karnøe (2003) emphasized the heterogeneous involvement of actors in innovation processes and added structural features when they spoke of 'technology entrepreneurship as distributed and embedded agency'. Actors "become interwoven into emerging technological paths that they shape in real time." (Garud/Karnøe 2003, p. 281) Actors are also embedded more broadly within the sectors in which they operate - relatively independently from particular paths.

Thus, institutional entrepreneurship, in general and with respect to new technologies, is distributed and embedded, cf. (Lounsbury/Crumley 2007). Having recognized this, a further step can be done: institutional change can also occur through or within spaces for interaction, in the sense that the actual dynamics are shaped by such spaces, e.g. a forum to promote a new technology, rather than the activities of individual institutional entrepreneurs. They can create new spaces (arenas, fora) for interactions, or exploit opportunities of spaces that emerge. Professional associations are one convenient venue for institutional entrepreneurship (Aldrich/Fiol 1994; Greenwood et al. 2002) and their conferences may act as field-configuring events (Garud 2008; Lampel/Meyer 2008). Consortia – with their meetings and conferences – also provide a space. The Kraft-led Nanotek Consortium in the food packaging sector was such a space, in which new relations between actors could be developed, connecting relatively disparate practices and resources. The configuration of a space and the variety of actors it is composed of then become important: if more heterogeneous actors are involved, also more aspects of distributed innovation will be captured.[1] In a sense, it is the space (and how it is used by a variety of actors) which becomes the change agent.[2]

Our understanding of institutional entrepreneurship as described, links up with criticisms of earlier studies, where institutional entrepreneurs are presented as "heroes who were disembedded from their institutional environment" (Leca et al. 2008, p. 5) It also moves on, by considering the complexity of enabling and constraining factors, (see also Maguire et al. 2004; Dorado 2005; Battilana 2006; Leca et al. 2008). If we start with the basic point that actors who act as institutional entrepreneurs must possess (or acquire) sufficient resources to be productive in the particular situation,[3] it is clear that when fields evolve (e.g. because issues such as regulatory and societal acceptance

[1] Such heterogeneous spaces may actually reduce the distribution of institutional entrepreneurship in terms of locations and separate activities as they may collect a variety of actor interests.

[2] Consortia, especially when there is strong leadership, can also be conceptualized as institutional entrepreneurs themselves, cf. the notion of 'collective institutional entrepreneurship' (Wijen and Ansari, 2007).

[3] These resources can take shape in the form of legitimacy, such as formal authority or leadership, their position in social networks, the ability to gather allies, co-ordinate collective action, access to and control of scarce resources (Leca et al. 2008).

in the development and societal embedding of new technologies become foregrounded in addition to expectations on economic prospects) the distribution of resources changes and thus the opportunities for institutional entrepreneurship. Thus, I expect that the type of actors more likely to take initiatives (and be productive) as institutional entrepreneurs will change over time.

2.2 Sectoral changes associated with emerging technologies

New institutions give rise to new patterns of behavior in a sector. 'Patterns which have become taken for granted and act as stable designs for repeated activities of which deviation is difficult or costly in some manner' (Garud *et al*. 2007). These patterns can include formal regulations, but also informal codes of conduct, norms and established practices with routinized (and legitimate) ways of behavior – all 'rules of the game'. Through interactions, orchestrated by institutional entrepreneurs, new patterns, and hence, new games can emerge. In the case of new and emerging technologies, for a long time, stabilization into patterns will only be partial, as the development will be fluid and open-ended, given uncertainties about future developments.[4]

This is an important phenomenon to understand changes at the sectoral level. Changes in a sector of industry involve more than changes in competition and in exchange relations. Evolutionary economists have already discussed the importance of broadening the notion of industry structure and taking more actors and relationships into account, including non-market relationships and transactions (Nelson 1995; Malerba 2002). Relevant actors in a sector include upstream and downstream chain relations, customers, regulatory authorities, researchers and NGOs involved in this sector (Granovetter/McGuire 1998), see also (Garud/Karnøe 2003) and (Scott/Meyer 1994). Anticipation on future relations between actors and technologies are particularly relevant for emerging technologies and are by now part of how games are played in a sector.

Expectations are known to play an important role in the dynamics of new and emerging technologies (Van Lente/Rip 1998; Borup et al. 2006). The anticipation on the embedding of new technologies helps to reduce the costs of learning by trial-and-error (Deuten et al. 1997). At firm level, firms can assess their future products' conformity with existing regulatory schemes or the risk of rejection by public interest groups, and adjust product development strategies to have a better chance. At the sectoral level, uncertainties may lead to waiting games, but are also fertile grounds for institutional entrepreneurship.

Actors in a sector are aware of each other and more or less of their interdependencies. Interdependent actors can hope that other actors will act to reduce uncertainties and thus wait before they themselves invest. Waiting games are sometimes almost unavoidable. A particular kind of institutional entrepreneurship might arise, trying to break through the waiting games. This goal constitutes a collective good, so there will be reluctance to work towards it, while identification with the promise of the new technology may be a positive incentive. Other considerations might also play a role, especially a possible lack of legitimacy in the introduction of new technologies, and the need to be clear about regulations that are applicable. This gives rise to new patterns, which pre-date the actual introduction and embedding of new technologies.

Adding such anticipation-oriented, "prospective" patterns to the broaden-

[4] Further development of these 'real world games' (Scharpf 1997) for game theoretic purposes would require more work as outcomes are unclear.

ing already identified by evolutionary economists, it is clear that industrial structures are much richer than traditional industrial economics conceived them. Rather than developing this in more detail, I introduce the term 'industry structure+', as a reminder that the richness of industry structures has to be part of the analysis, especially when looking at sector-level changes.

Embedded actors, including institutional entrepreneurs, shape sector-level dynamics related to technologies, but are also shaped by them. Sectoral structures and their associated institutions with respect to technology development and their embedding in society co-evolve, and institutional entrepreneurship is an important part of the co-evolution (see also Nelson 1995; Malerba 2002). In a sense, institutional entrepreneurs are just as much a vehicle for change as independent change agents. One can even take a further conceptual step, and consider the occurrence (and nature) of institutional entrepreneurship as an indicator for emerging entanglements between technologies, industry structures and associated institutions, shaping industry structure+. Then, analyzing institutional entrepreneurship is a way to follow sectoral changes.

What actors can do as institutional entrepreneurs, depends not only on their position, but also on developments with respect to institutionalization of emerging technologies in the sector. Institutional entrepreneurship initiatives may build on such developments. Perkmann and Spicer (2007) already speculated on this aspect of distributed institutional entrepreneurship in which an 'institutional project' may be pursued by various actors. For example, one individual may pioneer a novel institution, but it is taken further, propagated by another actor. For the embedding of emerging technologies, the situation is more diffuse. Institutional entrepreneurs will still build on earlier initiatives, but the overall effect is a patchwork of prospective patterns at the sector-level rather than a specific 'institutional project'.

2.3 Real time analysis of sectoral developments and institutional entrepreneurship

For a new technology with only few concrete products, we are in an early stage of co-evolutionary processes. To understand what happens, tracing ongoing activities and emerging patterns is important. Mapping eventual outcomes is not enough. Our entrance point is to map and characterize instances of entrepreneurship-in context.

Instances of institutional entrepreneurship in relation to the uptake of nanotechnologies were identified by analyzing the positioning of actors in various texts,[5] with supporting data from observations during meetings and informal interviews. We collected data from various sources.[6] I used the following criteria to identify

[5] The creation and circulation of texts is a key strategy in institutional entrepreneurship (Munir/Philips 2005) and discursive practices are a central topic in entrepreneurship studies, (see Philips et al. 2004; Lawrence/Suddaby 2006; Leca et al. 2008).

[6] I retrieved articles containing the terms nanotechnology and packaging that appeared during 2005-2008 in a specialized online food magazine and a website focused on nanotechnologies in general: foodproductiondaily.com and nanowerk.com. I attended various conferences: MinacNed seminar Food & Nutrition (Utrecht, 2006), Packaging Summit Europe (Amsterdam, 2007); final SustainPack conference (Prague, 2008); Nanotechnology and the Law: The legal nitty-gritty for nano foods, nanocosmetics and nanomedicine (Leuven, 2008). Presentations of conferences were retrieved: Future of Nanomaterials (Birmingham, 2004); Nano4food 2006 (Atlanta, 2006); Nanotechnology in Food and Agriculture (Washington, 2006); Food Packaging Innovations: The Science, Current Research and Future Research Needs (Baltimore, 2006). Reports on and publications of identified instances of institutional entrepreneurship were consulted. In addi-

institutional entrepreneurship: actors should be (1) mobilizing resources; (2) promoting the broad diffusion of rules, norms and practices related to nano enabled food packaging outside their own organization; (3) introducing 'institutional novelty', e.g. through combining disparate institutions, and or breaking with existing institutions in the food packaging sector. In addition, I collected and analyzed background information on developments in the food packaging sector in general, and nanotechnologies in particular through reports, interviews and attending nanotechnology and packaging conferences.

The research strategy of identifying real-time instances of institutional entrepreneurship (in context) and sectoral changes as they occur has limitations: it depends on what is visible. As nanotechnologies, and for that matter also sectoral changes, are still emerging, not all instances of intentional and unintentional institutional entrepreneurship will be visible immediately, while they could already have effects. Entrepreneurs can also dissemble strategically, downplay the radical nature of promoted new technologies and institutions in order to facilitate acceptance, and only later foreground the pioneering and radical aspects of their activities (Aldrich/Fiol 1994; Hargadon/Douglas 2001). While this will occur, it is problematic for the heroes-and-winners narrative of institutional entrepreneurship (Leca et al. 2008). By focusing on interactions of actors and spaces as sites of entrepreneurship, strategic dissembling is less of a problem in data collection.

An additional element to our mapping approach builds on the anticipatory activities of actors, how these entertain possible futures, and how future developments are shaped already by present industry structure and the entrepreneurial activities of actors. Thus, controlled speculations about future developments are possible, and these can be considered further data on sector-level change. In particular, as part of an interactive scenario workshop in February 2009 to explore future developments of nanotechnologies for food packaging technologies, we developed three scenarios, using as a baseline a situation, which emphasized risk avoidance in the food packaging sector, with stakeholders waiting for each other to make a first move.[7] Each scenario was constructed by envisaging a particular type of institutional entrepreneurship trying to resolve this impasse.[8] The scenarios will be used at the end of section 4 to discuss possible further developments.

3 The domain: nanotechnologies & the food packaging sector

Packaging is an omnipresent technology. Since the early 20th century it has become part of everyday life and subject of significant industrial activity. Nowadays, a wide variety of packaging materials is used in different forms and shapes from basic material such as wood, plastics, textiles, paper and paperboard, as well as additional materials such as inks and glues (Sandgren 1996). Global food packaging sales were valued at US$ 168 billion in 2003 and were expected to have grown to US$ 228 billion in 2009 (World Packaging Organisation/Pira International 2008).

3.1 Nano enabled food packaging technologies

Nanotechnologies are expected to have "the potential to transform food packaging materials in the future". (Brody et al. 2008, p. 113) In their re-

tion findings were discussed with actors in the food packaging sector.

7 The workshop was organized together with the Netherlands Packaging Centre, a 'branch' organization for the packaging value chain. Firms involved in food packaging, interest groups, researchers and governmental agencies, attended.

8 For a description of the scenario methodology see (Rip/Te Kulve 2008).

view of the usage of nanotechnologies in the food sector Chaudry, Scotter et al. (2008) identified four main applications for what they called 'food contact materials' (FCMs): FCMs incorporating nanomaterials to improve packaging properties (e.g. gas barrier properties); active FCMs that use nanoparticles with, for instance, antimicrobial properties; intelligent materials, for tracking and tracing purposes or incorporating sensors to monitor food conditions; biodegradable nanocomposites. Doyle (2006) identified additional application areas for nanotechnology such as pigments, inks and adhesives.

The development of nanotechnologies for packaging is not totally new. High expectations of their application can be traced back to the 1990s. In particular, the development of nanocomposites received much attention (Manolis Sherman 2004; Lagarón et al. 2005). Nanocor, a supplier of nanoclay additives, was established "in 1995, after market research suggested that nanocomposites would be a burgeoning field" (Gardner 2002b). Nanocomposites are not only useful for packaging. As a set of enabling technologies they are expected to be useful for a wide variety of products. At the end of the 1990s Sherman noted: "From auto parts to barrier packaging, the race is on to commercialize nanoclay thermoplastic composites (Sherman 1999)."

Approximately 10 years later, a relatively small number of nanotechnology packaging materials have entered the market – although market estimates vary. Nevertheless, market studies and packaging experts expect a steep rise in introduction of nanotechnology & packaging products (Brody et al. 2008; Chaudhry et al. 2008). In a report on the application of nanotechnologies in the food sector, the European Food Safety Authority (EFSA) referred to market studies that suggest that packaging will constitute the majority of applications in the food sector and even make up 19% of nano enabled consumer products by 2015 (Barlow et al. 2009). The report argued that the underlying dynamic in the growth of food packaging materials is the expectation that these applications are not likely to have 'any significant exposure to consumers' due to the embedded or fixed nature of nanotechnology engineered materials in packaging applications. Siegrist, Stampfli et al. (2008) also argued that the application of nanotechnologies for food packaging is perceived by consumers as less problematic, than their use for food.[9]

Still, while the application of nanotechnologies may seem to entail promising novel food packaging applications, the materialization of the promise is not straightforward. One reason is that risks of new nanotechnology engineered materials that come into direct contact with food are not fully understood. Furthermore, as we will see below, there is also the challenge of linking requirements of different players in a fragmented sector, which is generally cautious with respect to new technologies.

3.2 Actors and their position with respect to new technologies in the food packaging sector

The structure of the food packaging sector is conducive to actors' reluctant uptake of emerging technologies such as nanotechnologies. What are the key players and their position in the sector? And how then does the overall situation in the food packaging sector introduce challenges for embedding emerging technologies?

When discussing food packaging, it is somewhat misleading to talk about 'the food packaging industry', as this would suggest well defined boundaries to which actors begin and end to

9 The food sector is known to be conservative with respect to new and emerging technologies, while innovations are often related to packaging (Beckeman/Skjöldebrand 2007).

engage in food packaging production activities. The development, manufacturing and use of food packaging takes place through a number of steps, which are spread across a variety of actors. For actors involved in packaging, packaging is not likely to be their sole focus. Although material suppliers may not always see themselves as part of the packaging sector (Pira International 2003), they are still relevant, as they deliver the 'innovative power' for new packaging technologies (Prisma & Partners/MinacNed 2006). With such qualifications, the packaging sector is a chain of actors involved in the development, production and processing of packaging (cf. (Cottica 1994). Packaging is used for a number of products, food, but also for non-food items and pharmaceuticals, each of them having their own value chains. Thus, the food packaging sector is an intersection of the food and packaging chains.

Characteristic for packaging is that it is not an end product in itself, but 'a function to a product' (Nieuwesteeg 2007), such as protection of food or communication to stakeholders (e.g. of a preferred date for consumption). What actors consider valuable functions of (food) packaging is different throughout the chain, what increases problems of co-ordination along the chain. For brand owners, packaging acts as 'the silent salesman' of their product, which is reflected in their attention to packaging design, and aesthetic aspects of packaging (Alfranca et al. 2004). For retailers other functions may be (more) important. Whereas brand owners may favor novel sensors indicating food quality, such as freshness, retailers object to the incorporation of such sensors out of concern that consumers will only buy the freshest products.

A further challenge for coordinating the development and introduction of new packaging is the fragmentation of packaging knowledge, because relevant knowledge for packaging innovation is distributed across the sector. Brand owners value differentiation through unique packaging and increasingly take the lead in the development and introduction of new packaging.[10] They experience the fragmentation and cope with it by appointing packaging innovation managers, who need to develop partnerships with other actors in the sector and specify requirements for novel packaging. Upstream actors, such as material suppliers, may have more knowledge of novel technologies, while downstream actors know more of consumer demands. Signals downstream may not always reach upstream actors and vice versa.[11] This is another reason that actors may wait for each other to make the first step.

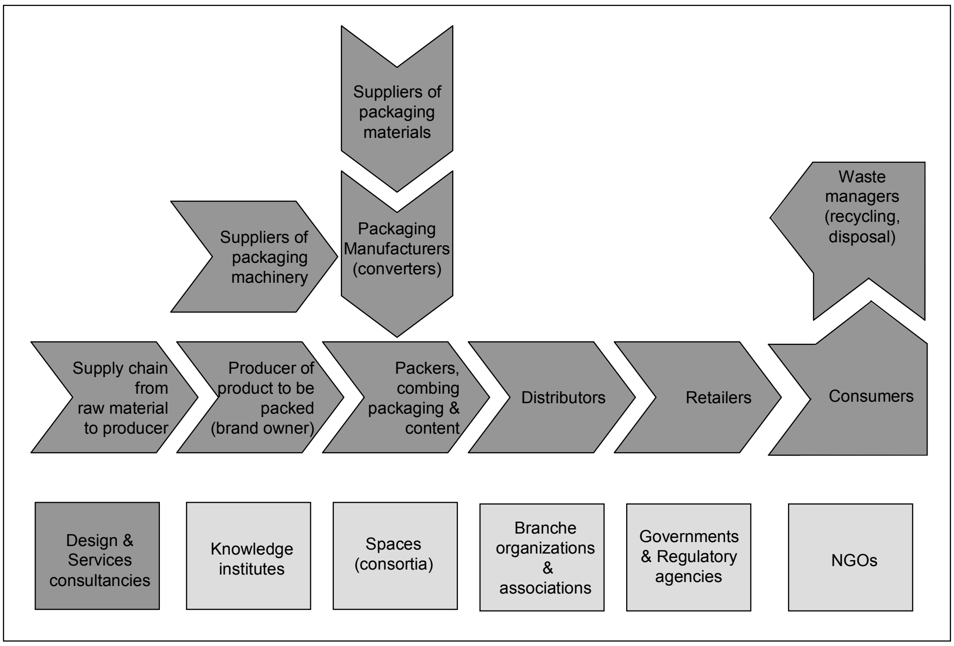
As to the distribution of firm size, large firms can be found, although not exclusively, at the beginning and end of the food packaging chain: Large packaging material suppliers, big food production companies (brand owners) who 'fill' the packages and at the other end, large retail chains, which can take initiatives and set requirements. The room to maneuver for packaging manufacturers (so called 'converters') is limited, as they often find themselves 'squeezed in between' their suppliers of materials, and their customers, such as brand owners and retailers (Pira International 2003).

Retailers act as gatekeepers for new products. In interviews with experts in the food packaging sector, retailers were identified as having a major influence in whether novel nanotechnology enabled packaging applications make it to the market, or not (Nanologue 2006). Uncertainty about retailers' position with respect to nanotechnologies will then make actors

[10] Correspondence with J. van der Heide, Product & Market Development Manager, Corus Packaging Plus, 29th May 2008.

[11] Based on observations and interviews during Packaging Summit Europe (2007) and Sustainpack (2008) conferences.

Table 1: Players in the food packaging sector



hesitant to initiate activities to introduce such packaging materials.

As I have argued in the previous section, for the development and embedding of new technologies, non-business actors, such as government regulatory agencies and civil society groups, constitute another significant set of actors, in general and definitely in the food packaging sector. Health, safety and environmental regulations are important drivers in food packaging development (Sonneveld 2000). Environmental considerations in general are prominent. Civil society groups voicing (consumer) concerns on impacts of food packaging on the environment have left their footprint on the packaging sector. Since the 1960s the sector, including governments, has taken a succession of measures to address concerns on packaging's impact on the environment. Packaging firms have established recycling programs, and product stewardship programs have been launched (Lewis 2005).

By now, sustainability is the buzz word in packaging conferences.[12] While the notion of sustainability may create openings to introduce new materials, such as nanotechnologies, uncertainties of their actual conformity to the (diffuse) notion of sustainability make actors reluctant.

Uncertainties on the distribution of costs and benefits as well as on health, environmental & safety issues make actors across the food packaging sector reluctant with respect to uptake of nanotechnologies.[13] If I add this to my earlier considerations, it is not surprising that there are waiting games, where even big players are reluctant to innovate.

Figure 1 offers an overview of the players in the food packaging sector. Additional players, such as suppliers specialized in inks, adhesives, additives and coatings; firms offering packaging machinery, design, testing and printing services; knowledge institutes and professional associations are shown as well.

[12] Observations during Packaging Summit Europe (2007).

[13] Interview with Dr. G. Yilmaz, Agrotechnology & Food Sciences Group, Wageningen University and Research Centre, 02-07-2008.

Table 1: Overview and characterization of distributed institutional entrepreneurs

Distributed Institutional Entrepreneurship	Theorization	Mobilization	Implementation
Kraft *Brand owner*	Acquire competitive advantage through novel combinations of nano and food	Financial resources; position of, and ambition of being a, leading brand owner; involving nanotechnology researchers	Creating a space for interaction through Nanotek consortium; linking up with trends in the packaging sector such as health and safety of food.
Sustainpack *Consortium*	Establish fibre based packaging as preferred packaging material through developing nano improved sustainable materials.	Acquisition of funding from interested parties and EU; fibre based packaging as recyclable and valuable sustainable materials	Creating and co-funding a space for interaction through involving nano scientists and actors throughout the packaging chain; linking up with sustainability repertoire and commercial interests.
ETC Group *NGO*	Prevent undesirable impacts through regulating introduction of nanotechnologies	ETC's expertise; position of NGOs as spokespersons for public interests and concerns	Engage with regulatory agencies and nano developers individually and with other NGOs; linking up with concerns to take into account civil society views.
MinacNed *Professional association*	Increase business for nanotechnology firms by developing novel nano & food (packaging) combinations and taking into account both business and societal considerations.	Support from the Ministry of Economic Affairs; co-operation with a management consultancy; expertise from nano & food experts	Creating a space for interaction between nano & food organizations, structured around a roadmap; linking up with trends in the sector such as health and safety, but also commercial and risk considerations.
DuPont & Environmental Defense *Material supplier / NGO*	Fill the gap in regulatory and risk assessment & management practices through developing a risk framework guide.	Expertise & legitimacy of both a large material supplier and an NGO; public consultation of a draft scheme	Broad dissemination of the framework and engagement with firms to implement the guide; linking up with nano risk assessment and management repertoire.
UK DEFRA *Government department*	Fill the gap in information to assess and manage risks through a voluntary reporting scheme	Legitimacy of regulatory authority; public consultation of a draft scheme	Dissemination of the scheme and engagement with firms; linking up with valued nano risk assessment and management repertoire
IG DHS *Professional association*	Fill the gap in regulatory practices and ensuring consumer confidence through a code of conduct	Retailers position in the chain; co-operation with risk management consultancy in drafting the code; signatures of retailers	Engagement with retailers to implement the code; linking up with expected consumer requirement of transparency of nano products.
Responsible Nanocode Working group *Consortium*	Establish more pro-active involvement of business in shaping regulatory practices and standards through a business focused code of conduct.	Involvement of actors throughout the supply chain, NGOs, scientific authorities; public consultation of a draft scheme;	Dissemination of the scheme and engagement with firms; linking up with business concerns on their (lack of) involvement in institutionalization processes.

4 The evolving patchwork of embedding nanotechnologies in the food packaging sector

This section develops a narrative account of an evolving patchwork of initiatives and their outcomes over almost a decade. To start, I give an overview of the thrust and strategies of typical initiatives (Table 1). I characterized their activities on the basis of some relevant literature showing that institutional entrepreneurship comprises three sets of activities: 'theorization', i.e. the articulation of chains of causes and effects, of framing problems and justifying innovations (Greenwood et al. 2002; Maguire et al. 2004), 'resource mobilization' and 'implementation' strategies and activities. In 'theorization', expectations play an important role in envisioning new institutions (Garud et al. 2007) and in convincing others to adopt new institutions. While actors will possess some relevant resources already, generally they need to engage in resource mobilization activities (Dorado 2005), enroll allies and create a better position for themselves. Depending on their position in the field (Maguire et al. 2004; Battilana 2006) entrepreneurs have access to limited resources, and will therefore work with existing relations in the sector. By "linking the new practices to existing organizational routines [....] aligning them with the values of diverse stakeholders" institutional entrepreneurs are known to implement new institutions (Maguire et al. 2004).

4.1 Early institutional entrepreneurship initiatives: promoting combinations of nanotechnologies and food packaging

My story begins in 2000 with the promotion of nanotechnologies for food packaging applications, visible in narratives of expectations of new products with wonderful packaging properties. This was the time of a steep rise in the interest in nanotechnology.[14] Governmental and commercial investments were increasing, and this was accompanied by a flood of publications on nanotechnologies' revolutionary potential (McCray 2005).

The first attempt to actively shape the embedding of nanotechnologies in the food sector was the establishment of an international consortium of researchers and funded by Kraft Foods Inc., while at the same time the Clinton Administration presented the National Nanotechnology Initiative to the US Congress. The consortium consisted of physicists, chemists and engineers from universities, governmental laboratories and start-up companies within the United States and Europe (Gardner 2002b; Goho 2004). As a large collaborative network researching the application of nanotechnologies in food and food packaging (Feder 2006; Berger 2008) and sponsored by one of the largest food and beverage firms in the world, the launch of the NanoteK consortium created legitimacy for the use of nanotechnologies in the food and food packaging sector.

While nano engineered packaging technologies were no new phenomena (work on nanocomposites already existed since the 1990s), Kraft, in striving to be a leader in the field, provided the field with a new impulse, also because of their high visibility in the sector. The pursuit of novel combinations by Kraft became was expressed in an interview with Kraft's vice-president of technology strategy: "Finding technologies that are not obviously applicable to the food business is both a challenge and an opportunity that could help improve our products and packaging [....] For Kraft the consortium opens new ways of thinking." (Fones 2005) The actual entrepreneurial action came from

[14] Nanotechnology is an 'umbrella term' covering a variety of technologies and research areas (Rip/Voß 2009), see also Wullweber (2008) on nanotechnology as an 'empty signifier'.

Manuel Marquez, who became director of the consortium. The consortium functioned as a space for interaction between different actors, and this was recognized by a participant: "Manuel has somehow gotten these people with many different areas of expertise, and the consortium lets us interact." (Gardner, 2002)

The promotion of the combination of nanotechnology and food packaging as a way of developing new packaging technologies was also pushed in Europe. In 2002, the research institute STFI-PACKFORSK in Sweden started to prepare the Sustainpack project (Johanssen 2008). Although not the first consortium related to nanotechnologies and packaging in Europe, Sustainpack stands out in size and scope.[15] Sustainpack claimed to be the largest packaging research program in history with a budget of 36 million euro, co-funded by the European Union. The four-year research project was launched in 2004, and was conducted by 35 partners, consisting of universities, research institutes and firms including a large UK retail chain. Sustainpack's institutional entrepreneurship is pronounced in their ambition to establish nano-engineered fibre-based packaging as the 'industry standard by 2015'.

To convince retailers, who act as gateway to consumers, was an important feature in Sustainpack's strategy. Sustainpack aimed to realize a standard "by creating a European research community focused on sustainable packaging which will pressure retailers to accept natural packaging as the way forward (Nanowerk News 2007b)." In this way, they also linked up with those retailers which were already prescribing the use of 'sustainable' or 'green' packaging technologies to their suppliers (Caul 2007; Wal-Mart 2007). Analyzing attitudes of retailers and consumers to prospective food packaging technologies was a further activity of the consortium (Østergaard 2008).

Sustainpack's entrepreneurship differs from Kraft/NanoteK's in the sense that it promotes a broad variety of products to be packed with new fibre based materials (and does so through addressing the packaging chain rather than a set of food packaging products). Whereas Kraft emphasized the food safety benefits of novel nano-engineered food packaging products, Sustainpack also emphasized broader benefits, i.e. desirable environmental aspects of their new fibre-based packaging materials. Sustainpack's positioning derives from ongoing competition between plastic-based packaging industries and paper/cardboard packaging industries, and the discourse on sustainable packaging within the sector.

By the mid 2000s there were still high expectations of nanotechnologies in general and for packaging in particular, but the overall situation in which actors contemplating nanotechnologies found themselves, was changing. The combination of nanotechnology and food packaging, and claims of their contribution to food safety and environmental impact, were now very visible in reports of industry observers such as PIRA International and Helmut Kaiser Consultancy (Moore 2004; Anonymous 2005). At the same time, debates on possible risks associated with emerging nanotechnologies surged, notably when re-insurance company Swiss Re entered the stage in 2004 (Rip/Van Amerom 2009). This overall shift from high expectations to concerns about risks of emerging nanotechnologies formed the backdrop to - and created openings for - new institutional entrepreneurship initiatives.

[15] SOLPLAS, EU funded project ran from 2002-2005.

4.2 Second round of initiatives: promoting and controlling combination of nanotechnologies and packaging

When the Sustainpack program was in its early years and Kraft/NanoteK continued its activities for some more time, a second wave of initiatives emerged. These pushed for the incorporation of broader societal and risk aspects in embedding nanotechnologies in the packaging sector.

Interestingly, in this second round actors outside the food packaging sector were important. Actually, given the enabling character of nanotechnologies actors not involved in the food packaging sector might have been expected to come in early, spreading the good message, and incumbents to follow. However, as relative outsiders they would not be able to become (and be readily accepted as) institutional entrepreneurs. It requires a certain initial level of (perceived) legitimacy and/or reference to earlier initiatives, for actors outside the sector to appear as institutional entrepreneurs.

Actors in this second round turned out to comment on possible developments of nanomaterials, rather than only on the specific combination of nanomaterials for food packaging applications. Here, it is the open-ended character of nanomaterials and nanotechnology as an umbrella term, which shape the emergence of institutional entrepreneurship activities within the food packaging sector. These entrepreneurs have a stronger technology-push or upstream focus than Kraft/NanoteK and Sustainpack (who already have a relatively strong technology push).

One interesting institutional entrepreneurship initiative from outside the packaging sector was pushed by the ETC Group. The ETC Group is an expert organization dedicated to sustainability issues and marginalized groups (ETC Group 2003, p. 80). The ETC group picked up on the steep rise in interest in nanotechnologies, including Kraft's NanoteK activities, during a time in which "civil society and governments [still] focus on genetic modification" (ETC Group 2003, p. 5) In 2004 the ETC Group published a report in which they assessed possible risks of the application of nanotechnologies for food and agriculture, including packaging (ETC Group 2004). They articulated concerns about the transfer of responsibility for food quality to consumers through the application of smart packaging (ETC Group 2004; Thomas 2006). The ETC Group proposed the development of new regulatory practices, up to a moratorium on nanotechnologies until these have proven to be safe.

While ETC Group's advocacy of new regulatory practices is broader than just food packaging, they played a relevant role as members of the ETC Group were involved in meetings on nano-engineered food and food packaging (Thomas 2006; Halliday 2007). Next to establishing cognitive legitimacy of new regulatory practices, they also aimed to push for new practices, such as through filing legal petitions. The ETC Group participated with Friends of the Earth and the International Center for Technology Assessment in ad hoc coalitions calling for regulation of nanotechnologies (Thomas 2006; Nanowerk News 2007a). Their entrepreneurship was mainly directed towards creating new framework conditions for further development.

Actors in the food packaging sector now found themselves in a different situation, as promotion of nanotechnologies became subject of critique by NGOs and other actors such as reinsurers, focusing on potential risk. New initiatives to promote development of new packaging technologies with help of nanotechnologies needed to take the strong debate on risks into account to maintain legitimacy.

This is visible in the initiative of a Dutch micro- & nanotechnology 'branch' association called MinacNed. MinacNed's primary mission is to stimulate economic activities based on micro- and nanotechnologies in the Netherlands, by developing and supporting networks, collaborations and identifying opportunities, using roadmapping as a tool (MinacNed 2007). In December 2005 the association initiated the development of a Food & Nutrition roadmap, including the theme packaging. It articulated expectations of benefits of nanotechnologies but also discussed potential health, environmental and safety risks.

MinacNed's initiative can be seen as building upon the first round of initiatives. The eventual roadmap document referred to an interview with a senior manager of Kraft in a newsletter, who remarked: "We're sponsoring research at these institutions to help us imagine the future of the food industry in the years ahead [...] We believe eventually nanotechnology may be a significant method by which we can deliver what consumers want." (Prisma & Partners/MinacNed 2006, p. 27) The document also referred to the importance of sustainable packaging materials and argued that plastic packaging can be replaced by bioplastics and cardboard packaging - reflecting the ambitions of the Sustainpack project.[16]

The roadmap initiative did not result in the formation of 'innovative clusters' desired by MinacNed.[17] During a seminar in which the roadmap was presented, participants commented that it was very difficult to bring actors in the food industry together and that they would be hesitant with respect to nanotechnologies. Potential participants were reluctant to take up nanotechnology projects. For them, both the feasibility and manufacturability of these technologies was too uncertain.[18] Actors waited for the availability of (large volumes of) nanotechnology-engineered materials before they were prepared to invest in the development and marketing of nano-engineered products.

Kraft's move to the background as an institutional entrepreneur and thereby putting a partial end to the first round of initiatives, is a further indicator of a changing overall situation. Kraft distanced itself from the NanoteK consortium by moving it to a subsidiary of Altria[19] and the consortium was renamed, possibly out of concern for controversies about risks of nanotechnologies (Feder 2006). Researchers from Kraft attending conferences emphasized that Kraft was only exploring possibilities of nanotechnology, and would take great care when deciding to introduce new nano products (Couttenye/Arora 2006). The overall climate in the food sector had become ambivalent about nanotechnology. This atmosphere is well captured in a phrase from a reporter attending a nanotechnology oriented food & health conference (which I quoted already in the opening paragraph of this paper): "The food industry is hooked on nano-tech's promises, but it is also very nervous" (Renton 2006).

Possible risks of nanotechnology-engineered food packaging were now firmly on the agenda. Another wait-

[16] The Sustainpack program emphasized the importance of risk assessment too, but except for some mapping, no explicit risk research activities were carried out in addition to the technology development activities.

[17] There was an attempt to form such a cluster in the Netherlands, not initiated by MinacNed. Called Nano4Vitality, and aiming at research and pre-competitive development of new nano enabled technologies, it was co-funded by two Dutch provinces. It referred to the roadmap in their call for tenders (Nano4Vitality 2007).

[18] Interview by the author, 19th March 2007.

[19] The Altria Group, previously named Philip Morris Companies, was Kraft's parent company from 1988-2007, see <www.altria.com>.

ing game emerged, now between firms and regulatory agencies. While regulatory schemes were in place, the problem was concrete assessments whether nanomaterials, including food packaging, would pose unacceptable risks. This was not at all straightforward. According to the European Commission's Scientific Committee on Emerging and Newly Identified Health Risks, but also to the European Food Safety Authority (risk assessment body food and feed safety) and US Food and Drug Administration (regulatory agency), more knowledge was required to develop risk assessment methodologies to evaluate potential risks of nanotechnologies (Scientific Committee on Emerging and Newly Identified Health Risks 2006; Food and Drug Administration 2007; EFSA 2008). Firms in the food packaging sector wanted to be assured about the safety of their nano-engineered products before market introduction and preferred clarity on the implementation of regulatory regimes.[20] On the one hand, regulating authorities awaited products so that they could test their compliance with safety regulations. On the other hand, firms in the food sector had become increasingly careful in mentioning their nanotechnology-related activities since mid 2000s, see Berger (2008). Thus, firms and governmental actors were waiting for each other to make the first step. This waiting game formed the backdrop, and created incentives for new institutional entrepreneurship initiatives, to break through this waiting game.

[20] In 2007, the Grocery Manufacturers Association and the Woodrow Wilson International Center for Scholars in the US took up this theme on a collective level and initiated a study to assess regulatory aspects and issues involved in nanotechnology-engineered food packaging materials (Taylor 2008).

4.3 Third round of initiatives: resolving the impasse

In the second half of 2000s a new round of institutional entrepreneurship activities occurred, partly overlapping with the second round. Now, initiatives did not mainly focus on legitimating the combination of nanotechnologies and packaging, but on how nanotechnologies in general should be developed and introduced on the market. While generic in nature, the impact of these initiatives on the food packaging sector lies in the fact that actors involved in these instances of institutional entrepreneurship were also embedded in the food packaging sector. The effect of the new round of initiatives included the resolution of the impasse between actors in the food packaging sector, although these initiatives often did not position themselves explicitly with respect to the food packaging sector.

All these initiatives had in common that they articulated general rules of behavior and ways of dealing with uncertainties about benefits and potential risks of nanotechnologies. Often they were framed as bridging a gap, proposing temporary measures until more certainty on risks and implementation of regulatory schemes existed. A common thread in these initiatives is that they promoted interactions between actors at different positions in the food packaging sector and/or promoted taking into account broader societal aspects.

One such initiative explicitly aiming to address the general impasse is the institutional entrepreneurship activity of DuPont together with Environmental Defense. Already in 2005, DuPont and Environmental Defense published an article, which discussed the need for more research and regulatory practices related to potential risks of nanotechnologies (Krupp/Holliday 2007). They compared nanotechnologies with earlier emerging technologies, which had unintended effects, such as the impact of the release of CFCs on the ozone layer. In their advocacy piece they argued that early assessment of possible risks and enactment of safety standards can "reap the benefits while minimizing the risks." DuPont and Environmental Defense called for 'a collaborative effort' between firms, academia, governments and public interest groups that "could set interim standards for nanotechnology around the world while regulations are under development." Later, their 'collaborative effort' would meet resistance by NGOs, exactly because of the 'interim' character of their approach (Civil Society-Labor Coalition 2007).

In 2007 they launched their Risk Framework 'offering guidance on risk evaluation and management, and communication with stakeholders' (Environmental Defense-Dupont Nano Partnership 2007, 14). The alliance did not position itself with respect to the food packaging sector due to the generic rather than specific nature of their risk framework, but one of the cases they used to 'test' the framework was a new titanium dioxide-based product to protect plastics from sunlight causing changes in color of plastic packaging (ElAmin 2007). They definitely had impact on the food packaging sector, also because the partnership believed that the framework could support a model for government policy on nanotechnology safety.

Governmental authorities also became entrepreneurial by trying to resolve the impasse through voluntary measures rather than top-down policy making. The Department for Environment, Food and Rural Affairs (DEFRA) in the UK was pro-active concerning the uncertainties associated with health and environmental safety issues of nanomaterials (including packaging), through launching a voluntary reporting scheme.[21] The occasion was provided by the UK Food Standards Agency (FSA) 2006 Report, which argued that although there were no major gaps in regulations, there nevertheless existed gaps with respect to risk assessment and information of manufactured nanotechnology products (Food Standards Agency 2006). Following the FSA, DEFRA launched a voluntary scheme in September 2006, a form of 'soft law' (Dorbeck-Jung 2007), to provide the UK government with information on properties and characteristics of new 'free' nano-engineered materials. In particularly it was expected to generate information to test existing regulatory measures. In this way, UK DEFRA aimed to bridge the gap between firms and regulators, with respect to uncertainties related to compliance with regulations. Responses to the scheme were relatively low and UK DEFRA had to put effort in getting responses. In March 2008 the UK Minister for Environment concluded that responses were disappointing and urged firms and researchers to commit to the scheme. The UK Minister hinted that more compulsory measures would be necessary when there was too little commitment to the scheme (Woolas 2008).[22]

A simultaneous approach to cope with uncertainties associated with risks of nanotechnology and implementation of regulatory frameworks was the development and promotion of voluntary codes of conduct.[23] One distributed institutional entrepreneurship initiative also relevant for the food packaging sector was set up by the UK Royal Society, Insight Investment and the Nanotechnology Indus-

---

21 The US's Environmental Protection Agency (EPA) launched its own voluntary 'stewardship program' in 2008 (Environmental Protection Agency 2008).

22 By July 2008 the EPA schema had also received limited responses. Interestingly, some branch organizations recognizing the importance of the scheme for the credibility of the nanotechnology sector, tried to push their members to participate, see (Kearnes/Rip 2009).

23 See also (Bowman/Hodge 2008).

tries Association. In the preparation, health, environmental and safety issues, regulation and voluntary reporting schemes, but also views put forward by NGOs such as the ETC group were topics for discussion (Sutcliffe/Hodgson 2006). One of the identified gaps was that businesses were too little involved in risk assessment developments (Royal Society et al. 2006). A working party was set up, which included actors from the food packaging sector: BASF (material supplier), Tesco (retailer) and Unilever (brand owner). The working party developed a code of conduct to bridge a 'transitional period', before there would be more certainty on implementation of regulatory frameworks. The code promoted a pro-active approach from companies towards assessing and mitigating possible risks of nanotechnologies, including the involvement of stakeholders (Responsible NanoCode 2008).

In 2008, the Swiss retailers organization IG DHS launched, in co-operation with a risk management consultancy, a code of conduct related to the application of nanotechnologies in food and food packaging (Jones 2008). One reason to launch such an initiative was that the Swiss federal government was working on a risk assessment and management framework, but in the meantime relied upon the responsible behavior of producers. They also referred to NGO viewpoints, such as articulated by the ETC Group and Friends of the Earth (Miller/Senjen 2008) regarding mandatory labeling of nano engineered products. Interestingly, IG DHS was explicitly referring to consumers' concerns. The association argued that Swiss consumers valued product information and that local retailers were in favor of labeling of nanoproducts. As retailers could not achieve this by themselves and needed co-operation across the food and packaging chains, a code of conduct could function as a tool to achieve this. The code obliged retailers to "require producers and suppliers to provide all the information necessary for assessing the safety of a product." (IG DHS 2008) IG-DHS was weaving another piece in the patchwork of emerging institutions.

While new initiatives emerged, other activities ended. In 2008, Sustainpack, one of the early entrepreneurial initiatives ended its activities. While the coordinator emphasized at the final conference that the heterogeneous consortium had proved to be able to successfully connect different aspects of packaging and could function as a platform for further developments, there was no clear prospect of continuing institutional entrepreneurship when the project was finished.[24]

4.4 Exploring future developments in the food packaging sector

The three waves of institutional entrepreneurship show how dedicated actors emerged, responding to changing situations in the food packaging sector and beyond. However, they had no apparent lasting effects yet in terms of innovation. By the end of 2008, relatively little was still happening regarding (known) product introductions engineered by nanotechnologies (Chaudhry et al. 2008). On the other hand, there are indicators for the uptake of proposed generic rules and practices. By the end of 2008 the EU confederation of food and drink industries (CIAA) was considering to adopt a code of conduct inspired by the Responsible Nanocode.[25]

What could be happening now? I suggest that there might be a fourth wave of initiatives defining themselves as attempts to break through the impasses, which are widely recognized. The promotion of generic rules and prac-

[24] Observations by the author during Sustainpack's final conference in May 2008.

[25] Observations by the author during Nanotechnology & the law conference in Leuven (2008).

tices about responsible development of nanotechnologies further paved the way for new institutional entrepreneurship. To explore this suggestion I refer to the scenarios we constructed for a stakeholder workshop about nanotechnology and food packaging.

The three scenarios had different starting points for institutional entrepreneurship: a group of technology developers revamping sustainability promises of nanotechnology engineered packaging materials; some pro-active regulators creating a financial safety net for liability claims; and a broad stakeholder platform exploring technological options and stakeholder requirements. Each scenario then explored actions and reactions, and shifts and changes over time. This is not the place to go into details. Suffice to say that none of the scenarios had an across the board uptake and acceptance of nanotechnology engineered products in food packaging as its outcome. Each initiative had limitations (up to blind spots), which created constraints on their uptake and the eventual outcome. They added a patch to the patchwork. The stakeholder platform achieved the most, which indicates the importance of such broad spaces for interaction, but in the scenario it eventually collapsed because the broad variety of participants led to internal struggles.

During the workshop, participants recognized the importance of co-ordination and the relevance of a broad stakeholder platform, and were interested in institutional entrepreneurship initiatives to create a breakthrough. Still, waiting games appeared to be on their minds. They were cautious about co-operation with other players and taking an initiative. Participants waited for their upstream or downstream partners to come up with concrete proposals (and materials). Their arguments referred to the importance of short term (3 years) return on investment, and pointed out uncertainties about actual performance (added value) of new packaging materials and whether these would fit existing production equipment. Anticipation on societal embedding was considered important, so important that one of the participants was willing to stop a nanotechnology food packaging product development trajectory, if there were concerns about lacking sustainability.

While the fourth wave of institutional entrepreneurs, possibly leading to sector-level changes, might draw on actors embedded in the food packaging sector, the latter appear to be constrained by the present structures and the attendant waiting games. Other actors, embedded in multiple sectors (like materials suppliers) and/or with an interest or stake in the embedding of nanotechnologies (as in the alliances between nanotechnology promoters and government funding agencies), will be more prepared, and more able, to start entrepreneurship initiatives. Authorities can introduce new patterns, such as standards or testing procedures to test compliance with regulatory proposals. This fourth wave and activities of authorities would further reduce uncertainties on societal embedding of nanotechnologies in the food packaging sector.

5 Conclusions

Through the lens of tracing institutional entrepreneurs and their activities, I was able to show a pattern of development in the food packaging sector where rules and practices emerged before the envisaged nano-enabled technologies entered the market. Anticipation on eventual embedding of these technologies drove the institutional entrepreneurs. Over time, further aspects of eventual embedding became important, and other kinds of institutional entrepreneurs became involved, including NGOs and regulatory agencies introducing voluntary schemes. The net effect is the emergence of a patchwork of rules and practices which extend further than industry structures as traditionally conceived. It is this patchwork which will act as a 'soft' framing condition for further developments in the uptake and embedding of nanotechnologies in the food packaging sector.

Considering how this patchwork emerged, there are, of course, factors and circumstances specific to the food packaging sector. But there are also general dynamics related to the uncertainties inherent to emerging technologies. This is clear in the waves of institutional entrepreneurship that were found. In the beginning, around 2000, the uncertainty about the eventual performance of nanotechnologies was addressed by actors promoting the legitimacy of the combination of nanotechnologies and food packaging technologies. This first 'wave' of dedicated initiatives was followed by a second wave in which other actors pushed for the incorporation of broader societal aspects and risks in embedding nanotechnologies in the packaging sector. Initial enthusiasm for nanotechnologies shifted to caution. Uncertainties related to risk assessment created a further waiting game between firms and regulatory authorities, in a sector which was already prone to the emergence of waiting games. Then, institutional entrepreneurship initiatives emerged that tried to break through these waiting games and overcome reluctance. Many of the initiatives, while focused on risk issues, maintained an appreciation of the potential benefits of nanotechnologies, but that did not lead to dedicated entrepreneurship promoting nanotechnology engineered materials. This implies that the whole notion of 'responsible development' of nanotechnology became important and that it became illegitimate to go for just promotional institutional entrepreneurship. Still, it might be possible that such institutional entrepreneurship occurs. One of the scenarios speculating on a next wave of activities did include such type of activities, but ran aground on waiting games in the food packaging sector. A next wave will likely be initiated by actors with broader interests than just food packaging, such as material suppliers, or coalitions of actors across the innovation and product value chain.

Thus, the conclusion about how a patchwork of anticipation-oriented patterns is emerging at the sector-level, before these technologies enter the market, extends beyond the food packaging sector. For all new and emerging technologies uncertainties have to be reduced to overcome waiting games. Such reductions will start with the promises of emerging technologies, and then address possible concerns. Actually, waiting games are also a reduction of uncertainties, by doing nothing (which will not appeal to technology promoters).

The nature of the reduction of uncertainties between supply and demand, and with respect to regulation up to broader societal acceptance will depend on the composition of the value chain and articulation of regulations (formal and informal) at the level of a sector. In the case of food packaging, intersecting value chains introduced specific complexities and uncertainties (such as the world of food, sensitive to public acceptance). In other sectors, such as micro/nanoelectronics, public acceptance is not a prominent issue. For new nano-enabled materials and surfaces, there appears to be broad public acceptance, but some consideration of risk, with reference to nano-particles. Particularly important, given the enabling character of nanotechnologies, is that intersecting value chains will occur more often, as with nano-engineered delivery systems for pharmaceuticals (drugs) and nutriceuticals (food). Preliminary data of my ongoing research in the drug delivery sector show a first wave of institutional entrepreneurship to promote and legitimize a link between the promise and possible use, but no second wave (yet).

Thus, the basic dynamics involved in developing and introducing new and emerging technologies in sectors of industry are carried by attempts at reduction of uncertainties, embedded in, and contributing to, sector-level development. This insight is not only a contribution to our understanding of new and emerging technologies. It also adds to the analysis of industrial change by including the dynamics of emerging technologies and how these incite anticipatory action of institutional entrepreneurs which, in addition to their immediate effects on product development, introduce further legitimation requirements and broaden industry structures.

In general, analyses of industrial change processes need to take into account emerging anticipatory patterns and distributed institutional entrepreneurship. Conversely, studies of institutional entrepreneurship need to take into account the distributed and embedded character of institutional entrepreneurship and emerging industry structures.

6 Acknowledgements

The author acknowledges important contributions and suggestions for the development of this paper from Arie Rip, and is grateful to the Editors, and to Bärbel Dorbeck-Jung, Martin Ruivenkamp and Louis Neven for their helpful comments and suggestions. This research is part of the Technology Assessment program of the R&D consortium NanoNed in the Netherlands (www.nanoned.nl).

7 References

Aldrich, Howard E. /C. Marlene Fiol, 1994: Fools rush in? The institutional context of industry creation. In: *Academy of Management Review* 19, 645-670.

Alfranca, Oscar et al., 2004: Innovation spells in the multinational agri-food sector. In: *Technovation* 24, 599-614.

Anonymous, 2005: *Nanotechnology sales increase to €687.5m in 2004*. Retrieved 31-03, 2010. <www.foodproductiondaily.com/content/view/print/119706>

Barlow, Sue et al., 2009: Scientific Opinion of the Scientific Committee on a request from the European Commission on the Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety. In: *The EFSA Journal* 958, 1-39.

Battilana, Julie, 2006: Agency and Institutions: The Enabling Role of Individuals' Social Position. In: *Organization* 13, 653-676.

Battilana, Julie et al., 2009: How Actors Change Institutions: Towards a Theory of Institutional Entrepreneurship. In: *The Academy of Management Annals* 3, 65-107.

Beckeman, Märit/Christina Skjöldebrand, 2007: Clusters/networks promote food innovations. In: *Journal of Food Engineering* 79, 1418-1425.

Berger, Michael, 2008: *Food nanotechnology - how the industry is blowing it*. Retrieved 20-08-2008, 2008. <www.nanowerk.com/spotlight/spotid=5305.php>

Borup, Mads et al., 2006: The Sociology of Expectations in Science and Technology. In: *Technology Analysis & Strategic Management* 18, 285-298.

Bowman, Diana M. /Graeme A. Hodge, 2008: 'Governing' nanotechnology witout government? In: *Science and Public Policy* 35, 475-487.

Brody, Aaron L. et al., 2008: Innovative Food Packaging Solutions. In: *Journal of Food Science* 73, 107-116.

Caul, Mark, 2007: *Packaging and the environment: A retailers perspective* Packaging Summit Europe, 26-27 June Amsterdam.

Chaudhry, Qasim et al., 2008: Application and implications of nanotechnologies for the food sector. In: *Food Additives and Contaminants* 25, 241-258.

Civil Society-Labor Coalition, 2007: *Civil Society-Labor Coalition Rejects Fundamentally Flawed DuPont-ED Proposed Framework*. Retrieved 09-08-2007, <www.etcgroup.org/upload/publication/610/01/coalition_letter_april07.pdf>

Cottica, Alberto, 1994: *The microeconomics of environmental innovation in the European packaging industry* Fifth Annual Conference of the European Association of Environmental and Resource Economists, 22-24 June Dublin.

Couttenye, Richard /Vijay Arora, 2006: *Nano4Food: Separating Fact from Fiction*. Nano4Food, 12-13 October Atlanta

Deuten, J. Jasper et al., 1997: Societal Embedding and Product Creation Management. In: *Technology Analysis & Strategic Management* 9, 131-148.

DiMaggio, Paul, 1988: Interest and agency in institutional theory. In: L. Zucker, *Institutional patterns and culture*. Cambridge, MA: Ballinger Publishing Company, 3-22.

Dorado, Silvia, 2005: Institutional Entrepreneurship, Partaking, and Convening. In: *Organization Studies* 26 3, 385-414.

Dorbeck-Jung, Bärbel R., 2007: What can Prudent Public Regulators Learn from the United Kingdom Government's Nanotechnological Regulatory Activities? In: *NanoEthics* 1, 257-270.

Doyle, M. Ellin, 2006: *Nanotechnology: A Brief Literature Review.* Madison: University of Wisconsin-Madison, Food Research Institute.

EFSA, 2008: *Draft Opinion of the Scientific Committee on the Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety.* Parma, Italy: European Food Safety Authority.

ElAmin, Ahmed, 2007: *New nano product protects plastic from sunlight*. Retrieved 30-07-2007, <www.foodproductiondaily.com/news/printNewsBis.asp?id=77603>

Environmental Defense-Dupont Nano Partnership, 2007: Nano Risk Framework. Washington DC & Wilmington, DE: Environmental Defense & Dupont.

Environmental Protection Agency, 2008: *Nanoscale Materials Stewardship Program*. Retrieved 27-10-2008, <www.epa.gov/oppt/nano/stewardship.htm>

ETC Group, 2003: *The Big Down. Atomtech: Technologies Converging at the Nanoscale.* ETC Group.

ETC Group, 2004: *Down on the farm: The Impact of Nano-scale Technologies on Food and Agriculture.* Ottowa (Canada): Action group on Erosion, Technology and Concentration.

Feder, Barnaby J. (2006). Engineering Food at Level of Molecules. The New York Times: pp. N.A.

Fones, Mardy (2005). Bite-by-Bite Science. New York Stock Exchange. 5: 9.

Food and Drug Administration, 2007: *Nanotechnology: A Report of the U.S. Food and Drug Administration Nanotechnology Task Force.* Rockville: Food and Drug Administration.

Food Standards Agency, 2006: *Draft report of FSA regulatory review*. Retrieved 13-03-2008, <www.food.gov.uk/multimedia/pdfs/nanotech.pdf#page=4>

Gardner, Elizabeth, 2002a: *Brainy food: Academia, industry sink their teeth into edible nano*. Retrieved 13-03-2008, <www.smalltimes.com/Articles/Article_Display.cfm?ARTICLE_ID=267909&p=109>

Gardner, Elizabeth, 2002b: *Chief sees great opportunity in building a better nanoclay*. Retrieved 12-02-3008, <www.smalltimes.com/articles/article_display.cfm?Section=ARCHI&C=Consu&ARTICLE_ID=267746&p=109>

Garud, Raghu et al., 2002: Institutional entrepreneurship in the sponsorship of common technological standards: the case of Sun Microsystems and Java. In: *Academy of Management Journal* 45, 196-214.

Garud, Raghu/Peter Karnøe, 2003: Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. In: *Research Policy* 32, 277-300.

Garud, Raghu et al., 2007: Institutional Entrepreneurship as Embedded Agency: An introduction to the Special Issue. In: *Organization Studies* 28, 957-969.

Garud, Raghu, 2008: Conferences as Venues for the Configuration of Emerging Organizational Fields: The Case of Cochlear Implants. In: *Journal of Management Studies* 45, 1061-1088.

Goho, Alexandra, 2004: Hungry for nano: the fruits of nanotechnology could transform the food industry. In: *Science News* 166, 200-201.

Granovetter, Mark /Patrick McGuire, 1998: The making of an industry: electricity in the United States. In: M. Callon, *The Laws of the Markets*. Oxford (UK) - Malden (USA): Blackwell Publishers, 147-173.

Greenwood, Royston et al., 2002: Theorizing change: The role of professional associations in the transformation of institutionalized fields. In: *Academy of Management Journal* 45, 58-80.

Halliday, Jess, 2007: *EFSA opens the floor on nanotechnology*. Retrieved 13-03-

2008, <www.foodnavigator.com/news/ng.asp?n=81616-efsa-nanotechnology>

Hargadon, Andrew B. /Yellowlees Douglas, 2001: When Innovations Meet Institutions: Edison and the Design of Electric Light. In: *Administrative Science Quarterly* 46, 476-501.

IG DHS, 2008: *Factsheet Code of Conduct for nanotechnologies*. Retrieved 23-10-2008, 2008. <www.igdhs.ch/m/mandanten/190/topic6220/story14345.html>

Jain, Sanjay/Gerard George, 2007: Technology transfer offices as institutional entrepreneurs: the case of Wisconsin Alumni Research Foundation and human embryonic stem cells. In: *Industrial and Corporate Change* 16, 535-567.

Johanssen, Kennert, 2008: *How the SustainPack Project came about* Retrieved 01-12-2008, <www.sustainpack.com/about.html>

Jones, Chris, 2008: *Swiss food retailers demand information on nanotech*. Retrieved 23-10-2008, 2008. <www.foodproductiondaily.com/Processing/Swiss-food-retailers-demand-information-on-nanotech>

Kearnes, Matthew B. /Arie Rip, 2009: The emerging governance landscape of nanotechnology. In: S. Gammel, A. Lösch and A. Nordmann, *Jenseits von Regulierung: Zum politischen Umgang mit der Nanotechnologie*. Berlin: Akademische Verlagsgesellschaft,

Krupp, Fredd /Chad Holliday, 2007: *Let's Get Nanotech Right*. Retrieved 10-03-2008. <www.edf.org/article.cfm?contentID=5952>

Lagarón, J.M. et al., 2005: Improving packaged food quality and safety. Part 2: Nanocomposites. In: *Food Additives and Contaminants* 22 10, 994-998.

Lampel, Joseph /Alan D. Meyer, 2008: Guest Editors' Introduction: Field-Configuring Events as Structuring Mechanisms: How Conferences, Ceremonies, and Trade Shows Constitute New Technologies, Industries, and Markets. In: *Journal of Management Studies* 45 6, 1025-1035.

Lawrence, Thomas B. /Roy Suddaby, 2006: Institutional work. In: S. Clegg, C. Hardy and T. Lawrence, *Handbook of Organization Studies*. London: Sage, 215-254.

Leca, Bernard et al., 2008: *Agency and Institutions: A Review of Institutional Entrepreneurship.* Harvard Business School.

Lewis, Helen, 2005: Defining product stewardship and sustainability in the Australian packaging industry. In: *Environmental Science & Policy* 8, 45-55.

Lounsbury, Michael/Ellen T. Crumley, 2007: New Practice Creation: An Institutional Perspective on Innovation. In: *Organization Studies* 28, 993-1012.

Maguire, Steve et al., 2004: Institutional Entrepreneurship in emerging fields: HIV/AIDS treatment advocacy in Canada. In: *Academy of Management Journal* 47 5, 657-679.

Malerba, Franco, 2002: Sectoral systems of innovation and production. In: *Research Policy* 31, 247-264.

Manolis Sherman, L., 2004: Chasing Nanocomposites. In: *PlasticsTechnology* 11, 56-61.

McCray, W.P., 2005: Will Small be Beautiful? Making Policies for our Nanotech Future. In: *History and Technology* 21 2, 177-203.

Miller, Georgia /Rye Senjen, 2008: *Out of the laboratory and on to our plates: Nanotechnology in Food & Agriculture*. Retrieved 15-02-2008, <nano.foe.org.au/node/26>

MinacNed, 2007: *Missie en doelstellingen*. Retrieved 12-08-2007, <www.minacned.nl/nl/over/missie.php>

Moore, Graham, 2004: *What does nanotechnology mean for you?* The Future of Nanomaterials, 29-30 June Birmingham (UK)

Munir, Kamal A. /Nelson Philips, 2005: The Birth of the 'Kodak Moment': Institutional Entrepreneurship and the Adoption of New Technologies. In: *Organization Studies* 26, 1665-1687.

Nano4Vitality, 2007: *Nano4Vitality Programma*. Retrieved 23-10-2008. <provincie.overijssel.nl/contents/pages/115742/programmadocument_n4vopsite.pdf>

Nanologue, 2006: *Nanologue Opinions on the Ethical, Legal and Social Aspects of Nanotechnologies - Results from a Consultation with Representatives from Research, Business and Civil Society*. Retrieved 08-03-2007, <www.nanologue.net>

Nanowerk News, 2007a: *Broad international coalition issues urgent call for strong nanotechnology oversight* Retrieved 13-03-2008, <www.nanowerk.com/news/newsid=2306.php>

Nanowerk News, 2007b: *Nanotechnology solutions for the packaging waste problem* Retrieved 01-08-2007, <www.nanowerk.com/news/newsid=1852.php>

Nelson, Richard R., 1995: Co-evolution of Industry Structure, Technology and Supporting Institutions, and the Making of Comparative Advantage. In: *International Journal of the Economics of Business* 2, 171-184.

Nieuwesteeg, Michael, 2007: *Fundamentals of sustainability in packaging*. Packaging Summit Europe, 26-27 June Amsterdam

Østergaard, Søren, 2008: *Communicative Packaging in Real Life*. Sustainpack Conference, 6-7 May Prague

Philips, Nelson et al., 2004: Discourse and Institutions. In: *Academy of Management Review* 29, 635-652.

Pira International, 2003: *Packaging in the 3rd Millennium: Competitiveness Study for The Packaging Industry in the UK*. Retrieved 04-12-2007, <www.packagingfedn.co.uk/>

Prisma & Partners /MinacNed, 2006: *Roadmap Microsystem- & Nanotechnology in Food & Nutrition.* Warnsveld - Amersfoort: Prisma & Partners, MinacNed:

Renton, Alex, 2006: *Welcome to the world of nano foods*. The Observer Retrieved 11-01-2007, <www.informationliberation.com/print.php?id=18893&PHPSESSID=023bbdfafa12497e768d4ad1ca7e3d79>

Responsible NanoCode, 2008: *The Responsible NanoCode - update May 2008*. Retrieved 27-10-2008. <www.responsiblenanocode.org>

Rip, Arie /Haico te Kulve, 2008: Constructive Technology Assessment and Socio-Technical Scenarios. In: E. Fisher, C. Selin and J. M. Wetmore, *The Yearbook of Nanotechnology in Society, Volume 1: Presenting Futures*. Springer, 49-70.

Rip, Arie /Marloes Van Amerom, 2009: Emerging *De Facto* Agendas Surrounding Nanotechnology: Two Cases Full of Contingencies, Lock-outs, and Lock-ins. In: M. Kaiser, M. Kurath, S. Maasen and C. Rehmann-Sutter, *Governing Future Technologies: Nanotechnology and the Rise of an Assessment Regime*. Springer, 131-155.

Rip, Arie /Jan-Peter Voß, 2009: *Umbrella terms in the governance of emerging science and technology: bridging the tension between relevance and scientific advantage*. Governance von Zukunftstechnologien, Tagung des AK "Politik und Technik" der Deutschen Vereinigung für Politische Wissenschaft, 22 May, Berlin.

Royal Society et al., 2006: *How can business respond to the technical, social and commercial uncertainties of nanotechnology?: Workshop report*. Retrieved 27-10-2008. <www.responsiblenanocode.org/documents/Workshop-Report_07112006.pdf>

Sandgren, Kevin, 1996: Material Flow Analysis for an Industry--A Case Study in Packaging. In: *Nonrenewable Resources* 5, 235-247.

Scharpf, F.W., 1997: *Games Real Actors Play: Actor - Centered Institutionalism in Policy Research.* Boulder, CO/Oxford: Westview Press.

Scientific Committee on Emerging and Newly Identified Health Risks, 2006: *The appropriateness of existing methodologies to assess the potential risks associated with engineered and adventitious products of nanotechnologies.* Brussels: European Commission.

Scott, Richard W. /John W. Meyer, 1994: The Organization of Societal Sectors: Propositions and Early Evidence. In: W. W. Powell and P. J. Dimaggio, *The New Institutionalism in Organizational Analysis*. Chicago and London: The University of Chicago Press, 108-140.

Sherman, Lilli Manolis, 1999: Nanocomposites--A Little Goes A Long Way In: *Plastics Technology* 6, 52-56.

Siegrist, Michael et al., 2008: Perceived risks and perceived benefits of different nanotechnology foods and nanotechnology food packaging. In: *Appetite* 51, 283-290.

Sonneveld, Kees, 2000: What Drives (Food) Packaging Innovation? In: *Packaging Technology and Science* 13, 29-35.

Sutcliffe, Hilary /Simon Hodgson, 2006: *Briefing paper: An uncertain business: the technical, social and commercial challenges presented by nanotechnology.* London: Acona.

Taylor, Michael R., 2008: *Assuring the safety of nanomaterials in food packaging: The Regulatory Process and Key Issues.* Washington: Woodrow Wilson International Center for Scholars.

Thomas, Jim, 2006: *Analysing the Societal, Health and Environmental Impacts From a Civil Society Perspective.* Nanotechnology in Food and Agriculture, June 7 Washington

Van Lente, Harro /Arie Rip, 1998: The Rise of Membrane Technology: From Rhetorics to Social Reality. In: *Social Studies of Science* 28, 221-254.

Wal-Mart, 2007: *Wal-Mart Pledges Packaging Reduction*. Retrieved 05-03-2007,

<www.walmartstores.com/GlobalWMStoresWeb/navigate.do?catg=677>

Woolas, Phil, 2008: *The UK voluntary reporting scheme for engineered nanoscale materials*. Retrieved 23-10-2008. <www.defra.gov.uk/ENVIRONMENT/nanotech/pdf/vrs-letter-p-woolas.pdf>

World Packaging Organisation /Pira International, 2008: *Market Statistics and Future Trends in Global Packaging*. Retrieved 01-12-2008. <www.worldpackaging.org>

Wullweber, Joscha, 2008: Nanotechnology - An Empty Signifier à Venir? A Delineation of a Techno-socio-economical Innovation Strategy. In: *Science, Technology and Innovation Studies* 4, 27-45.

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI
Studies
www.sti-studies.de

Strategies for the Scientific Progress of the Developing Countries in the New Millennium

The case of Serbia in comparison with Slovenia and South Korea

Vuk Uskoković (University of California, San Francisco, CA, USA)
Milica Ševkušić (Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, Serbia)
Dragan P. Uskoković (Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, Serbia)

received 9 December 2009, received in revised form 21 June 2010, accepted 25 June 2010

Abstract

The underlying premise of this essay is the hypothesis that quality and significance of scientific research in any given society could be used as mirrors reflecting its true prosperity. By comparing the two cases of comparatively prosperous scientific management of South Korea and Slovenia, with the example of Serbia, illustrating the poor scientific and industrial productivity typically faced by the developing countries, a few general guidelines for the evolution of a society towards higher scientific and social prominence are outlined. It is argued that the most favourable pattern of growth should be based on the parallel progress in control of scientific policies on one side and the excellence of scientific and basic education on the other. The "leapfrog" tactics, according to which the less developed countries should learn from the natural cycle of alternate progressions and regressions that the developed countries experience, is especially highlighted. Applied research is demonstrated to be most productive when it is carried out on top of already established and prolific infrastructural and industrial bases. Examples are given in favour of the fact that the technological design and industrial solutions shown as successful in the context of a developed society, often turn out to be impractical and inefficient when straightforwardly transformed to less developed social settings. As a result, the strategy of adjustment of production capacities to local needs is advised to be considered when implementing a new technology on different social, political and economic grounds. Finally, it is concluded that to provide conditions for effective transfer and implementation of advanced know-how and novel technologies, embedment into international science and engineering networks is required as much as strong and sustainable local scientific and technological bases.

"There is something within me that might be illusion as it is often case with young delighted people, but if I would be fortunate to achieve some of my ideals, it would be on the behalf of the whole of humanity. If those hopes would become fulfilled, the most exciting thought would be that it is a deed of a Serb." (Nikola Tesla, Address at the Belgrade Train Station, June 1, 1892)

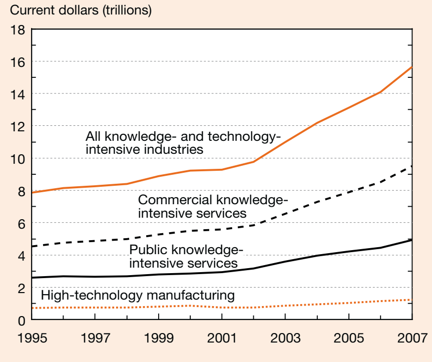
1 Introduction

Innumerable studies have been conducted in support of the view that quality and significance of scientific research in any given society could be seen as mirrors of its long-term prosperity. Scientific excellence looped with high levels of industrial productivity and openness to innovation has been considered as grounds for thriving global economies (Inter Academy Council 2004). An OECD report has concluded that "links to science are more important than in the past" and called for an inevitable "intensification of industry–science relationships in the knowledge economy" (OECD 2002). Fig. 1 nicely illustrates that knowledge- and technology-intensive economies create well paid jobs, contribute to the local economy with a high-value output, and ensure economic competitiveness, which shows that knowledge-intensive industries have grown exponentially in the past decade and more rapidly than other segments of economic activity. A continual rise in the science and engineering occupation share of total civilian employment has thus been evident in the US and other developed countries of the world (NSB 2004).

On the other hand, we seem to live in a world in which inequalities and ill distribution of wealth present some of the crucial social factors of its instability and non-sustainability. To illustrate this, Fig. 2 demonstrates the disparity between rich and poor countries of the world by the champagne-glass shaped distribution of the global income, showing that the poorest 20 % of the human population hold less than 1 % of the global wealth, whereas the richest 20 % are associated with more than 85 % of the world GDP (UNDP 1999, Watkins 2006). The aim of this report is to provide a perspective on some of the essential relationships that could be used in directing the planetary growth towards amelioration of the problem of inequality and finding the ways to fruitfully incorporate the cutting-edge scientific practice into less developed regions and countries of the world.

The implicit assumption that the following discourse will be based on is that science, seen as fundamentally underlying the prosperity of a society, can be used as the most direct tool in levelling the disparity in development between wealthy and poor countries of the world. Two cases of comparatively prosperous management of science and technologies (S&T), that is, of South Korea and Slovenia, are thus presented with the aim of finding the principles that would help to outline the convenient policies and progressive directions for the developing countries, the example of which is in this work taken to be Serbia.

Figure 1: Global value added of knowledge- and technology-intensive industries for the time period of 1995–2007. Source: NSB 2010.

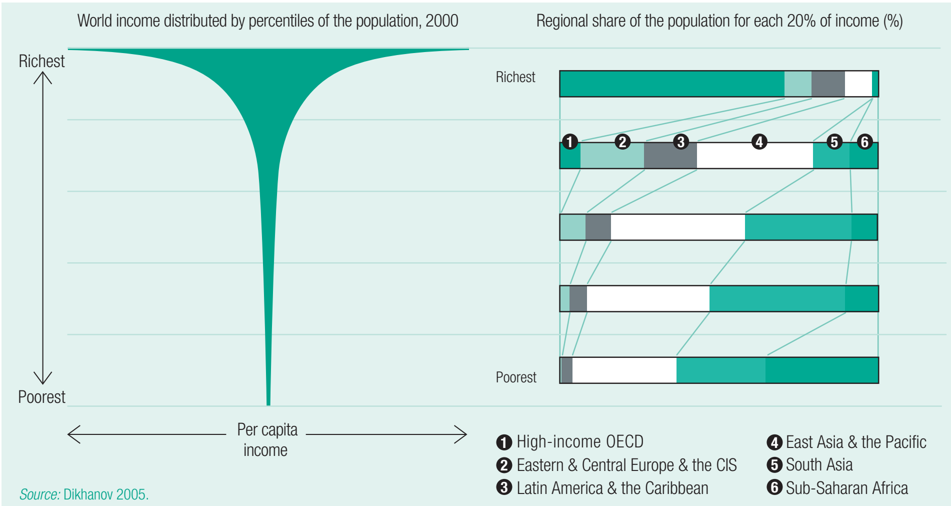


NOTES: Industries defined by Organisation for Economic Co-operation and Development. See glossary for definitions of knowledge-intensive services and high-technology manufacturing.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations.

Science and Engineering Indicators 2010

Figure 2: The disparity between rich and poor countries of the world demonstrated by the champagne glass shaped world income distribution in percentiles of the population (left), and shares in the world wealth held by populations from different regions of the world (right). Source: Watkins 2006



Methods

In this work we provide a few systemic guidelines for the design of science policies for underdeveloped countries, while referring to some of the basic criteria for the evaluation of progress in all scientific disciplines. The chosen parameters for this assessment partly belong to the S&T Indicators for European Research Area (STI-ERA) and have been regularly used for this purpose (European Commission 2007; Turlea et al. 2010). Serbia is going to form the central element in the discourse at hand. South Korea and Slovenia were chosen to provide a constructive contrasting comparison with the case of Serbia on the one hand, because Eurostat has provided annual statistic comparisons with South Korea, and on the other hand because of the increasing social prosperity that has been connected to appropriate S&T policies. As countries that enabled this path, after eras of economic and public safety turmoil, they may demonstrate how to substitute the downward path of warfare, poverty and international isolation with that of scientific prominence, economic prosperity and worldwide recognition. What makes Slovenia and Serbia comparable is the fact that they once shared a common political system within the former Yugoslav constitution. The funding and management in their R&D sectors once conformed to the same practices, and after the dissolution of the former Yugoslavia they also inherited the same educational traditions.

This paper also presents an analysis of various statistical and bibliometric indicators of progress in research. Such analyses have been a widely accepted tool for assessing the quality of the scientific output of countries or institutions (Alik 2008, Gupta/Dhawan 2009, Csajbók et al. 2007). Several such analyses were carried out with the aim of assessing the scientific productivity of Serbia and other former Yugoslav countries (Jovanović et al. 2010, Lewison/Igic 1999, Igić 2002, Bencetić Klaić/Klaić 2004, Sambunjak et al. 2008, Lukenda 2006, Andreis/Jokić 2008). Details regarding the bibliometric analysis method that we have used are given in the Appendix.

2 The case of South Korea

Many developing countries are nowadays facing similar challenges as the ones faced by South Korea prior to setting forth an aim to transform its society from the war stricken society of the 1950s, to the one marked with scientific and technological prominence of today (Oh 2007). South Koreans have demonstrated that with appropriate social and scientific policies, an extraordinarily high rate of development could be attained. As such, South Korea sets an example for numerous countries in the embryonic stages of scientific development.

2.1 Investments in R&D

The South Korean science policy has been typified by exceptionally high investments in R&D. By investing 3.5 % of its GDP to research, South Korea is a world leader in the governmental support of R&D (DESTATIS 2009) (Fig. 3). Although South Korea was considered a poor country in the early 1960s, it increased the per-capita GDP by 7 % by 1990, mostly owing to an export-oriented economic strategy and investments in innovative industrial production (Rodrik 1995). In the early 1990s, connections between academia and private industries were established, endowing the universities with a more entrepreneurial role and transforming them from primarily teaching-oriented to research-oriented centres, which resulted in the rise in research productivity (Eom/Lee 2010).

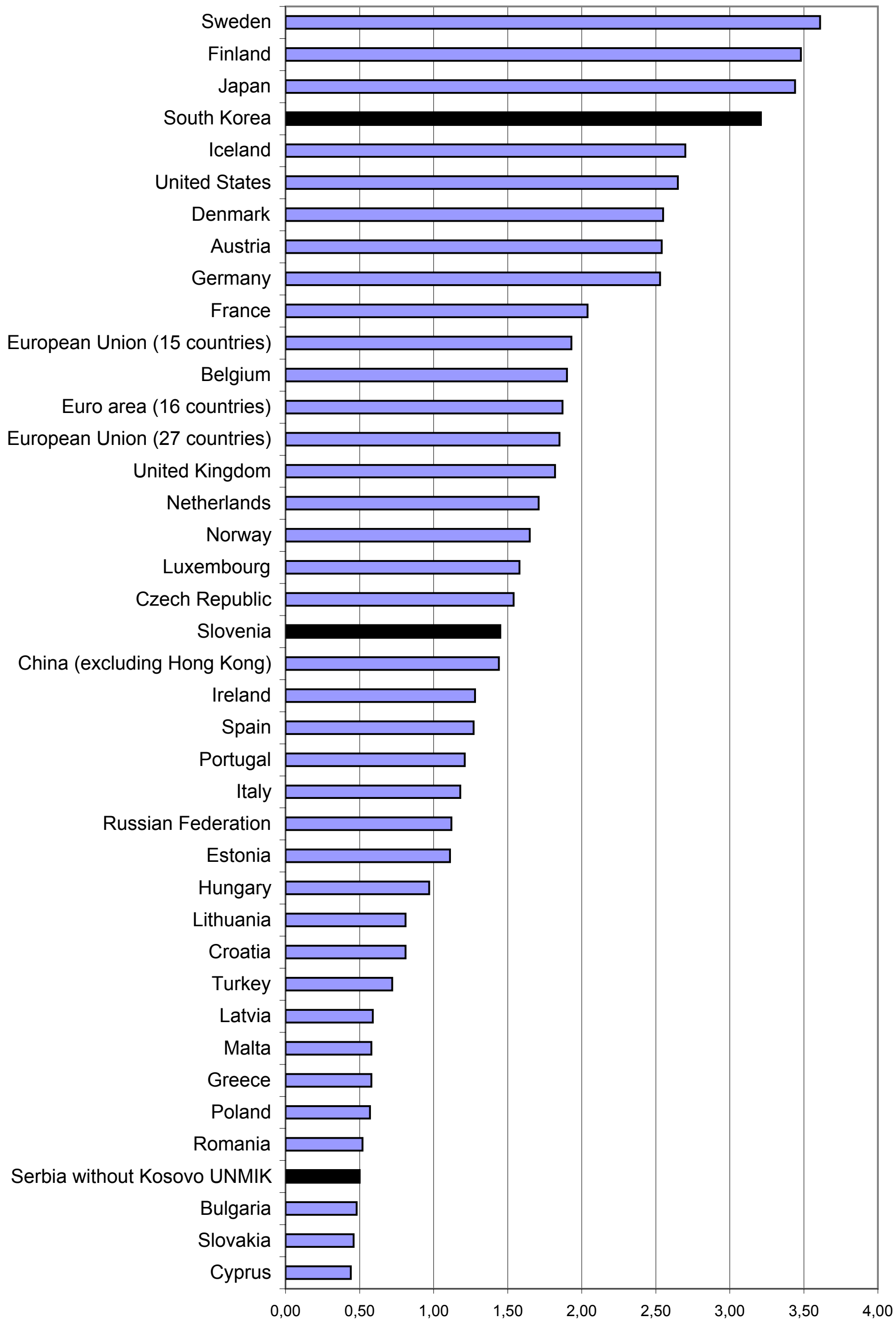
Patenting of scientific inventions has been equally encouraged, and South Korea currently ranks first on the list of the number of patents per GDP worldwide (Mahlich 2007). The 1997 crisis was blamed on the dependence of the South Korean economy on only a few key industries, and since then the industrial diversification and the development of a broad range of high-tech projects and activities has been incentivized by the government (Tearse 2008). Also, in 1967, a special governmental agency was created with to attract outstanding South Korean scientists from abroad. Excellent job opportunities for college graduates were provided too, so that nowadays more than 80 % of high-school graduates decide to enrol in one of the colleges (Hyeon 2007).

2.2 Adverse effects

However, each pattern of growth in its wake inevitably produces a set of adverse effects, which, on the other hand, provide opportunities for further research and growth (Uskoković 2009b). In view of that, a few detrimental consequences of the progressive path of the South Korean scientific society should be mentioned as well. One of them is the strong pressure for scientists to publish in order to maintain and strengthen their faculty positions. The number of publications is, thus, frequently regarded as more important than their quality, which spurs scientists to publish their works prematurely and in less prominent journals, resulting in low citation frequency of South Korean researchers when normalized to the total number of publications in comparison with other scientific powers of the world.

Another side effect of the South Korean S&T policy has been placing too much emphasis on applied research and too little on the fundamental. In fact, only 10 % of all grant applications in basic sciences are approved with the overall spending also at ~10 % of the total R&D budget. This is in spite of the fact that as of 2009, 3.5 % of the state budget is allocated to research, and by 2012 South Korea plans on reaching 5 % and becoming the world's leading country in terms of the amount funding normalized to GDP (Tong-Hyung 2009). Furthermore, with the government share in research investments of 25 %, the portion of basic science projects funded from the budget is only 2.5 % of the total. Communication between de-

Figure 3: Total R&D investments for different countries expressed in GDP percentages. Sources are given in Table 4.



partments within any given research institution is said to be low, and they mostly function in isolation from each other, which presents an obstacle for multidisciplinary research. Competition for funds has, just as in many other academic institutions in the developed world, left scientists without a broad technical and administrative support (Oh 2007). Promotion and compensation mechanisms at South Korean universities are still largely based on the number of years spent in service, although some institutions have adopted salary schemes based on the number of published papers and their impact on the national economy (Nature Materials 2007a). Finally, only 10 % of the South Korean faculty members and less than 15 % of all the researchers are women (Fig. 11), which indicates that the intellectual potential of the country has not been exerted to its full capacity. The results of a SWOT analysis of the South Korean R&D sector are presented in Table 1.

3 The case of Slovenia

Slovenia is regarded as a country with one of the most impressive combinations of GDP, life standard, economic prosperity and scientific productivity among the members of the EU that joined the latter in 2004. Its current growth rate with respect to technological performance is above the EU average, and it is the only accession country that spent more than 1.5 % of its GDP on research and development in early 2000s, and the only one that produced more than 415 publications per million inhabitants (Nature Materials 2004). Despite the fact that shrinkage of the local market that followed the collapse of the Yugoslav constitution forced many industries to undergo restructuring, downsizing or even bankruptcy, with proper revitalization incentives from the government level and an openness of academic research to cooperation with industry, an ascending trend in S&T performance has been made possible.

3.1 Strategies of growth

Promotion of academic research partnerships with various national and international industries has been seen in Slovenia as the most important incentive for scientific productivity and

Table 1: SWOT analysis of the South Korean R&D sector.

Strengths	Weaknesses	Opportunities	Threats
One of the highest rates of state investments in science and engineering in the world	Lack of openness to integrate foreign researchers in local academia and industry	Pushing the industry-academia partnerships, which are already one the leading in the world, to a new level	Too little of emphasis placed on fundamental research versus the applied one
Excellent level of industry-academia partnership	Low level of interdepartmental communication and interdisciplinary collaborations	Benefiting from promotion of cross-disciplinary research	A period of stagnation may follow the actual period of intensive growth, as they have alternated in the past
Well-developed industry-based research with a large share of the global market	Low technical and administrative support	Bringing in foreign talented students and postdocs and integrating them in the Korean science system	"Publish or perish" pressure may lead to publication quantity being given greater importance over their quality
Being one of the most technologically advanced countries, a leader in electronic communications	Low percentage of female scientists	Introducing a salary scheme based not only on the number of published papers, but on their impact on the national economy too	Uncompetitive promotion and compensation mechanisms may lower scientific productivity
High levels of international research cooperation activity, including both academic and private scientific centers	Low citation frequency of publications originating in Korean scientific institutions	Introducing innovative programs to attract students to science careers, such as Brain Korea 21	Weak technical and administrative support may hinder the research efficiency

technological success (Kornhauser 2000). For example, a single department within Jožef Stefan Institute, Department of Advanced Materials, with less than 20 employees, has maintained a persistent cooperation with a dozen of national and international industries in the past decade.

Among business corporations, smart innovation policies resulted in the public company, Gorenje, becoming one of the eight largest European manufacturers of white goods with a 4% share of the European market in 2006. In 2004, as part of the efforts to extend its links to R&D domain, it contributed as one of the industrial cofounders of the Jožef Stefan International Postgraduate School.

As early as 1985, Slovenia launched the 2000 Young Researchers programme with the aim to promote graduate studies in science and engineering and form a strong research basis that would satisfy both academic and industrial needs. To improve the ratio of industrial versus academic doctoral degrees (only 20 % in 1995), in 1995 the Ministry of S&T decided to subsidize the salaries for the first three years of newly employed scientists with master and doctoral degrees in industrial research departments.

Other legislative incentives were brought forth with the purpose of supporting business enterprises in technological development and strengthening their R&D potentials. Knowing that public knowledge institutions are usually not the main source of innovation, the Centres of Excellence were established at the major academic research institutions with the aim to integrate basic research with the stages of prototyping, testing and production in selected cooperating companies.

Table 2: SWOT analysis of the Slovenian RTDI system.

Strengths	Weaknesses	Opportunities	Threats
Well-developed and financially stable educational system	Low mobility from academic to industrial research sector	Increased public and private investments in RTDI	Failing to increase public and private investments in RTDI
Large interest in higher education studies	Low citation index and patenting performance	Raising research excellence through competition and strengthening of academic-business links	In the implementation of S&T policies, individual interests could prevail over national ones
EU average in the number of researchers per capita, and no significant “brain drain”	Scientific excellence limited to few disciplines and mono-disciplinary approaches	Enhanced internationalization of higher education, science, technology and innovation	Initiating “brain drain” by an openness to the international community
Well-developed research and communication infrastructure	Low level of research and innovation management skills	Fiscal policy measures	Failing to establish a policy making process that would flexibly follow the research innovations
High levels of innovational capacity in some industrial sectors, e.g. telecommunications, electronics, pharmaceuticals	Underdeveloped venture capital market and low market share of high-tech products	Establishment of intermediary knowledge-transfer institutions and networking (e.g. technology platforms)	Employees inflexible to the trans-disciplinary demands of globalization
Well-developed international scientific relationships	Insufficient funding of industrial R&D	Increased concentration of public funds in priority S&T areas	Prioritization of large integrated projects within Framework Programs

3.2 Pitfalls

However, despite the traditionally developed international and regional scientific cooperation and relationships, Slovenia comprises a comparatively small gross scientific network. Even though, as of 2008, it was involved in 850 bilateral scientific projects with countries from all continents of the world with the exception of Australia, the small number of Slovenian project coordinators is often quoted as a sign of incapacity to support the development of this solid networked basis for cooperation.

The questions on future prospects of the impressive economic growth of Slovenia – so far still provided more by large infrastructural investments, and less by the targeted development of "knowledge-based" products – are also often posed in view of more open scientific, social and immigration policies adopted by the majority of other EU countries.

Small market size naturally limits the efficiency of translation of research findings into the commercial domain. As much as the small size of Slovenian R&D sector could lead to smooth collaboration among scientists and engineers, its detrimental potentials may become obvious in the evaluation of research proposals, during which grant approvals could become based on social and scientific prominence rather than on true scientific excellence. It is only during the past three years that the practice of an international review of scientific project proposals has been noticed. By promoting conditions for an unbiased competition for research funds, a more efficient expenditure of public funds could be expected. The results of a SWOT analysis of the Slovenian Research, Technological Development and Innovation (RTDI) system (Komac 2005), are presented in Table 2.

4 The case of Serbia

In comparison with the example of South Korea, a country that has raised its economic and scientific performance and prestige in the past few decades, Serbia illustrates a country that lived through the opposite path (Benson 2004).

Neutral with respect to the Cold War, Yugoslavia was considered one of the freest countries of the world, acting as an excellent bridge for scientific communication between the East and the West prior to the fall of the Iron Curtain. For example, in the period between 1969 and 1989, Yugoslavia was the permanent host country of the World Conference on Sintering (Kuczynski et al. 1987, Palmour et al. 1990). As a founder of the largest union of third-world countries, it also provided possibilities for their successful integration into hopes and promises of the developed world.

Breaking away from the Stalinist central planning system immediately after the end of World War II, Yugoslavs designed a more humane system which provided conditions for an open participation of the workers in conducting the management of their companies (Estrin 1993; Lynn et al. 2002), and the UN Economic Commission found in the early 1960s that Yugoslavia had the highest rate of expansion in Europe (Schultze 1962). The first large-scale foreign investments in Eastern European countries were found in Yugoslavia: Murata/EI Niš, Philips/EI Niš, and Sandvik/Prvi Partizan were some of the research-intensive industrial partnerships.

However, the breakup that began in 1991, slumped the Serbian life standard. In less than a few years, Serbia shifted from a relatively prosperous path to a scenario facing international sanctions and isolation, the relocation of resources to fund the war, and 1027 an overall hyperinflation impact rate between 1990–1994.

4.1 The education system

One of the positive aspects of the Serbian science, preserved even during the harshest times, has been the rigorous and comprehensive education system. However, an overly ample education takes its toll as well. For example, the annual transience rate at the Faculty of Physical Chemistry, one of the most prestigious colleges at Belgrade University, has been as low as 10 %, whereas the average duration of studies is at 8 years almost twice longer than the anticipated 4.5 years.

The perception that science careers are reserved only for superbly talented ones is thus widely present in the society, which detracts many young scholars from careers in research and science colleges in general. Consequently, with ~10,000 researchers (0.13 % of the overall population), Serbia has ~10 times lesser population of researchers per capita compared to the EU average (Yucht 2005), and is rated low on the scales of scientific talent and creativity indices. The educational system is also blamed for its lack of flexibility, as most colleges pursue only general study programs, without offering options to begin with professional specialization at an early undergraduate stage. In Slovenia, in contrast, all science students are obliged to spend at least six months at one of the external research institutions prior to graduation.

The recent adoption of the study management in accordance with the Bologna declaration is expected to increase flexibility and diversity of the teaching system. However, despite having been enacted in 2003, the Bologna declaration targets the transience rate of 80 %, and yet at the University of Belgrade as a whole, it is currently as low as 16 %. In general, only 25 % of high-school graduates enrol in one of the colleges in Serbia, whereby 70 % of the admitted subsequently drop out.

4.2 Missing links

Another major demerit of the college education is that it occurs in isolation from the S&T needs of the society. Previous studies have shown that efforts from the higher education sector need to be explicitly linked to the rate of innovations and fields of expertise on which this innovation depends in order to positively influence the growth in labour productivity (Aghion/Howitt 1998). Still, many people oppose an education system that would be less comprehensive and more optimized for the demands of the society, referring to certain fields, such as information technologies (IT), in which a drop in the quality of knowledge that students gained was observed following a high demand for IT engineers.

The lack of coordination between the study programmes and the actual labour market as a result leaves 95 % of fresh graduates unable to find a job without an additional training. Furthermore, there is a consequent disparity between close to a million of unemployed adults and about 50,000 permanently open positions due to the lack of appropriate qualifications and skills (Šekeljić 2007).

Instead of engaging students in projects of real-life importance for their social environment, their professional training typically deals with comprehensive theoretical calculations and laboratory exercises which are rarely tied to outcomes of an immediate R&D significance. Freshly graduated students thus have little awareness of how their knowledge could be implemented in the "real world", and the most talented graduates decide to pursue their subsequent studies abroad. 90 % of the graduates of the Faculty of Electrical Engineering in Belgrade from 1992 to 2000 thus continued their careers abroad, whereas the general trend estimated among natural science students at Belgrade University is slightly less drastic: 33 % find positions in foreign countries after the graduation.

4.3 Brain drain – brain gain

The number of Serbian emigrants in the world is estimated to be more than 3.5 million, which is a number that is equal to 50 % of the current population of Serbia (MDRS 2010, SORS 2010). A large portion of these emigrants are highly educated individuals that left the country during the harsh economic era of the past two decades (UNDESAPD 2005). In comparison, the majority of Slovenian doctoral scientists leave only for short-term postdoctoral stays in foreign laboratories. The positive side of the "brain drain", however, is that it could provide a crucial impulse in the networking of local R&D infrastructure with international institutions and associations. As such, it has a potential to be renamed into "brain gain" under certain conditions.

In 2010, the Serbian Ministry of Science has begun the process of collecting information about Serbian scientists based in foreign labs with the aim to promote their collaboration with the domestic R&D sectors. According to the report given by the Serbian Ministry of S&T, an international refereeing system will be established using the capacity of the Serbian science community in exile and possibilities will be opened up for Serbian researchers living abroad to be part of national projects (MSTDRS 2009).

Fostering a more official recognition and integration of small foreign-based islands of experts into science policy making through common research projects, transfers of technologies or expert consultations is thought to be an excellent step forward. The contemporary electronic communication systems can significantly facilitate the process of seeking partnerships as the society strives to unfold the positive potentials of the "brain drain". The results of a SWOT analysis of the Serbian R&D sector are presented in Table 3.

4.4 Breaking walls

The Yugoslav Materials Research Society has through its annually held YUCOMAT conferences proven that the intellectual Diaspora can attract renowned scientists from abroad and provide a local forum for exchange of ideas and formation of collaborative networks (Uskoković D. 2007). Such meetings have also provided an excellent opportunity to initiate collaborations with scientists from the neighbouring states, many of which belonged to the former Yugoslav constitution.

Somewhat similar to Serbia, South Korea has struggled with a tenuous past in relations with its neighbours. In its case, it has been shown that scientific connections established by universities and industries, owing to the traditionally more open-minded and cosmopolitan nature of intellectuals, could present the first steps in breaking the walls of mistrust held in place in people's minds by remembering the historic events (Park/Leydesdorff 2010).

Unlike the relations between North and South Korea, which have exceptionally slowly improved and are still filled with tensions (Cumings 1998), Serbia revitalized its economic and political relations with all the former Yugoslav republics, now independent states, promptly after the 1990s wartime period. The number of cooperation projects between the successor states of the former Yugoslavia has been increasing ever since (Jovanović et al. 2010). With 100 such collaborations in 2007, Serbia has doubled their number compared to the pre-civil War state of affairs (55 in 1990 and 50 in 1991). However, with 1.75:1 as the calculated ratio of the dominance factors between Slovenia/Croatia and Serbia, as of 2007, Slovenia and Croatia tend to be the dominant partners in these cooperative projects (Jovanović et al. 2010).

Table 3: SWOT analysis of the Serbian R&D sector.

Strengths	Weaknesses	Opportunities	Threats
Broad research experience	Lacking well structured strategy and vision of scientific development	Using worldwide connections provided by Diaspora to form international collaborations	Failing to increase the already low public and private investments in R&D sector
Long tradition of high-quality basic education	Insufficient modernization of the research equipment within scientific centers	Taking full advantage of modern communication networks and infrastructure	Monopolization of private sector and the threat that short-term individual interests may prevail over the long-term national ones
Comparatively high number of publications in journals with high reputation	Investments in research from the budget stagnating despite the 6-fold increase in GDP in the same time period	Formation of collaborative multi-disciplinary networks around centers of excellence	Initiating even more of the “brain drain” by the increased openness to the international community
High research efficiency reflected in comparatively low cost per publication	Discrepancy in research excellence between academic and industrial sectors	Appropriate fiscal policy measures that would promote partnerships with companies, academic spin-off and startup projects	Failing to define a clear vision of scientific progress and enable sustained funding for R&D sector
High rate of economic recovery, resulting in more than 6-fold increase in GDP in the 2000-2008 period	Low interest in higher education studies and significant level of “brain drain”	Broad demand for marketable research products, such as in biotechnology, agriculture, medicine, energy sectors and ecology	Fragmentation of research due to lack of collaboration interests and/or communication skills
Respected and well established scientific Diaspora	Weak academic-business links and underdeveloped venture capital market	Provision of outsourcing services	Possibility that a rise in political nationalism may destabilize the trend of economic recovery
Well balanced gender population among researchers	Low levels of innovational capacity in most industrial sectors and a lack of impetus for their investing in research	Creation of the National Innovation System with looped Governance, Human resources, Science base, Business R&D and innovation, and Economic and market development	Failure to focus on a few national priorities that would bring major economic benefits
Joint work between the Ministry of Education and Ministry of S&T Development on optimizing R&D system	Little developed mechanisms to attract and support talented young researchers as well as promote social affirmation of scientists and innovators	Possibility of successful participation in the Lisbon agenda and alignment with EU research priorities	Continued superficial evaluation of scientific performance at the academic level
Links with institutions leading FP7 projects with participating Serbian scientists	Low critical mass of researchers within scientific centers (only 4 institutions with more than 100 researchers)	Approved project of development of centers of excellence, academic research centers and IT infrastructure	Continued social marginalization of prominent scientists internationally established in their fields

4.5 Increasing output

Although without any official nanotechnology initiative, around 700 research papers arising from Serbian scientific centres and relating to the field of nanoscience have been published in the 1996-2009 period (Ševkušić/Uskoković 2009). These papers were cited 5.1 times on average and their Hirsch index is equal to 26. They contribute to 5-6 % of the scientific works published and originating from Serbian scientific institutions, which is comparable with many developed countries of the world.

There is also an increasing trend in the annual output of such publications. Hence, from 1998 to 2002, around 20 nano-prefixed papers affiliated with Serbian institutions were published annually, after which an exponential growth took over, resulting in 65 papers in 2005 and 154 in 2007 (Ševkušić/Uskoković 2009). Materials Science Forum, the series that published the highest quality works presented at the YUCOMAT conferences from 1996 to 2006, is by far leading in the number of the papers published: 13 % of them. This signifies a major role that an international meeting such as YUCOMAT may play in promoting dissemination of locally conducted research in compliance with the highest quality standards.

4.6 Missing infrastructure

Only a spinning windmill can mill the wheat, and any grains thrown into a still mill are predestined to go rotten. The same happens to human knowledge in the deficiency of an intellectual infrastructure within the society. In a country like Serbia, the major problem behind the scientific inefficiency in both research and application domains is associated with an inability of scientific research to find a fertile ground at the local level.

That Serbia is far from being a knowledge-based economy is supported by the fact that the professionally creative part of the overall population (2.6 %) accounted for creating only 1.1 % of the country's GDP in 2005 (Komnenić/Mikić 2008). This explains why the current R&D investments relative to GDP are at 0.5 % extremely low in comparison with other European countries and with the range of 2–3.5 % existing in the developed countries on average (cf. Fig. 3 on page 37 & Table 4, column 4).

As high-quality research stands at the basis of competitive and innovative industrial sectors, the vice versa argument applies too, that is, low investments in research can be used to explain the undersized and internationally uncompetitive economy. The recent program of S&T development in Serbia designed by the Ministry of S&T has thus concluded that

"Serbian science, despite improvements in the past few years, is still on an unsustainable path; investing in S&T is, for Serbia, the only way to create a sustainable economy and society" (MSTDRS 2009).

As shown in Fig. 3, the results from 2007 suggest that Serbia is still at the very bottom in terms of R&D investments with respect to GDP.

Fig. 4 shows that although government expenditures on S&T have been increasing in the past decade in absolute numbers (Fig. 4a), they have been stagnating in terms of their relative amount with respect to the GDP (Fig. 4b). In terms of absolute funding, in 2008 the best subsidised research field in Serbia was chemistry with €7.5 million, which is a minor amount in comparison with the average US National Institutes of Health monetary grant size of $400,000, and the total budget of the NIH that stands close to $30 billion (Giles/Wadman 2006).

4.7 Underdeveloped academia-industry links

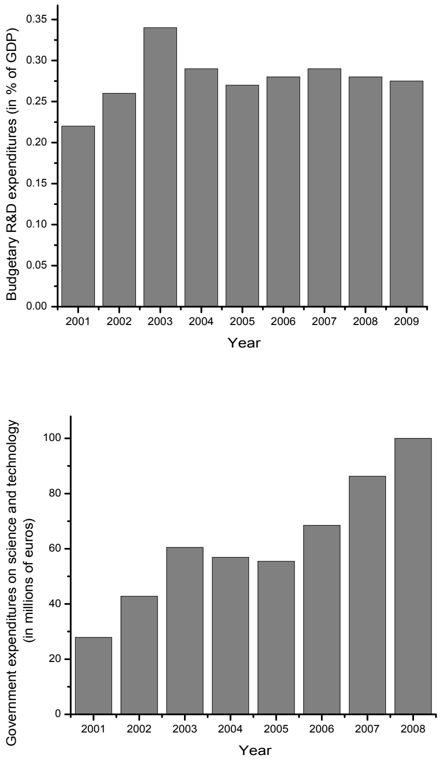
Low investments have naturally corresponded to negligible levels of scientific productivity on average. According to our bibliometric analysis,

Table 4: Scientific and technological R&D parameters for different European counties, European Union, US, China, Japan and South Korea as of 2007

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Country	Population in millions	2007 GDP per capita in 1,000 EUR	Total research funds and funds from the budget in % of GDP		Total research funds and funds from the budget per capita (EUR)		Total research funds and funds from the budget in millions of EUR		Total GBAORD as a % of total general government expenditure	ISI publications	Number of ISI publications per one million residents	Average costs per single ISI publication from total and budget funds (1,000 EUR)		Patent applications to the EPO at the national level per one million inhabitants	High-tech export of total export (%)
			Total	Budget	Total	Budget	Total	Budget				Total	Budget		
European Union (27 countries)	495.2	24.9	1.85	0.23	462.4	58.5	229014.63	28961.21	1.55	393000	793.62	582.73	73.69	118.37	15.97
European Union (15 countries)	319.8	29.2	1.93	0.24	694.6	84.6	222138.93	27063.52	1.60	357000	1116.32	622.24	75.81		
Euro area (16 countries)	325.2	27.6	1.87	0.26	516.9	71.5	168103.69	23259.01	1.62	260000	799.51	646.55	89.46	:	
Belgium	10.6	31.5	1.9	0.15	600.6	48.5	6356.93	513.28	1.25	13252	1250.19	479.70	38.73	141.22	6.63
Bulgaria	7.7	3.8	0.48	0.28	18.2	10.6	139.61	81.62	0.66	2078	269.87	67.18	39.28	3.97	3.49
Czech Republic	10.3	12.3	1.54	0.32	190	39.6	1955.04	407.21	1.36	6640	644.66	294.43	61.33	13.44	14.13
Denmark	5.4	41.6	2.55	0.08	1064.6	34.9	5798.95	190.06	1.56	9065	1678.70	639.71	20.97	216.08	11.69
Germany	82.3	29.5	2.53	0.35	746.9	103.8	61481.98	8540.20	1.76	74106	900.44	829.65	115.24	301.95	12.99
Estonia	1.3	11.6	1.11	0.10	129.4	11.2	173.65	15.04	1.43	891	685.38	194.89	16.88	14.14	7.81
Ireland	4.3	43.5	1.28	0.09	564.4	39.7	2434.20	171.00	1.36	6394	1486.98	380.70	26.74	67.84	25.73
Greece	11.2	20.2	0.58	0.12	117.4	25.1	1311.40	280.68	0.67	8884	793.21	147.61	31.59	11.94	4.74
Spain	44.5	23.5	1.27	0.22	300	52.8	13342.37	2348.84	2.74	33312	748.58	400.53	70.51	36.99	4.24
France	63.6	29.7	2.04	0.32	608.1	96.1	38689.79	6113.21	1.42	51668	812.39	748.82	118.32	137.13	15.57
Italy	59.1	26.0	1.18	0.17	308.3	44.7	18231.40	2644.30	1.34	41881	708.65	435.31	63.14	88.79	6.00
Cyprus	0.8	20.3	0.44	0.11	90.4	21.8	70.38	16.99	1.00	378	472.50	186.18	44.96	30.35	14.64
Latvia	2.3	9.3	0.59	0.14	55.1	13.4	125.60	30.46	0.83	341	148.26	368.32	89.34	11.94	4.62
Lithuania	3.4	8.5	0.81	0.17	68.7	14.3	232.59	48.48	0.96	1248	367.06	186.37	38.85	2.95	7.34
Luxembourg	4.8	78.1	1.58	0.21	1242.4	165.9	591.60	79.00	0.92	236	49.17	2506.78	334.75	245.87	32.40
Hungary	10.1	10.1	0.97	0.23	97.1	23.5	977.49	236.07	0.78	4829	478.12	202.42	48.89	15.15	21.36
Malta	0.4	13.3	0.58	0.02	78	2.0	31.82	0.82	0.47	74	185.00	429.97	11.07	40.14	47.83
Netherlands	16.3	34.7	1.71	0.22	594.6	77.0	9726.00	1259.00	1.52	23810	1460.74	408.48	52.88	205.52	18.28
Austria	8.3	32.6	2.54	0.14	829.1	44.3	6867.82	367.30	1.34	9006	1085.06	762.58	40.78	201.42	11.11
Poland	38.1	8.2	0.57	0.20	46.3	16.4	1763.62	624.92	0.75	13314	349.45	132.46	46.94	3.65	3.04
Portugal	10.6	15.4	1.21	0.11	186.1	17.4	1972.73	184.48	1.70	6159	581.04	320.30	29.95	15.46	6.52
Romania	21.6	5.8	0.52	0.18	30.3	10.3	652.82	221.62	1.03	3333	154.31	195.86	66.49	1.87	3.50
Slovenia	2.0	17.1	1.45	0.35	249	60.9	500.51	122.49	1.23	2220	1110.00	225.45	55.18	64.57	4.62
Slovakia	5.4	10.2	0.46	0.16	46.7	16.5	252.10	89.13	0.62	2164	400.74	116.49	41.19	6.55	5.00
Finland	5.3	33.9	3.48	0.29	1183	100.1	6242.67	528.28	2.05	8463	1596.79	737.64	62.42	250.59	17.52
Sweden	9.1	36.9	3.61	0.17	1310.3	62.9	11940.84	573.62	1.54	16624	1826.81	718.29	34.51	287.03	13.84
United Kingdom	60.8	33.5	1.82	0.16	610.9	53.8	37150.25	3270.27	1.49	77605	1276.40	478.71	42.14	84.81	16.17
Croatia	4.4	9.7	0.81	0.21	78.4	20.0	348.00	88.72		1916	435.45	181.63	46.31	6.81	6.61
Turkey	69.7	6.7	0.72	0.08	48.9	5.2	3409.56	359.83		15065	216.14	226.32	23.89	3.37	1.74
Iceland	0.3	48.0	2.7	0.48	1303	232.2	400.90	71.46	1.95	473	1576.67	847.56	151.07	:	1.64
Norway	4.7	60.2	1.65	0.25	996.5	152.6	4664.94	714.51	1.86	7099	1510.43	657.13	100.65	122.78	3.28
Switzerland	7.5	42.0	:	:	:	:	:	:	:	17374	2316.53			453.08	20.15
Russian Federation	142.2	12.5	1.12	0.33	74.5	21.7	10596.75	3083.67	:	23627	166.15	448.50	130.51	2.69	1.23
United States	301.1	38.4	2.65	0.29	902.6	97.9	272231.30	29524.99	2.76	346000	1149.12	786.80	85.33	120.67	20.34
China (excluding Hong Kong)	1338.6	4.5	1.44	0.28	27	5.2	35614.43	6849.94		97736	73.01	364.39	70.09	1.77	28.13
Japan	127.4	25.0	3.44	0.27	861.9	67.0	110115.97	8554.23	1.88	72411	568.38	1520.71	118.13	166.50	17.96
Korea (Republic of) (South)	49.0	21.8	3.21	0.37	507.4	59.1	24588.88	2866.03	2.92	29281	597.57	839.76	97.88	139.88	28.15
Serbia (without Kosovo UNMIK)	**7.4**	**3.9**	**0.50**	**0.30**	**18.1**	**11.6**	**143.9**	**86.30**	**1.13**	**2112**	**285.41**	**68.14**	**40.86**		

Source - Eurostat
Source: Statistical Office of the Republic of Serbia
Source: Scientific and Technological Development Strategy of the Rrepublic of Serbia
Source: CIA World Factbook
Web of Science® with Conference Proceedings or calculated according to data provided by Web of Science® with Conference Proceedings
estimation
Calculated according to data provided by Eurostat and Web of Science® with Conference Proceedings

Figure 4: Government expenditures on S&T in Serbia in the period of 2001–2008 (a), and budgetary R&D expenditures in terms of percent of GDP for the same period (b).



in a five-year period, 2000–2004, only 25 % of scientists funded by the Ministry of Science had at least one article published in one of the ISI Journals. Furthermore, the average research costs per article were at €33,000 by an order of magnitude lower in comparison with the averages for the second-wave members of the EU.

Although Figs. 5–6 demonstrate that scientific output stands in direct proportion with the amount of investments, it is uncertain whether simple increases in investments in science without a well-coordinated action of other governmental, fiscal and industrial sectors, and the long-term prospect of the local economy, present an optimal solution. A classical analysis of national systems of technical innovation has shown that factors involved in shaping an effective innovative performance include high-quality education and training on one side, and stable and facilitative economic and trade policies on the other (Nelson 1993).

Therefore, any progressive social policies would need to place more emphasis on the significance of science in Serbia, since scientific productivity presents a strong indicator of the

Figure 5: Number of ISI publications per million residents as a function of research funds from the budget in EUR per capita for most European countries, including China and the US.

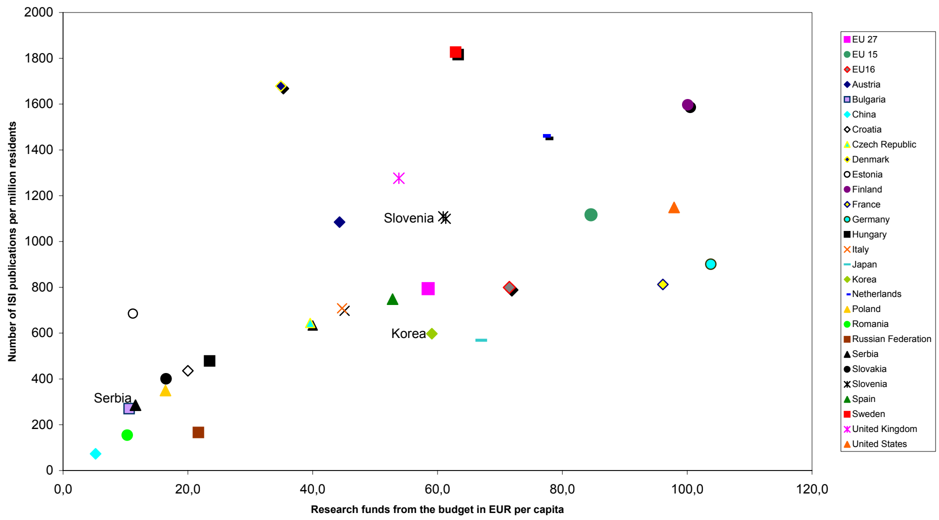


Figure 6: Number of ISI publications per million residents as a function of research funds in EUR per capita for most European countries, including China and the US.

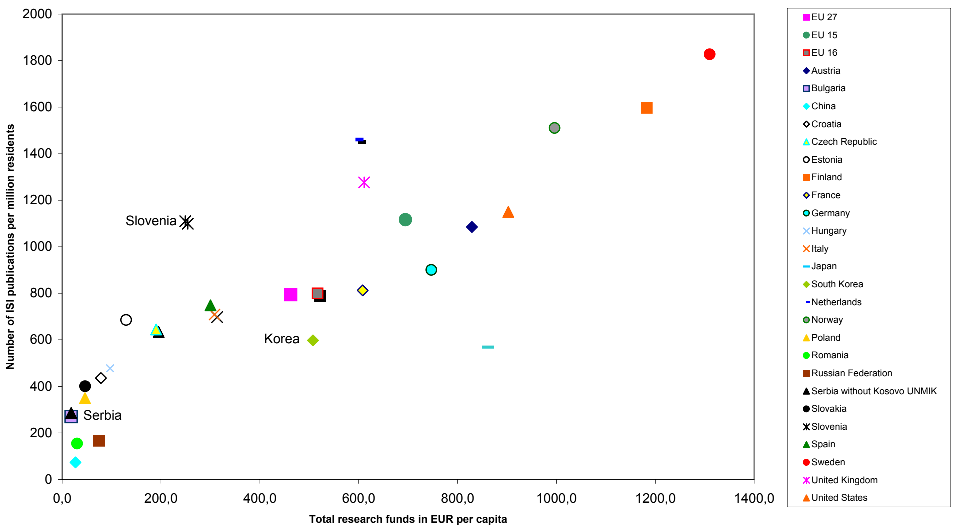
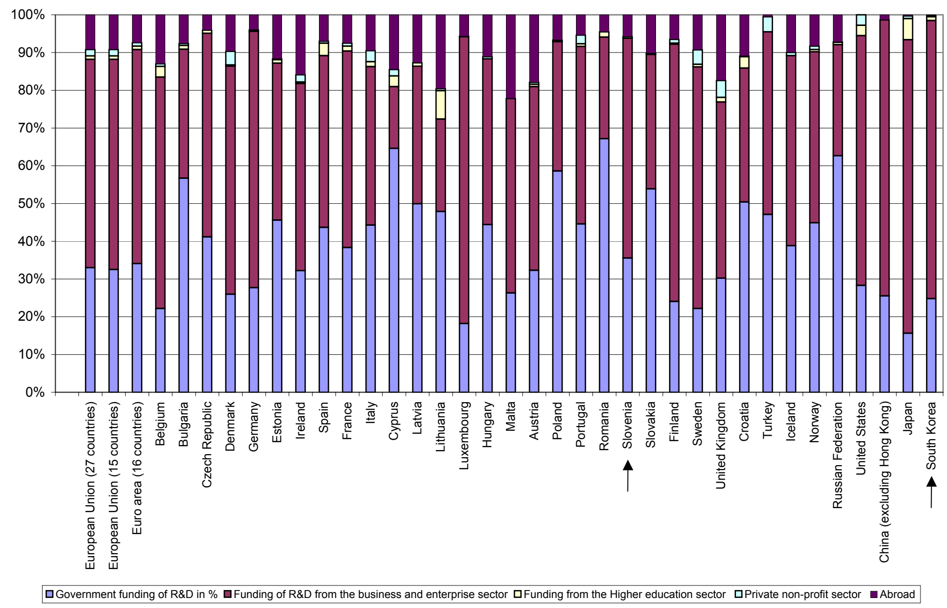
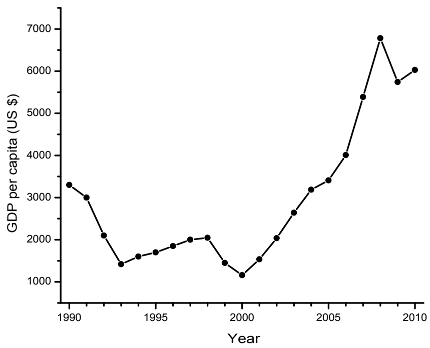


Figure 7: Proportions of R&D funding that come from governments, business and enterprise sectors, higher education sectors, private non-profit sectors and abroad for different European countries, including the US, China, Japan and South Korea.



overall social welfare. An awareness that parallel investments in basic research and in the improvements of the existing infrastructure and technological bases of the society are needed has been spurred and along with the projected growth in the funding of research, €400 million are said to have been allocated for investment in several key infrastructural projects for S&T in Serbia, through a joint loan with the European Investment Bank, World Bank and other international financial institutions and donations (MSTDRS 2009).

Figure 8: GDP per capita for the Republic of Serbia without UNMIK/Kosovo in the 1990–2010 period. Sources: IMF 2008, World Bank 2010, Aleksić 2001, UNECE 2000.

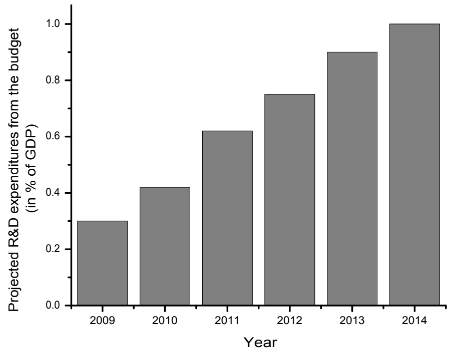


Diversification of R&D funding sources could thus be used as an indicator of how balanced scientific policies are in terms of the implementation capacity of discoveries and innovations produced at either academic or industrial levels, and one such comparison of funding sources is displayed in Fig. 7. The average funding for research coming from the business and entrepreneurial sectors equals ~ 70 % worldwide; in view of that, 60 % of funding for research related to the university sources in Serbia could be used as an indicator of underdeveloped academia-industry links.

4.8 Trends of recovery

An encouraging feature of the Serbian economy has been its exceptional recovery following the economic breakdown that followed the collapse of Yugoslavia and the times of the socialist regime that pushed the country into a decade permeated with wars and international isolation. This is illustrated in Fig. 8, which shows from 1994 on an almost continual rise in the country's GDP, with the exception of the 1998–2000 period, when the NATO bombing campaign and the Kosovo war left devastating traces on the local economy, and 2009 due to the effects of the global economic crisis.

Figure 9: The projected growth of governmental R&D expenditures on S&T in the 2009–2014 period.



The funds dedicated to research from public sources have thus been in increase during the past decade. Hence, the absolute amount of investments added up to €18.1 per capita in 2007 (cf. Table 4), €7.5 per capita in 2004, and only €1.5 per capita in 2000, which accounts for a 12-fold increase in the 2000–2007 period . However, as already mentioned, the relative amount of investment in science with respect to the GDP has not improved in the past decade. The current plan outlined by the Serbian Ministry of Science is therefore to establish annual increases in R&D expenditures from the state budget over the next five years, as shown in Fig. 9, and reach the goal of 1 % of GDP by 2014. This plan seems particularly positive with

Figure 10: Number of scientific publications affiliated with domestic institutions for Serbia (-∆-) and a few countries in the region, including Slovenia (-o-), Croatia (-□-), and Bulgaria (-◊-).

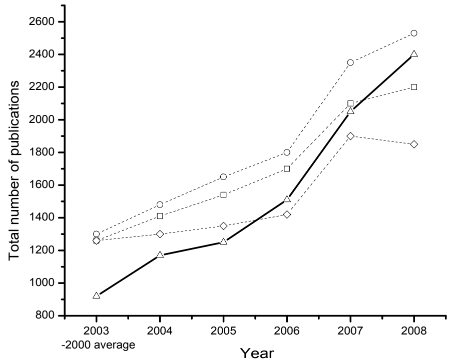
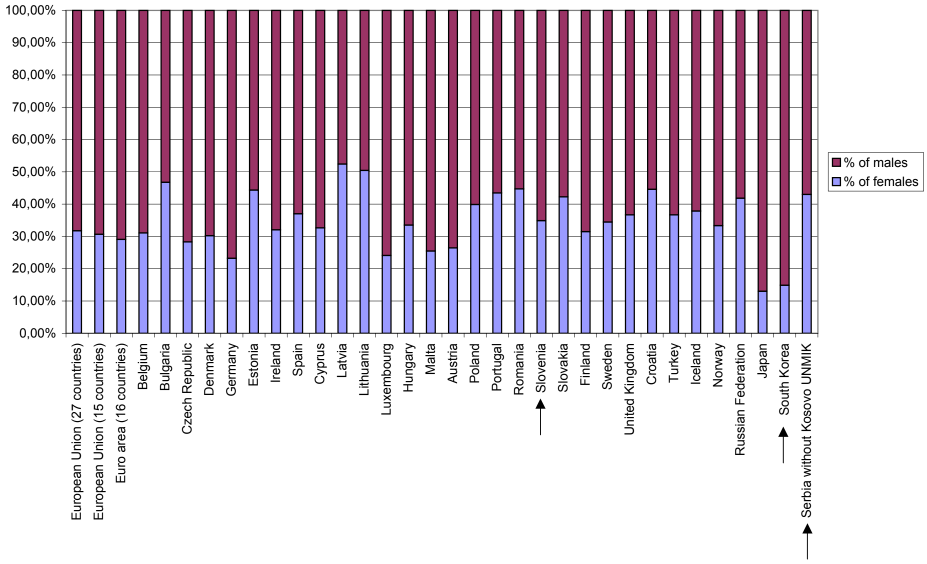


Figure 11: Gender structure among research population for different European countries, including Japan and South Korea.



regard to the opposite trend that some of the former Yugoslav states are undergoing; for example, investments in R&D from the budget in Montenegro have been in constant decline: 0.83 % in 2001, 0.30 % in 2004 and 0.13 % in 2006 (Vukćević 2009).

4.9 Other indicators

Also, as could be seen from Fig. 10, the number of papers published and originating in Serbian institutions has doubled in the period of 2004–2008, which is a significantly higher rate of growth compared to most countries in the region. Also, the overall costs per publication are lower than the European average. In the research group led by one of the authors, 48 ISI publications were produced in the period between 2005 and 2009, during which the funding was equal to €1 million, resulting in costs of €21,000 per publication, which is significantly less than the European Union average of approximately €74,000 per publication. The latter value was averaged for funding from the state budgets only; averaged for the total funds this cost would be equal to about €600,000 per publication, as can be seen from Table 4, column 13. In fact, if costs per publication could be used as a measure of research efficiency, as of 2008, with the average costs per publication of €39,000, Serbia surpasses both Croatia (€121,000) and Slovenia (€178,000) in this respect (MSTDRS 2009).

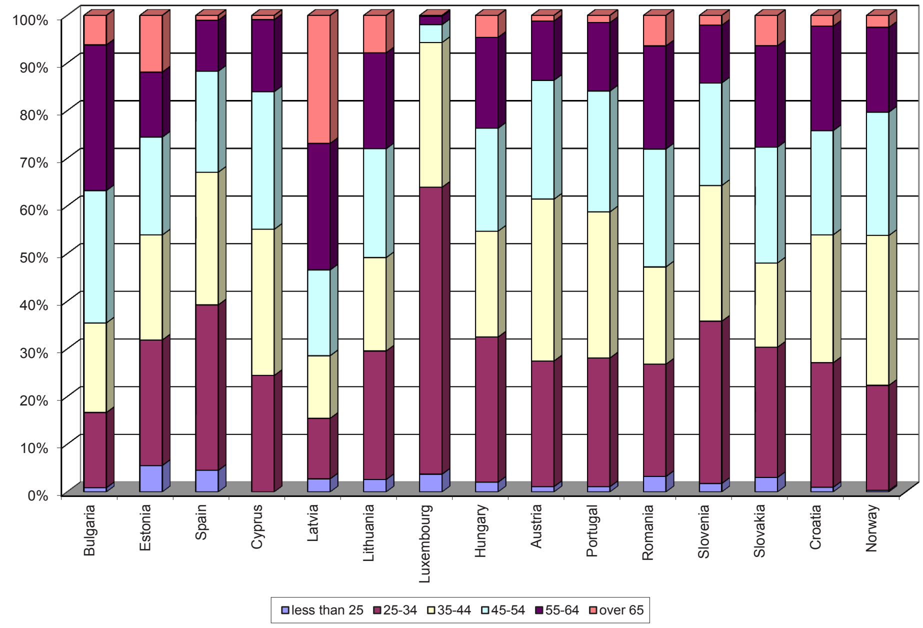
With more than 40 % of female researchers, Serbia also represents a well balanced research population in terms of gender, and finds itself much ahead of the European Union average (~30 %), as shown in Fig. 11.

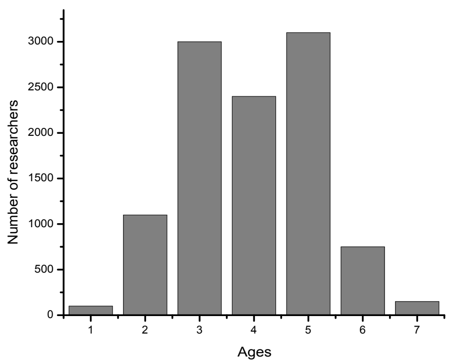
Finally, despite the significant brain drain, which certainly diminishes the quality of local research excellence, the age pyramid of the scientific community in Serbia does not show a significant lack of young researchers and is comparable to most other European states, as can be seen from Fig. 12.

5 Systemic set of strategies for the progress of developing countries

In order to reach the levels of development that typify rich countries, the developing countries should ideally use the “leapfrog” tactics (Barro/Sala-i-Martin 1997, Bernard/Jones 1996b, Bernard/Jones 1996a). There are many factors that lead to the leaders’ “stumbling” along the road of their

Figure 12: Age structure of the research population in different European countries (top) and in Serbia (bottom).





progress, enabling their followers to catch-up, including rigid dependence on old-fashioned technologies (Lazonick 1994), declining social welfare, political turmoil, ecological recklessness and other mistakes that threaten their sustainability, typically resulting in a cycle of periods of ascension, growth plateau and fall (Olson 1984).

Accordingly, the developing countries are instigated to keep their eyes on the natural cycle of alternate progressions and regressions that the developed countries experience, and discern the reasons behind these soars and slumps. As in accordance with the classical Schumpeter's theory of creative destruction (Schumpeter 1962), it is the unending need to embrace new innovations and discard obsolete methods that hinders the progress of the leaders and gives a chance to the followers to reach the same level of development (Aghion/Howitt 1992). Studies have shown that more than 50 % of long-term economic growth is connected with timely introduced technological innovations (Goldsmith 1970). Development and adoption of new technologies is thus crucial in sustaining the international competitiveness and economic growth (Kim/Dahlman 1992).

5.1 Catching-up the developed countries

Mistakes and opportunities

Thereupon, instead of going through the same mistakes that the developed countries have committed, the developing countries would be able to circumvent them by implementing the right solutions even before immanent problems occur in the their own systems or by thinking ahead and coming up with original innovations that would boost the local economies and increase the international competitiveness. It has been shown that during the past three decades, a number of late industrializing countries have sufficiently increased their levels of innovative productivity to compete with the former leaders in innovation, with South Korea, Taiwan, Ireland, Israel and Singapore being some of the examples (Furman/Hayes 2004).

Leapfrogging strategies

One such opportunity for developing countries to leapfrog a problematic development and thereby catch up with the developed states, are the ecological flaws committed by the developed societies (Grubb 1990, Raufer/Li 2009). Thus, instead of repeating the same instances of ecological recklessness that have occurred in the developed world (UNEP 2005), the less developed countries could apply the policies for their prevention before the ecological problems become evident in reality (Biello 2007). In the past decade, an awareness of the challenges to balance a continued economic growth while satisfying the requirements of sustainability has been increased in the developing world. he retardation of the progress that this challenge will inevitably bring along, is seen as a great opportunity for the countries in developing stages to draw alongside the developed ones (Blinc et al. 2006).

Riding waves

It has already been suggested that as technological and scientific development follows a similar sinusoidal path driven by the stages of conception, expectation, hype, saturation, over-hype and backlash, the ability to predict rises and surges of interests in given ideas or technologies is crucial in learning how to smoothly ride on these waves (Pearton 2007).

South Korea experienced alternate waves of soars and slumps in terms of R&D after gaining independence, and one such negative period of growth in manufacturing between 1960 and 1987 was ascribed not only to a lack of investment in R&D, but also to increasing reliance upon imitation, capital deepening, and scale economies to increase output (Park/Kwon 1995).

The "leapfrog" tactics in general presents a convenient mechanism for the gradual bridging of large gaps in prosperity that exist between the developed and the underdeveloped societies. In addition, this gap is considered as one of the brakes of an efficient and prosperous globalization in terms of preventing the possibilities for a convenient transfer of advanced know-how and new technologies (Olson 1996). Implementing policies for its remission may thus turn out to be crucial for sustainability of the entire humanity.

Detrimental aspects

To satisfy the ideals of leapfrogging, a clear view of disadvantageous aspects of a scientific policy of growth has to be formed in parallel with the prosperous ones. A few of such detrimental aspects were selected for both the South Korean and the Slovenian case. For example, although South Korea indeed invests a relatively high percentage of its GDP to R&D, these high investments have required a sufficiently propitious basis (including up-to-date equipment, productive industrial sectors and a thriving economy) in which they would find a fertile ground to be able to induce truly productive research.

Another drawback of the rapid streaming to achieve extraordinary scientific productivity and secure one's place in the field in the South Korean model has been the tendency to publish prematurely and in journals with less intensive peer-review process and lower prestige. Yet, a study has shown that authors whose records weighed quality over quantity tended to be associated with more prestigious institutions (Haslam/Laham 2010).

On the other hand, science develops incrementally and a timely feedback from the scientific society is an important drive for a successful research. It is, therefore, essential to find the right time to publish, and thus avoid both premature announcements of one's accomplishments and retardation of the progress of the field by their prolonged concealment. To succeed in that, softening up the attitude that fosters competitiveness between individual research groups and selflessly seeing scientific achievements as products of the scientific society and mankind as a whole may be required (Laband 1985).

Intellectual freedom

Yet another one of the mentioned drawbacks for the South Korean case was the tendency to neglect fundamental research on the account of the applied one. Many modern professional settings, including those that have traditionally fostered uptight and disciplined creative approaches, such as industries, are nowadays changing towards balancing the emphasis on sheer productivity with cultivating more intellectual freedom. Genentech, the company celebrated for its pursuance of innovation and seven times selected as the "top employer in the biopharmaceutical industry" by Science magazine, most recently in 2009, has adopted the merits of curiosity-driven research (Bonetta 2009).

"No one from management can ask what a postdoc's work has to do with the mission of the company. They are free to work on whatever intrigues them", a company's executive said (Kaplan 2009).

Still, science remains an issue of public interest because social values inevitably underlie scientific thinking and because even the most fundamental scientific studies are carried out while keeping an eye on how the findings could be applied for the sake of elevating the quality of life.

However, the links between scientists and the governmental and corporate funding agencies in the developed world, which includes South Korea, have become so tight that the basic science that yields fundamental and long-term benefits often becomes depreciated in favour of applied research that is meant to bear fruits in short terms. Yet, as basic research is the substratum of the applied one (Braben 2008), the results of the former often lead to unforeseen but incredibly versatile ways of utilizing them. The cases of quantum mechanics, which was first used decades after its invention in the design of microelectronics, and molecular biology, the basic principles of which are nowadays applied in drug discovery and other biotechnologies, may illustrate this point.

Commercialized science?

Still, in many developed countries university research projects with a higher chance of commercialization are preferred in the funding selection processes. However, too much focus on creating spin-offs without careful prior analyses of their true potentials can be detrimental for the overall research quality (Nature Materials 2006). In enforcing policies that instigate pushing academic research to the commercial level, another extreme may be reached, wherein corporate spirit would begin to pervade the freedom of thought that universities have fostered for centuries (Washburn 2005).

As an example the case of the Yale University and the pharmaceutical company Bristol-Myers can be cited. Yale was generously funded by Bristol-Myers, giving the exclusive manufacturing rights of the AIDS drug D4T in return. It turned out that Bristol-Myers was not able to produce D4T at a price affordable for the third world. But although competing pharmaceutical companies could produce the drug at a considerably lower price, Yale claimed its hands were tied by an agreement signed with Bristol-Myers. This practice is covered by the Bayh-Dole Act adopted in 1980, which gave universities intellectual property rights to federally funded research in the US.

Lack of transparency

Failing to encourage smart and competent methods for the allocation of research funds has been shown as another main threat for S&T policies of the developing countries. In Serbia, for example, the general lack of transparency is reflected in the fact that governmental committees are partly involved in nomination and selection of heads of the research organizations, which similarly to other social domains indicates that fulfilling political interests might be more important than claiming scientific or other types of professional excellence.

In view of the largest concentration of scientists at or around the academic and independent research institutions rather than within industrial centres, a novel and multidimensional method for financing research is needed. A recent analysis of the innovational character of S&T in Eastern European countries in transition has confirmed the role of universities and existing national knowledge bases complemented by R&D commitments from both public and private sources as the main drivers of their innovative output (Krammer 2009). Tax benefits and other incentives promoting partnerships between industry and academia also present a vital feature of scientific and technological progress of a developing country (Etzkowitz 1998).

Cycle of productivity

Applied research is, as the name itself suggests, most productive when it is carried out on the basis of an already established infrastructural and industrial prosperity. The first stage in the example of South Korean development corresponded to technological and industrial improvements spurred by the cycle of export-oriented economy, promotion of international recognition and attraction of foreign investors (Chen/Sewell 1996). Only under these circumstances the scientific productivity can be increased.

On the other hand, the success of basic research nowadays similarly depends on expensive high-tech equipment. Even though a general consequence of the post-World War II division to abundant funding of research in the West and poor funding in the East has predisposed researchers in the former regions to become more oriented towards experimentation and the latter to attain strong theoretical capabilities (Nature Materials 2007b), theoretical research nowadays frequently requires expensive computational equipment to satisfy the needs for competitive, high-quality simulations and modelling (Johnson 2009).

However, this is not to say that there is no hope for basic research in less developed countries (Salam 1984). Quite contrary, the recent breakthroughs in simple and yet very efficient soft chemical methods of synthesis provide the opportunities for competition of low-cost experimental setups with expensive lithographic techniques, at least when the aspect of materials science is concerned (Uskoković V. 2007; Masala/Seshadri 2004).

5.2 Systemic guidelines for sustainable management

Global trends and local needs

Hence, a systemic guideline for developing countries would be to follow the steps of the developed world, and yet to be active and ready to implement actions to prevent the mistakes made in the very same developed world in due time. Based on economic predispositions and cultural and geographical background, each society requires a unique internal organization, while at the same time a certain level of similarity of the patterns of growth is to be expected among individual societies. As observed by the Brazilian scientist and policy maker, José Goldemberg,

"We in developing countries should not expect to follow the research model that led to the scientific enterprise of the US and else-

where. Rather, we need to adapt and develop technologies appropriate to our local circumstances, help strengthen education, and expand our roles as advisers in both government and industry. In this way, we can prevent the brain-drain that results when scientists are not in touch with the problems of their home countries or when they face indifference – and poor financial support – from their governments." (Goldemberg 1998)

The nationwide decision to switch from gasoline to ethanol, obtainable from sugarcane, the traditional crop in Brazil, as the major fuel can be used as an example of one such eco-technological idea created by focusing on local needs rather than on copying the trends existing in the developed world (Clendenning 2006).

Top-down and bottom-up

It is an old cliché that the correct approach in helping underprivileged societies is not to hand people their fish, but to teach them the art of fishing. Instead of a passive servitude promoted by the former approach, sustained social benefits could be fostered by the latter approach. Hence, instead of investing in tops of the frequently corrupt governments of the poor countries, the attitude of providing a high-quality education and a fertile ground for the locally sustained economic growth should become more pervasive.

Consequently, the route to development occurs at the intersection of two directions: top-down and bottom-up. Whereas the former corresponds to the management of social relationships by means of policies brought about from centralized hierarchical levels, the latter belongs to improvements of the society at its fundamental organizational levels, including the provision of educational opportunities and generation of productive academic and industrial bases upon which scientific research would find a fertile ground.

This perspective may be said to fit the concept of the learning economy coined by Bengt-Åke Lundvall. It encompasses both, the idea that high-quality education is rooted in productive and sustainable social organizations, and the core of the "leapfrogging" approach, which implies an incessant orientation towards innovation that narrows the gap between the followers and the leaders (Lundvall 1999, 1992, 1995).

Good education is oftentimes considered the general recipe for social prosperity (Uskoković 2009a). When society invests in high-quality education, which includes not only professional trainings, but general knowledge, ethical teaching and upbringing in childhood as well, it gains an ability to live through hard times without reaching the states of civil anarchy. In accordance with the circular causal nature of physical phenomena in general (Bateson 1972), the attempts to improve the rate of development of a given society in a politically hierarchical, top-down fashion sooner or later encounter complex circular causal chains in which each cause presents an effect and vice versa (Beer 1967).

It can thus be noted that in order to solve the problem of poverty, stable political and security bases should be set, which requires good educational foundations, for which the solution of existential poverty becomes the necessary precondition (Churchman 1968). Sustaining a productive society can be thus said to lie in the coalescence of smart policies that descend down from the top levels of governmental regulations, and promotion of valuable education that extends from the invisible foundations of the society up.

Smart policies

Also, in the context of globalization and internationalization, a developing society should maintain the balance between preserving its cultural bases and fostering openness to information exchange with the rest of the world (Kelly 1995). Forms of openness to external influences that erase the cultural background of the society or closeness to international communication driven by fears that the national heritage would be diminished both deviate from the optimal, middle way approaches.

Openness that allows for facile transmission of technical information has been shown to encourage researchers and entrepreneurs to innovate and pursue the most up-to-date approaches and technologies (Grossman/Helpman 1993). It also broadens the market size and leads to reallocation of resources that may positively affect growth.

On the other hand, focusing on technological solutions that satisfy local needs rather than looking after competing on the international scene at every cost, even though the discoveries arrived at may never be implemented locally, may prevent futile dissipations of research creativity.

Human nature

This guideline is, in fact, consistent with both the nature of perception and biological constitution of human beings (Glasersfeld 1996). Firstly, perceptual experiences proceed from within the brain as much as they are being influenced by the sensual detection of physical features of the surrounding world (Uskoković 2009c). Secondly, biological creatures are intrinsically built on the principle of balancing thermodynamic openness and operational closeness (Maturana/Varela 1987).

Namely, whereas the former explains for the exchange of matter, energy and information with the environment, in which the living creatures need to be constantly engaged in order to maintain their physical structures, the latter is descriptive of closed metabolic loops that comprise biological entities and are essential in preserving their integrity and autonomy, preventing their disintegrative dissipation into the environment.

Naturally, we imitate others and primarily those who we admire and whom we aspire to become. Yet, without sanely being in touch with our own inner source of creativity, such an imitational approach would turn us into blind followers of leaders and authorities of the world, prone to manipulation and not living up to the fullest of our creative potentials.

Cultural diversity of societies

The same can be said to be valid for countries and societies of the world: the sense of respect would naturally yield a healthy dose of imitation, whereas a focus on building original and unique social bases of welfare and prosperity starting from the local scale and certainly comprising heavy investments in research would maximize fulfilment of the creative potentials of the given society and eventually promote cultural diversification of the planet instead of threatening it by the extensive imitation of the leaders. “Focus and Partner”, the slogan given for the development plan for S&T in Serbia by the Ministry of S&T, nicely captures this balance between cooperative openness and operational closeness (MSTDRS 2009).

Local needs

It has been witnessed that technological design and industrial solutions shown as successful in the context of a developed society may turn out to be impractical and inefficient when straightforwardly introduced into a less developed society (Schumacher 2000). An example of innovation aimed at suiting primarily the local needs and yet open to international transfer of knowledge is given by a Slovakian team of scientists that commercialized a nanobiocomposite electrode for in situ analysis of wine components, thus linking nanotechnology with the traditional winemaking in an inexpensive and elegant way (Tkac et al. 2007).

Sustainable management

Adjusting the technological performance of a small country to its size and to local needs and capabilities should present only an aspect of a wider social plan of economically and ecologically sustainable management (Uskoković 2008). Considering the fact that rich countries have based their progress on an overall degradation of the underlying natural capital, the chance of the developing countries to overtake the developed societies lies exactly in timely adoption of progressive ecological policies.

In that sense, Serbia could learn a lot from Germany and the way in which it transformed its destructive nationalism of the World War II era into one of the most influential environmental conservation movements. With the right incentives from the international community and appropriate technological and educational policies, a similarly devastating nationalism, arising of which followed the breakdown of Yugoslavia, could be transformed into a truer and more productive "love of the land".

The opening passage by Nikola Tesla demonstrates one such balance between a locally oriented patriotism and a working dedication to the entire humanity. With such an approach, hopes remain that the Berlin Wall of international isolation that has taken an enormous toll on the intellectual potential of Serbia could be toppled down. The local political and social problems would thus become only remnants of the faint past of a society which is soon to be transformed into a vital member of the European science and economy.

6 Conclusion

By comparing the two cases of fairly prosperous scientific management, of South Korea and Slovenia, with challenges tied with poor scientific and industrial productivity, typical for the developing countries and illustrated on the example of Serbia, a few guidelines for the evolution of a society towards higher scientific and social prominence were outlined.

Establishing innovation-fostering academia-industry partnerships, which would promote research with high applicative potentials in addition to that pertaining to fundamental discoveries was laid out as a part of the solution. Prioritizing R&D areas through national research programs and reforming the higher education sector to follow the local demands of the society were also discussed as positive factors in integrating scientific potentials of a developing country within its total economic performance. The most favourable pattern of growth should be based on the parallel control of scientific and fiscal policies on one side and the excellence of basic education and scientific training on the other.

To succeed in this dream of raising a society with an average scientific and technological performance into clouds of excellence, embedment into international science and engineering networks is required as much as strong local scientific and technological bases. The former would be vital in maintaining up-to-date R&D interests and priorities, whereas the latter would provide a fertile ground for an efficient transfer and implementation of the foreign-based capital and knowledge.

Systemic nature of progress

Furthermore, the signs of healthy progress of any given society or natural system are evident in the parallel development of communicational complexity between their constitutive entities and of their intrinsic versatility. In their healthy states, natural systems are diversified and functionally differentiated as much as they are unified and well integrated. Once this systemic property of progress becomes openly recognized, both rich and poor countries would gain responsibility to promote it at their respective organizational levels.

The former should primarily reorient towards ensuring not only fair transactions in terms of short-term reciprocity, but primarily long-term socially, economically and ecologically sustainable interactions between the developed and underdeveloped countries of the world, which would foster the appropriate systemic balance between unity and diversity. The developing countries have the same task, which is to be carried out in far smaller domains.

And we, individual human beings, in accordance with the tradition of wisdom and ethics of our civilization, are responsible to pay attention to the importance of the invisible roots of science, thought and creativity as much as on the measurable welfare. For, in the end, what this paper has primarily aimed at is to provide a glimpse of a profound education as standing at the foundations of a truly sustainable society.

Acknowledgments

This work has been dedicated to all the peoples of the former Yugoslavia and hopes that cosmopolitan spirits and optimistic gazes into the future in this region of the world will prevail over the past permeated with nationalistic intolerance and delusions of ethnic and religious disparity. The authors also thank Johannes Weyer, the STIs Editor, for useful suggestions during the preparation of this article.

7 Appendix: The bibliographic analysis method

The major part of the statistical data used in the analysis was drawn from various Eurostat databases available online. All the data are from 2007 because the statistics for 2008 and 2009 are incomplete. In case Eurostat (Eurostat 2010) did not provide data on a particular indicator, we used other primary sources like the CIA World Factbook (CIA 2010) and the databases of the Statistical Office of the Republic of Serbia (Statistical Office of the Republic of 2010b), and secondary sources, like the policy document of the Ministry of Science and Technological Development of the Republic of Serbia Scientific and Technological Development Strategy of the Republic of Serbia, 2010–2015 (Ministry of Science and Technological Development of the Republic of Serbia 2009). Estimations were made only when it was not possible to draw reliable data from the primary and secondary sources and they were calculated on the basis of the known parameters.

Bibliometric data, primarily related to the number of publications written by authors coming from a particular country or area and indexed by the International Scientific Institute (ISI), were drawn from the Web of Science® with Conference Proceedings, namely from the following databases: Science Citation Index Expanded (SCI-EXPANDED) – 1996–present, Social Sciences Citation Index (SSCI) – 1996–present, Arts & Humanities Citation Index (A&HCI) – 1996-present, Conference Proceedings Citation Index – Science (CPCI-S) – 2001-present, and Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH) – 2001–present. In order to draw relevant data, we performed a series of advanced searches limiting search parameters to the following document types: “Article”, “Proceeding Paper” and “Review”, and the time span “2007”. Having in mind that search results usually include a number of documents from years before or after, though the time span is specified in the initial search, they were further refined using the “Publication Year” filter. In order to retrieve data for the United Kingdom, the terms “Great Britain”, “England”, “Wales”, “Scotland”, and “Northern Ireland” were included in the search, whereas for the Russian Federation we included the names of a dozen major cities as search terms. Since the number of documents retrieved in the searches related to the European Union (EU 27, EU 15 and EU 16) and the United States of America was beyond the search limit (100,000), it was necessary to make estimation. The estimations were made on the basis of data provided by the Web of Science: in a series of separate searches we established the number of relevant documents ("Article", "Proceeding Paper" and "Review") in the Social Sciences Citation Index (SSCI) – 1996–present, Arts & Humanities Citation Index (A&HCI) – 1996-present and Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH) – 2001–present; and the number of Proceeding Papers and Reviews in the Science Citation Index Expanded (SCI-EXPANDED) – 1996–present and Conference Proceedings Citation Index – Science (CPCI-S) – 2001-present; having in mind that the share of Articles in the Science Citation Index Expanded (SCI-EXPANDED) – 1996–present and Conference Proceedings Citation Index – Science (CPCI-S) – 2001-present for other countries is about 70 percent (as we calculated it), it was easy to calculate the estimated number of Articles for the European Union and the United States of America and add it to the results of the performed searches.

The data related to the costs of a single ISI publication were calculated from the figures obtained from the Web of Science® with Conference Proceedings and those drawn from Eurostat databases. There are several parameters in Table 4 that have to do with the funds allocated to R&D. The idea was to give a multifaceted view of R&D expenditures by presenting absolute amounts (column "Total research funds and funds from the budget in millions of EUR"), by normalizing them per GDP and population (columns "Total research funds and funds from the budget in % of GDP" and "Total research funds and funds from the budget per capita"), and by highlighting the structure of R&D funding and the share of R&D expenditures in the overall government budget (column "Total GBAORD as a % of total general government expenditures"). Total research funds include funding from: (a) government; (b) business and enterprise sector; (c) higher education sector; (d) private non-profit sector; and (e) abroad, i.e., both the funds allocated by the government (a) and funding from other sources (b-e). Research funds from the budget (a) include merely the R&D funds provided by the government. This parameter is called Government Budget Appropriations or Outlays for Research and Development, abbreviated as GBAORD. According to the definition provided by Eurostat, it includes "all appropriations (government spending) given to R & D in central (or federal) government budgets". In Table 4, EPO stands for the European Patent Office.

8 References

Aghion, Philippe/Peter Howitt, 1992: A Model of Growth through Creative Destruction. In: *Econometrica*60 (2): 323-351.

---, 1998: *Endogenous growth theory*. Cambridge, Mass.: MIT Press.

Aleksić , Jasna, 2001: Appendix 1: Scope and basic status of education system. In: *The Development of Education: National Report of the Federal Republic of Yugoslavia – Serbia,* Belgrade: Ministry of Education and Sports of the Republic of Serbia

Alik, Jüri, 2008: Quality of Estonian science estimated through bibliometric indicators (1997–2007). In: *Proceedings of the Estonian Academy of Sciences* 57 (4): 255-264.

Andreis, Mladen/Maja Jokić 1, 2008: An impact of Croatian journals measured by citation analysis from SCI-expanded database in time span 1975–2001. In: *Scientometrics* 75 (2): 263-288.

Barro, Robert J./Xavier Sala-i-Martin, 1997: Technological Diffusion, Convergence, and Growth. In: *Journal of Economic Growth* 2 (1): 1-26.

Bateson, Gregory, 1972: *Steps to an Ecology of Mind: Collected Essays in Anthropology,* *Psychiatry, Evolution, and Epistemology.* San Francisco: Chandler Pub. Co.

Beer, Stafford, 1967: *Cybernetics and management.* English Universities Press.

Bencetić Klaić, Zvjezdana/Branimir Klaić, 2004: Croatian scientific publications in top journals according to the Science Citation Index for the 1980–2000 Period. In: *Scientometrics* 61 (2): 221-250.

Benson, Leslie, 2004: *Yugoslavia: A Concise History: Revised and Updated Edition.* Houndmills, Basingstoke, Hampshire; New York Palgrave Macmillan.

Bernard, Andrew B./Charles I. Jones, 1996a: Comparing Apples to Oranges: Productivity Convergence and Measurement Across Industries and Countries. In: *The American Economic Review* 86 (5): 1216-1238>.

---, 1996b: Technology and Convergence. In: *The Economic Journal* 106 (437): 1037-1044.

Biello, David, 2007: Solution to Energy and Climate Crises? A Game of Leapfrog: Scientific American. In: *Scientific American* October 2007 <www.scientificamerican.com/article.cfm?id=solution-to-energy-and-climate-crises-in-game-of-leap-frog>.

Blinc, Robert et al., 2006: Sustainable development after Johannesburg and Iraq: The global situation and the cases of Slovenia and Croatia. In: *Energy* 31 (13): 2259-2268.

Bonetta, Laura, 2009: Innovation More Critical Than Ever. In: *Science Careers* <sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2009_10_02/science.opms.r0900079>.

Borden, Jennifer, 2005: University, Inc.: An interview with author, Jennifer Washburn. In: CorpWatch April 11, 2005 <www.corpwatch.org/article.php?id=12066>.

Braben, Donald W., 2008: *Scientific Freedom: The Elixir of Civilization.* Hoboken, N.J.: Wiley-Interscience.

Chen, Cheng-Fen/Graham Sewell, 1996: Strategies for technological development in South Korea and Taiwan: the case of semiconductors. In: *Research Policy* 25 (5): 759-783.

Churchman, C., 1968: *The systems approach.* New York: Delacorte Press.

CIA, 2010: *CIA – The World Factbook,* retrieved on May 20, 2010 <https://www.cia.gov/library/publications/the-world-factbook/>.

Clendenning, Alan, 2006: Brazil leading world in effort to boost use of ethanol as renewable fuel. In: *Alexander's Gas & Oil Connections* 11 (7) <www.gasandoil.com/goc/news/ntl61483.htm>.

Csajbók, Edit et al., 2007: Hirsch-index for countries based on Essential Science Indicators data. In: *Scientometrics* 73 (1): 91-117.

Cumings, Bruce, 1998: *Korea's Place in the Sun: A Modern History.* New York: W. W. Norton & Company.

DESTATIS, 2009: *Country Profile: G-20 advanced industrial and emerging countries Republic of Korea (South Korea).* Statistisches Bundesamt Deutschland, <www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/EN/Content/Publikationen/SpecializedPublications/Countryprofiles/Content75/RepublicKorea2009,property=file.pdf>.

Eom, Boo-Young/Keun Lee, 2010: Determinants of industry-academy linkages and, their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. In: *Research Policy* 39 (5): 625-639.

Estrin, Saul, 1993: *Self-Management: Economic Theory and Yugoslav Practice.* Bath, UK: Cambridge University Press.

Etzkowitz, Henry, 1998: The norms of entrepreneurial science: cognitive effects of the new university-industry linkages. In: *Research Policy* 27 (8): 823-833.

European Commission, 2007: *Towards a European Research Area: science, technology and innovation : key figures 2007.* Luxembourg: Office for Official Publications of the European Communities.

Eurostat, 2010: *Eurostat,* retrieved on May 20, 2010 epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.

Furman, Jeffrey L./Richard Hayes, 2004: Catching up or standing still?: National innovative productivity among 'follower' countries, 1978-1999. In: *Research Policy* 33 (9): 1329-1354.

Giles, Jim/Meredith Wadman, 2006: Grants fall victim to NIH success. In: *Nature* 443 (7114): 894-895.

Glasersfeld, Ernst von, 1996: *Radical constructivism: a way of knowing and learning.* London: Falmer.

Goldemberg, Jose, 1998: Essays on Science and Society: What Is the Role of Science in Developing Countries? In: *Science* 279 (5354): 1140-1141

Goldsmith, Maurice (ed.), 1970: *Technological innovation and the economy: a Science Foundation Symposium on Technological Innovation and the Growth of the Economy held at Churchill College, Cambridge, England, April 11/13, 1969.* Chichester: Wiley-Interscience.

Grossman, Gene M./Elhanan Helpman, 1993: *Innovation and Growth in the Global Economy.* Cambridge, Mass.: MIT Press.

Grubb, Michael, 1990: The Greenhouse Effect: Negotiating Targets. In: *International Affairs (Royal Institute of International Affairs 1944-)* 66: 67-89.

Gupta, B./S. Dhawan, 2009: Status of India in science and technology as reflected in its publication output in the Scopus international database, 1996–2006. In: *Scientometrics* 80 (2): 473-490.

Haslam, Nick/Simon M. Laham, 2010: Quality, quantity, and impact in academic publication. In: *European Journal of Social Psychology* 40 (2): 216-220.

Hollingsworth, Rogers J., 2007: High cognitive complexity and the making of major scientific discoveries. In: Arnaud Sales/Marcel Fournier (eds.), *Knowledge, Communication and Creativity,* London: Sage Publications.

Hyeon, Taeghwan, 2007: The path of chemistry in Korea. In: *Nature Materials* 6 (8): 541-543.

Igić, Rajko, 2002: The influence of the civil war in Yugoslavia on publishing in peer-reviewed journals. In: *Scientometrics* 53 (3): 447-452.

Inter Academy Council, 2004: *Inventing a better future: A strategy for building worldwide capacities in science and technology.* Amsterdam: Inter Academy Council.

IMF (International Monetary Fund), 2008: *World Economic Outlook Database, October 2008.* <www.imf.org/external/pubs/ft/weo/2008/02/weodata/index.aspx>.

Johnson, Mark A., 2009: Experiment and theory in harmony. In: *Nature Chemistry* 1 (1): 8-9.

Jovanović, Miloš et al., 2010: Effects of civil war: scientific cooperation in the republics of the former Yugoslavia and the province of Kosovo. In: *Scientometrics* 82 (3): 627-645.

Kaplan, Karen, 2009: Industrial endeavours. In: *Nature* 461 (7263): 554-555.

Kelly, Kevin, 1995: *Out of Control: The New Biology of Machines, Social Systems, & the Economic World.* Basic Books.

Kim, Linsu/Carl J. Dahlman, 1992: Technology policy for industrialization: An integrative framework and Korea's experience. In: *Research Policy* 21 (5): 437-452.

Komac, M., 2005: The Framework for Research and Technology Policies in Small Countries: The Case of Slovenia. In: Dragan P. Uskoković/Slobodan K. Milonjić/Dejan I. Raković (eds.), *Current Research in Advanced Materials and Processes;* Zurich: Trans Tech Publications: 1-6 (Materials Science Forum, 494).

Komnenić , Biserka/Hristina Mikić , 2008: Managing and Measuring Intangibles as Key Resources for Development of Sustainable Competitiveness of the Republic of Serbia. *Development Cooperation and Competitiveness: 4th International Conference of ASECU, May 2008,* Bucharest, Romania: 340-350 <www.asecu.gr/files/RomaniaProceedings/36.pdf>.

Kornhauser, Aleksandra (ed.), 2000: *University-industry cooperation: how to make it work? : teaching learning manual based on examples of good practice from chemistry and related disciplines.* Ljubljana: Faculty of Natural Sciences and Engineering International Centre for Chemical Studies University of Ljubljana Slovenia.

Krammer, Sorin M. S., 2009: Drivers of national innovation in transition: Evidence from a panel of Eastern European countries. In: *Research Policy* 38 (5): 845-860.

Kuczynski, George Cz. et al. (eds.), 1987: *Sintering '85.* New York: Plenum Press.

Laband, David N., 1985: An Evaluation of 50 "Ranked" Economics Departments: By Quantity and Quality of Faculty Publications and Graduate Student Placement and Research Success. In: *Southern Economic Journal* 52 (1): 216-240.

Lazonick, William, 1994: Social Organization and Technological Leadership. In: William J. Baumol/Richard R. Nelson/Edward N. Wolff (eds.), *Convergence of Productivity: Cross-National Studies and Historical Evidence,* Oxford University Press, USA: 164-196.

Lewison, G./R. Igic, 1999: Yugoslav politics, "ethnic cleansing" and co-authorship in science. In: *Scientometrics* 44 (2): 183-192.

Lukenda, Josip, 2006: Influence of the 1991-1995 war on Croatian publications in the MEDLINE database. In: *Scientometrics* 69 (1): 21-36.

Lundvall, Bengt-Åke, 1992: *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* Pinter Publishing.

---, 1999: Technology Policy in the Learning Economy. In: Daniele Archibugi/Jeremy Howells/Jonathan Michie (eds.), *Innovation Policy in a Global Economy,* Cambridge University Press: 19-34.

Lynn, Monty L. et al., 2002: Democracy without empowerment: the grand vision and demise of Yugoslav self. In: *Management Decision* 40 (8): 797-806.

Mahlich, Jörg, 2007: *Innovation and technology in Korea challenges of a newly advanced economy.* New York: Physica-Verlag, Springer.

Masala, Ombretta/Ram Seshadri, 2004: Synthesis routes for large volumes of nanoparticles. In: *Annual Review of Materials Research* 34 (1): 41-81.

Maturana, Humberto R./Francisco J. Varela, 1987: *Tree of Knowledge: The Biological Roots of Human Understanding.* Shambhala.

MDRS (Ministry of Diaspora of the Republic of Serbia), 2010: *Serbian diaspora*, retrieved on May 31, 2010 <www.mzd.gov.rs/Eng/Ministry/SectorDetails.aspx?id=48&color=true&cid=461>

MSTDRS (Ministry of Science and Technological Development of the Republic of Serbia), 2009: Science and Technological Development Strategy of the Republic of Serbia, 2010–5015, <www.nauka.gov.rs/eng/index.php?option=com_content&task=view&id=361>.

Nature Materials, 2004: Accepting the East. In: *Nature Materials* 3 (6): 343-343.

---, 2006: The business of science. In: *Nature Materials* 5 (12): 921-921.

---, 2007a: Building bridges to North Korea: [Interview with Chan-Mo Park]. In: *Nature Materials* 6 (10): 711-712.

---, 2007b: The long way to integration. In: *Nature Materials* 6 (2): 85-85.

Nelson, Richard R., 1993: *National Innovation Systems: A Comparative Analysis.* Oxford University Press, USA.

NSB (National Science Board), 2004: *Science and Engineering Indicators – 2004.* <www.nsf.gov/statistics/seind04/>.

---, 2010: *Science and Engineering Indicators: 2010.* Arlington, VA: National Science Foundation, <www.nsf.gov/statistics/seind10/>.

OECD (Organisation for Economic Co-operation and Development), 2009: *OECD Science, Technology and Industry Scoreboard – 2009.* OECD, <www.oecdilibrary.org/content/book/sti_scoreboard-2009-en>.

Oh, Se-Jung, 2007: Academic research in Korea. In: *Nature Materials* 6 (10): 707-709.

Olson, Mancur, 1984: *The Rise and Decline of Nations: Economic Growth, Stagflation, and Social Rigidities.* Yale University Press.

---, 1996: Big Bills Left on the Sidewalk: Why Some Nations are Rich and Other Poor. In: 10 (2): 3-24

Palmour, Hayne III et al. (eds.), 1990: *Science of Sintering: New Directions for Materials Processing and Microstructural Control.* Springer.

Park, Han Woo/Loet Leydesdorff, 2010: Longitudinal trends in networks of university-industry-government relations in South Korea: The role of programmatic incentives. In: *Research Policy* 39 (5): 640-649.

Park, Seung-Rok/Jene K. Kwon, 1995: Rapid Economic Growth with Increasing Returns to Scale and Little or no Productivity Growth. In: *The Review of Economics and Statistics* 77 (2): 332-351.

Pearton, Steve, 2007: The shifting tide of expectations. In: *Materials Today* 10 (10): 6.

Raufer, Roger/Shaoyi Li, 2009: Emissions trading in China: A conceptual 'leapfrog' approach? In: *Energy* 34 (7): 904-912.

Rodrik, Dani, 1995: Getting Interventions Right: How South Korea and Taiwan Grew Rich. In: *Economic Policy* 20: 55–107.

Salam, Abdus, 1984: *Ideals and Realities: Selected Essays of Abdus Salam, editors: Z. Hassan and C.H. Lai.* World Scientific Publishing Company.

Sambunjak, Dario et al., 2008: Representation of journals from five neighboring European countries in the Journal Citation Reports. In: *Scientometrics* 76 (2): 261-271.

Schultze, Theo, 1962: Yugoslavia's Way – The Workers' Council System. In: *International Socialist Review* 23 (3): 84-86,90.

Schumacher, E. F., 2000: *Small Is Beautiful, 25th Anniversary Edition: Economics As If People Mattered: 25 Years Later . . . With Commentaries.* Hartley and Marks Publishers.

Schumpeter, Joseph A., 1962: *Capitalism, Socialism, and Democracy.* Harper Perennial.

Šekeljić , Srećko, 2007: Šta Srbija nudi mladima? [editorial]. In: Student October 2007

Ševkušić , Milica/Dragan P. Uskoković, 2009: Analiza aktivnosti u oblasti nanonauka i nanotehnologija u Srbiji na osnovu bibliometrijskih pokazatelja (State of the Art in Nanoscience and Nanotechnology in Serbia: A Preliminary Bibliometric Analysis). In: *Tehnika – Novi materijali* 18 (5): 1–16.

SORS (Statistical Office of the Republic of Serbia), 2010a: *CENSUS 2002: Citizens of the Republic of Serbia working abroad for a foreign employer or working independently, and family members living with them, by country and length of work-stay,* retrieved on May 20, 2010 <webrzs.stat.gov.rs/axd/en/drugastrana.php?Sifra=0013&izbor=odel&tab=27>.

Tearse, Graham, 2008: Why Science is Golden for South Korea. In: *CNRS International Magazine* 10 <www2.cnrs.fr/en/1171.htm>.

Tkac, Jan et al., 2007: Nanotechnology gets into winemaking. In: *Nano Today* 2 (4): 48.

Tong-Hyung, Kim, 2009: 5% of GDP Set Aside for Science Research. In: The Korea Times, December 12, 2009 <www.koreatimes.co.kr/www/news/biz/2010/01/123_57782.html>

Turlea, Geomina et al., 2010: *The 2010 report on R&D in ICT in the European Union.* European Commission. Joint Research Centre Institute for Prospective Technological Studies, <ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3239>.

UNDESAPD (United Nations. Department of Economic and Social Affairs. Population Division), 2005: *World population policies 2005.*

UNECE (United Nations Economic Commission for Europe), 2000: *Catching Up and Falling Behind: Economic Convergence in Europe.* <www.unece.org/press/pr2000/00gen14e.htm>.

UNEP (United Nations Environment Programme), 2005: *Millennium Ecosystem Assessment Synthesis Report*, < www.millenniumassessment.org>.

UNDP (United Nations Development Programme), 1999: *Human development report 1999.* New York; Oxford: Oxford University Press.

Uskoković, Dragan P., 2007: Editorial. In: D. P. Uskoković/S. K. Milonjić/D. I. Raković (eds.), *Research Trends in Contemporary Materials Science,* Zurich: Trans Tech Publications: VII (Materials Science Forum, 555).

Uskoković, Vuk, 2007: Nanotechnologies: What we do not know. In: *Technology in Society* 29 (1): 43-61.

---, 2008: Of sustainability, elephants and Prefab Sprouts. In: *International Journal of Sustainable Society* 1 (1): 85-102.

---, 2009a: On Science of Metaphors and the Nature of Systemic Reasoning. In: *World Futures: Journal of General Evolution* 65 (4): 241-269.

---, 2009b: On the Light Doves and Learning on Mistakes. In: *Axiomathes* 19 (1): 17-50.

---, 2009c: On the Relational Character of Mind and Nature. In: *Res Cogitans: Journal of Philosophy* 6 (1): 286-400.

Vukćević, Mira, 2009: State of the Art and the Strategy of RD&I Development in Montenegro. *Contribution of Research and Technology Development to developing sustainable knowledge-based economies in Central and South East Europe,* University of Dubrovnik, Croatia, May 22–23, 2009.

Washburn, Jennifer, 2005: *University, Inc: the Corporate Corruption of Higher Education.* Basic Books.

Watkins, Kevin, 2006: *Human Development Report 2006: beyond scarcity: power, poverty and the global water crisis.* New York NY [etc.]. Palgrave Macmillan for UNDP.

World Bank, Group, 2010: *World Development Indicators & Global Development Finance,* retrieved on May 20, 2010 <databank.worldbank.org/ddp/home.do?Step=1&id=4>.

Yucht, Madelyn, 2005: *The Rise of the Creative Class: How Combining Talent, Technology and Tolerance Leads to Regional and Organizational Development*, <www.iegd.org/spanish800/adjuntos/risecreativeclass.pdf>.

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI
Studies
www.sti-studies.de

Discussion:
Mode 2 revisited?

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI Studies
www.sti-studies.de

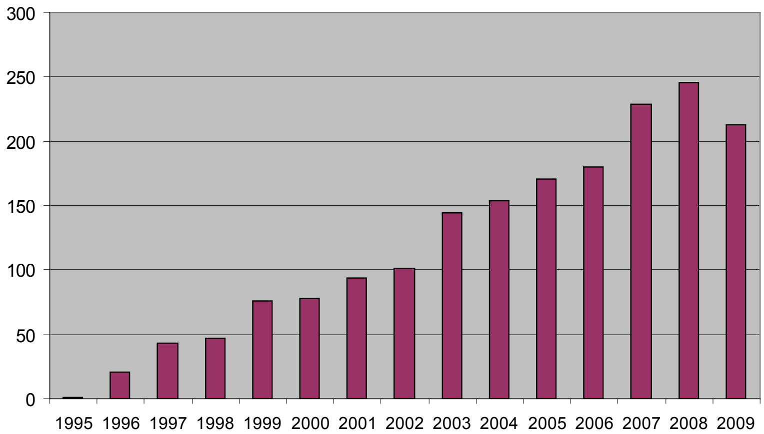
The mixed blessing of Mode 2 knowledge production

Laurens K. Hessels (University of Utrecht, The Netherlands)
Harro van Lente (University of Utrecht, The Netherlands)

The notion of Mode 2 knowledge production (Gibbons et al. 1994, Nowotny et al. 2001) already has a remarkable history. It was launched fifteen years ago to capture the ongoing changes in the world of science, science policy and the knowledge economy at large. While it is not the only attempt to make sense of the change, it definitively is the most popular. Since its publication in 1994, 'The New Production of Knowledge' (Gibbons et al. 1994), which has coined the notions of Mode 1 and Mode 2, has received almost 1900 citations in scientific journals (see Figure 1). It is a blessing that it has helped both scholars and policymakers to get a grip on the profound changes going on in contemporary science systems. But the concept of Mode 2 knowledge production also proved to be a mixed blessing by creating confusion and by conflating interrelated yet independent trends.

In our 2008 review of literature about changing science systems, we identified and discussed a number of problems related to the concept of Mode 2 knowledge production (Hessels & van Lente 2008). We concluded that most of them can be summarized under two headings, limited empirical support and conceptual weaknesses. First, there is no (fully) convincing evidence available for the claim that science is

Figure 1: ***Number of citations of The New Production of Knowledge (Gibbons et al., 1994) in Scopus***[1]



[1] Scopus search on June 14th 2010. Total number of citations (including 2010): 1879. The apparent decrease in 2009 is probably due to the delayed publication of some journals.

indeed increasingly characterized by the five features that together define Mode 2 knowledge production. For some of these attributes there is quite some empirical support (such as the increasing heterogeneity of science), but some other are disputed, such as the claims about novel quality control and the increasing reflexivity of knowledge production. Second, the notion of Mode 2 and the concomitant diagnosis is poorly embedded in sociological literature, and questions have been raised about the mutual coherence of its five constitutive features.

Two papers published in a recent issue of *STI-Studies* (Hansen 2009, Kurath 2009) can be read as attempts to address these two problems. Janus Hansen outlines a possible theoretical enrichment of the debate about Mode 2 by introducing the rich tradition of Luhmann and other systems thinkers; Monika Kurath provides an empirical analysis of the social robustness of nanoscience and -technology (NST) governance arrangements. Both papers, we think, testify to the status of Mode 2 as a mixed blessing.

Reaction to Kurath

The rise of nanosciences and –technologies (NST) has been accompanied with many promises and concerns regarding the economic and societal potential of this emerging field (van Lente & van Til 2008). In many countries funding schemes for NST have been launched in the last decade, as well as attempts to anticipate and regulate possible outcomes. Kurath has made a timely overview of the various approaches, under the heading of public engagement, and draws on the Mode 2 ideas on 'social robustness' to assess these attempts. The outcomes of Kurath's analysis (2009) are surprising. Of all fourteen self-regulatory and soft-law approaches, and all six public engagement projects she has investigated, only three score positively on her social robustness scale, and none of them scores really high. For example, both the UK Responsible Nano Code 2008 and the EU Nanologue 2005-2006 score negatively on the criteria 'stability' and 'acceptability'.

This is surprising because the need for socially robust knowledge is one of the key claims of the influential Mode 2 diagnosis, and the governance of NST can be expected to be a very suitable setting for it. With its high uncertainty about potential risks and benefits and the high stakes involved, NST deserves careful governance. Governments, industry and the other actors involved can be expected not to rely on conventional policy instruments. To put it in stronger terms: if there is one technological domain deserving to be handled with the most innovative, participatory and robust approaches available, it is NST. And yet, as Kurath's results seem to imply, these attempts are all failing.

Does this mean that NST governance is still following a traditional modernist approach, characterized by limited accountability and democracy? In our opinion there are two explanations for Kurath's surprising outcome, a conceptual and an empirical one. First, the conceptual explanation may be found in the way Kurath has used the notion of social robustness in her analysis. While this notion was introduced to characterize knowledge and knowledge production, Kurath applies it to governance schemes. In principle it makes sense to think about socially robust governance as well, but this requires a careful reconsideration of the definition of social robustness (see also Rip, *this issue*). The paper, however, directly translates the characteristics of socially robust knowledge as presented by Nowotny et al. (2001) into five 'criteria' of social robustness and uses them as criteria of governance schemes. Kurath pays little attention to the differences between a research project and a governance arrangement. Characteristics such as 'stability' and 'acceptability' have quite a different meaning in these two different contexts. The conceptual shift leads to various difficulties, for instance to the paradoxical situation that the stability of a *soft-law* governance scheme is measured by the degree to which outcomes are 'enforceable'. Kurath could have stayed closer to the Mode 2 ideas of social robustness, if she had chosen to analyze governance for socially robust nanosciences and -technologies (NST) instead of the social robustness of NST governance.

The empirical explanation for Kurath's surprising findings would be the discrepancy between the popular and innovative ideas about social robustness that have inspired the various participatory and democratic governance arrangements in the first place, and the inert practices of science and technology governance that inhibit their implementation. Clearly the use of social knowledge and mutual learning is not a straightforward 'instrument' but increases the complexity and unpredictability of the process. This type inertia can be compared to the phenomenon we observed in the dynamics of academic research practices. Our fieldwork on Dutch university research shows that funding sources provide incentives for researchers to promise strongly contextualized research, but that the limited rewards for fulfilling these promises almost nullify these incentives (Hessels et al. 2009). In practice the dominant reward structure of university research is not compatible with all attributes of Mode 2 knowledge production and it exerts a conservative force on the dynamics of university research. Research evaluations, ruled by bibliometric quality indicators, favor traditional forms of knowledge above socially robust knowledge. They typically give most credits to mono-disciplinary achievements that can be published in high-impact scientific journals (Weingart 2005). The criteria ruling formal evaluation procedures also shape informal processes of gaining credibility and building reputations. As a consequence, transdisciplinary research, or strong engagement with societal stakeholders yields little recognition. In a similar vein, the pressure for accountability of NST governance may also indirectly restrict the possibilities for more democratic governance arrangements: participation may simply be too expensive.

Reaction to Hansen

The diagnosis of Mode 2 can also be enriched with theoretical strands. Hansen (2009) seeks to enrich the discussion with the work of Niklas Luhmann. A central tenet of this framework is the understanding of society as a set of relatively independent systems of communication. To rephrase and enrich the claims about Mode 2, Hansen suggests distinguishing between two levels of social reality: 'societal sub-systems' and 'organizations'. According to Luhmann, societal sub-systems, such as science and the economy, can be seen as self-referential systems, operating by means of mutually exclusive, binary codes of communication, like true/false and payment/non-payment. Although these systems are locked into each other, they are autonomous in their operations. Unlike these sub-systems, organizations have 'members', of which there are 'behavioural expectations'. Moreover, organizations recursively make decisions that shape their identity. Together, the notions of societal sub-systems and organizations would allow an analysis of both stability and change in the ongoing transformation of knowledge production. As Hansen rightfully argues, there cannot be only change and the blurring of boundaries.

The Mode 2 diagnosis, then, can be translated in this framework by the following two claims: (i) the structural couplings between the societal subsystems are becoming stronger, for example between science and politics; (ii) new types of organizations are evolving, operating at the intersection of a multiplicity of subsystems, for example technology transfer offices that form a bridge between science and the economy.

Hansen's paper shows that the Luhmannian framework provides opportunities for further analysis of the Mode 2 diagnosis. The concept of Mode 2 suffers from its enthusiastic reception: due to its wide scope and universal appeal, everyone can use the term as he likes, which complicates systematic comparisons. Thanks to its conceptual clarity and coherence, the framework presented by Hansen could facilitate gathering and comparing data about public engagement in different scientific fields and national contexts.

However, to this end, there is still work to do. Hansen's suggestions for empirical research' are rather abstract, and do not provide concrete starting points for scholars willing to adopt his approach. The questions he raises (e.g. 'Where and how are public engagement procedures anchored institutionally?' (p. 85)) are interesting, but they are insufficiently specific. What is lacking is an operationalization of the Luhmannian concepts into empirically measurable indicators. What kind of data should one collect in order to investigate structural couplings between societal subsystems?

In particular, the framework is still open with regard to the cross-national comparisons that Hansen advocates. The three dimensions of political culture borrowed from Jasanoff (2005), should 'serve as a tool to order observations of local or "institutional" specifications into how science interacts with politics, the economy and the legal system' (Hansen 2009 p. 81). However, 'representation', 'participation' and 'deliberation' are quite general characteristics of public engagement in different contexts. Again, what types of data could be used in an empirical analysis of these variables? And how do these variables relate to the Luhmannian subsystems and organizations?

An important characteristic of Luhmann's approach, and ipso facto also of Hansen's framework is that it uses communication as the entrance point for studying social reality. A risk of starting with communication patterns is that practices and agency may remain obscured. With regard to science, one runs the risk of overlooking the content of science and the dynamics of actual research practices. As the success of the field of scientometrics shows, publications can serve as valuable indicators of research practices, but they miss some aspects of the practices as well. Collaboration patterns, for example, are known to be only partly reflected in co-authorships (Laudel 2002). Also content analysis of scientific publications can be deceptive, as researchers may strategically adopt fashionable terms, without actually changing their research activities.

Another possible route to theoretically embed the Mode 2 claims is to put the research practices central. Elsewhere (Hessels et al. 2009) we have outlined, that it is fruitful to analyze the changing research practices with the credibility cycle (Latour & Woolgar 1986). This model, which is rooted in a constructivist tradition, explains how struggles for reputation influence the behaviour of individual scientists. Scientists possess different forms of credibility, which function as resources to be invested and earned back in another form. Conceived in this way, the research process can be depicted as a repetitive cycle in which conversions take place between money, staff, data, arguments, articles, recognition, and so on.

An analysis of this cycle gives powerful insights into the changes in actual practices of university research. It facilitates investigation of the agency of scientists, influenced by changing structural conditions. It also helps to differentiate the Mode 2 claims for different scientific fields. In some fields, such as Catalysis and Paleo-ecology, the orientation on practical outcomes has strengthened over the past 35 years. In fields like Biochemistry and Cell Biology, however, the traditional academic orientation was conserved and even strengthened by the increased pressure for academic publications. In other words, Mode 2 characteristics are becoming more visible in some fields, while they remain absent in others. Differences between the fields can be further explained by their communication culture, social organization and characteristics of their societal stakeholders.

To conclude

The notion of Mode 2 has proved to be an important step towards both the visibility and the understanding of important trends in contemporary science systems. Yet, it is also a source of questions and confusion. Conceptually, it is still underdeveloped and prone to further refinement. Empirically, its arguments are too brittle and equivocal to be used as a basis for convincing assessments and interventions. In the attempt to address these weaknesses, Hansen and Kurath seem to have divided the enrichment labour. While one focussed on theoretical enrichment, the other made an empirical effort. We would recommend them to join forces. To turn the notion of Mode 2 into a blessing of a better mix, a balanced combination of conceptual refinement and empirical testing is needed.

References

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. & Trow, M. 1994, *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, SAGE, London.

Hansen, J. 2009, Mode 2, systems differentiation and the significance of politico-cultural variety, *Science, Technology & Innovation Studies,* 5, p. 67-85.

Hessels, L.K. & van Lente, H. 2008, Rethinking new knowledge production: A literature review and a research agenda, *Research Policy,* 37, p. 740-760.

Hessels, L.K., van Lente, H. & Smits, R.E.H.M. 2009, In search of relevance: the changing contract between science and society, *Science and Public Policy,* 36, p. 387-401.

Jasanoff, S. 2005, *Designs on Nature: Science and Democracy in Europe and the United States*, Princeton University Press, Princeton.

Kurath, M. 2009, Nanotechnology governance: Accountability and democracy in new modes of regulation and deliberation, *Science, Technology & Innovation Studies,* 5, p. 110.

Latour, B. & Woolgar, S. 1986, *Laboratory Life: The Construction of Scientific Facts*, Sage, London.

Laudel, G. 2002, What do we measure by co-authorships? *Research Evaluation,* 11, p. 3-15.

Nowotny, H., Scott, P. & Gibbons, M. 2001, *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*, Polity Press, Cambridge.

Van Lente, H. & van Til, J.I. 2008, Articulation of sustainability in the emerging field of nanocoatings, *Journal of Cleaner Production,* 16, p. 967-976.

Weingart, P. 2005, Impact of bibliometrics upon the science system: inadvertent consequences? *Scientometrics,* 62, p. 117-131.

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI
Studies
www.sti-studies.de

Social Robustness and the Mode 2 Diagnosis

Arie Rip (University of Twente, The Netherlands)

The Hansen and Kurath articles in the December 2009 issue have public engagement as their topic, and mobilize the notion of 'social robustness' as discussed by Helga Nowotny, one of the Mode 2 authors (see Nowotny et al. 2001). Janus Hansen used it as a link with public engagement and offered a plea for comparative studies which he located in a conceptual critique of the Mode 2 thesis. Monika Kurath decided to use her version of the notion of 'social robustness' to evaluate attempts at regulation of, and engagement with, nanosciences and nanotechnologies, conjuring up ratings for each of the cases she described.

Social robustness

Monika Kurath (2009: 90) assumes that the notion of social robustness is linked to the authors of the diagnosis of the Mode 2 of knowledge production, but the notion and the practice have a longer history. In particular, learning in and through controversies can be mapped and evaluated in terms of social robustness (see Rip 1986 and the literature referred to there). It applies to science-internal as well as science-external criteria of quality, and offers a comprehensive approach. Drawing on Stirling et al. (1999) and (Rip 2001), the approach can be formulated in three steps.

First, solidity of scientific achievments as well as of outcomes of controversies is a matter of alignment of findings, arguments, perceptions, interests, and dominant values – and circumstances. Quality and validity are *made*, and the 'robustness' of such constructions shows in its resiliency with respect to disturbances and interventions. The eventual alignment creates a repertoire of considerations which are difficult to go against (see the example of the smoking-health link, below). In that sense, the outcome is robust, even if it can be undermined when new arguments, interests, or values unravel the existing alignment.

Second, robustness resides in the combination of consolidation and well-articulated alignment. The smoking-health link, for example, was strongly implicated in the prohibition of smoking in some USA states around 1900, the argument being that smoking is what morally depraved individuals do (so it must be prohibited) and will lead to diseases (as punishment for their sins). This not very well articulated alignment broke down in and after the first world war, when the cultural aspects of smoking cigarettes shifted. Citizen groups started to send cigarettes to soldiers because the cigarette was an "indispensable comfort to the men." Moral associations now became positive, the cigarette being identified with "quiet dignity, courage, and dedication above all." (Troyer and Markle 1983, p. 40-41) In contrast, by the 1970s, after extended controversies, the smoking-health link had been articulated in great detail, and cultural shifts (for example, the attempt to link smoking with individual freedom) could not undermine the "edifice" that had been constructed. (Rip 1986)

Third, antagonistic (and in general, agonistic) struggles provide coordination and learning: they force actors to articulate the merits of their position, to search for arguments and counter-arguments, to commission special research, to interact with more actors. Of course, such struggles can also lead to impasses, when parties limit themselves to mutual labeling the other as contemptibly wrong.

One can turn the understanding of agonistic alignment dynamics into ways to do better. This is how one can understand Nowotny et al.'s call for social robustness: they want to do better by strengthening the input of society ("speaking back to science"). However, this "doing better" is then reduced to interaction with and acceptability to publics, as Hansen and Kurath do as well. There is little attention to the question *why* this would contribute to doing better.

Other approaches to "do better" could be entertained. A concrete example is the SocRobust project (Larédo et al 2002), which developed ways to extend the horizon of managers of techno-scientific projects so as to improve eventual embedding of the (modified) projects in society. Constructive Technology Assessment (cf. Schot and Rip 1997) has the same overall goal, and has by now developed effective and reflexive ways to broaden techno-scientific developments, e.g. nanosciences and nanotechnologies, starting with the immediate and secondary "enactors" of innovations (Rip and Te Kulve 2008).

Implications of the broader approach

One implication of this approach is that 'social' is superfluous as a qualifier: robustness is always social. The qualifier serves to push interactions with society, but that may background other important aspects of robustness, depending on circumstances. It may also induce shifts, as when Kurath (e.g. 89) focuses on robustness of governance, rather than of knowledge or innovations. She creates five dimensions on which to rate exercises in regulation and engagement. The added value of this evaluation, which are only tenuously connected with the Nowotny et al concept, is not clear because they are not operationalized sufficiently to allow the reader to recognize why the scores are given. Sometimes, the rating expresses enthusiasm about intentions rather than actual outcomes, for example with the UK NanoJury – which was a failure, I would argue, but is now rated highly by Kurath.

Similarly, Hansen (71-72) claims that "the image of 'social robustness' captures well the overall ambition of most public engagement processes whatever their specific format. The aim of most public engagement processes – at least according to their self-understanding – is to draw in various ways upon the experiences, knowledge and concerns of 'ordinary people' in order to develop science and technology in better accordance with the broader values and goals of the societies into which they are introduced." However, most exercises in public engagement are symbolic: "See, we have engaged", and not interested in better development of science and technology.

This is a critique of Hansen and Kurath, but also a stepping stone towards a critique of Mode 2. Hansen offers a lead into this, because his comments about the Mode 2 diagnosis are general and conceptual, not depending on the nature of public engagement exercises and their institutionalization. His key point is that the Mode 2 approach "fails to distinguish analytically between changes in the mutual interaction between societal subsystems and changes occurring in the organisations producing and governing innovation." (p. 73) His reference to Luhmann here is less important than his subsequent attempt to capture what is happening by introducing the notion of 'resonance' between societal subsystems, and the idea of organizations having to operate in different contexts (with different 'codes') at the same time. The Mode 2 diagnosis can then be positioned as a specific cross-section of this complex constellation, focusing on moves of organizations to accommodate new contexts. However, Hansen does not develop this further because he is more interested in cross-national comparisons, and mobilizes ideas of Jasanoff to indicate dimensions of comparisons.

Mode 2 revisited?

What if one develops the multi-level perspective further? Should one revisit the Mode 2 diagnosis even if by now the original energy of the diagnosis has been spent? The ongoing changes discussed under the heading of Mode 2 are real, but the claim that they add up to a new regime is doubtful (especially in its triumphant version of the original 1994 publication). The claim of Mode 2 became a policy fashion (Rip 2000), but the policy agendas have moved on. But it was also an attempt to diagnose ongoing transformations. Even when one disagrees with the diagnosis, one can still learn from the attempt.

This is where Hansen's criticism of the Mode 2 diagnosis as empirically located at the level of organizations, rather than at the societal level where de-differentiation is claimed to occur, is valuable, independently of the reference to Luhmann. More relevant for an evaluation of the diagnosis of a Mode 2 Society (Nowotny et al. 2001) is Ulrich Beck's work on reflexive modernization (Beck et al. 1994). Many features of Mode 2 are instances of blurring of boundaries, a key dimension of reflexive modernization. While Beck's programmatic diagnosis of first and second modernity (broadening his 1992 diagnosis of the risk society) is just as triumphant , and thus analytically disappointing, as in the original Mode 2 diagnosis, there is also an understanding of re-institutionalization as the reflexive construction of new boundaries and differentiations (Beck and Lau 2005, contra Nowotny et al (2001: 17) somewhat superficial critique).

There have been interesting empirical studies in Beck's DFG-funded Sonderforschungsbereich which show the interactions between the societal and organizational levels (see <www.sfb536.mwn.de>, cf. also Beck and Lau, 2005). With Pierre Delvenne, I have contributed to such empirical analyses by tracing changes in science institutions like funding agencies and Parliamentary TA organizations, and positioning them as instances of an overall pathway of reflexive modernization (Delvenne 2010, Delvenne and Rip submitted).

The question about the value of the Mode 2 diagnosis (revisited) then shifts to a broader question about new regimes of knowledge production that might emerge under changing societal circumstances and challenges. A key entrance point to address this question is how conditions and requirements for societal robustness of knowledge production are changing, and what the responses are from within the established system of (scientific) knowledge production, and from without. In Rip (2000) I offered a plea to postpone stabilization (i.e. a lock-in in a new regime) and be willing to entertain heterogeneity. This was a process argument, but based on the substantial diagnosis that the emerging regime of 'Strategic Science' would get locked-in prematurely. One normative evaluation included in this diagnosis was how techno-scientific promises lead to a focus on competition through (fast) innovation, which then backgrounds alternative innovation dynamics of 'collective experimentation' (Joly et al. 2010). These arguments still apply.

References

Beck, U. (1992) *Risk Society. Towards a New Modernity*. Cambridge: Polity Press.

Beck, U., A. Giddens and S. Lash (1994) *Reflexive Modernization*. Cambridge: Polity Press.

Beck, U. and C. Lau (2005) 'Second Modernity as a Research Agenda: Theoretical and Empirical Explorations in the 'Meta-Change' of Modern Society', *British Journal of Sociology* 99(4): 525-557.

Delvenne, P. (2010) *Mise en perspective des offices parlementaires de Technology Assessment: modernisation réflexive et décision publique*, Liège: Université de Liège. PhD thesis, defended 6 May 2010.

Delvenne, Pierre, and Arie Rip (2010), Reflexive Modernization in Action: Pathways of Science and Technology Institutions, manuscript submitted to *Social Science Information*

Hansen, J. 2009, Mode 2, systems differentiation and the significance of politico-cultural variety, *Science, Technology & Innovation Studies,* 5 (2), p. 67-85.

Joly, Pierre-Benoît , Arie Rip, and Michel Callon, 'Reinventing Innovation', chapter in Maarten Arentsen, Wouter van Rossum, and Bert Steenge (eds.), *Governance of Innovation*, Edward Elgar, November 2010.

Kurath, M. 2009, Nanotechnology governance: Accountability and democracy in new modes of regulation and deliberation, *Science, Technology & Innovation Studies,* 2 (87), p. 87-110.

Larédo, Ph., Jolivet, E., Shove, E., Raman, S., Rip, A., Moors, E., Poti, B., Schaeffer, G.-J., Penan, H., and Garcia, C.E.: 2002, *SocRobust Final Report*, Project SOE 1981126, Management Tools and a Management Framework for Assessing the Potential of Long-Term S&T Options to Become Embedded in Society, TSER Programme of the European Commission, January 2002, Ecole des Mines, Paris.

Nowotny, Helga, Peter Scott and Michael Gibbons, *Re-Thinking Science. Knowledge and the Public in an Age of Uncertainty*, Cambridge: Polity Press, 2001.

Rip, Arie, 'Controversies as Informal Technology Assessment', *Knowledge 8*(2) (Dec. 1986) 349-371.

Rip, Arie (2000), 'Fashions, Lock-Ins, and the Heterogeneity of Knowledge Production, in Merle Jacob and Thomas Hellström (eds.), *The Future of Knowledge Production in the Academy*. Buckingham: Open University Press (2000), 28-39.

Rip, Arie, Designing Robust Knowledge, paper prepared for the Conference "Learning Capacities in Knowledge Production Systems", Lausanne, 18-19 May 2001

Rip, Arie, and Haico te Kulve, 'Constructive Technology Assessment and Sociotechnical Scenarios. In Erik Fisher, Cynthia Selin, Jameson M. Wetmore (eds.), *The Yearbook of Nanotechnology in Society, Volume I: Presenting Futures*, Berlin etc: Springer, 2008, pp. 49-70.

Schot, J. and Rip, A.: 1997, The Past and Future of Constructive Technology Assessment, *Technological Forecasting & Social Change* 54, 251–268.

Stirling, Andrew, *On Science and Precaution in the Management of Technological Risk. Volume 1. A synthesis report of case studies.* Brussels/Luxembourg: European Commission, 1999. A report based on four evaluative survey studies: formal decision analysis and economics (Salo), institutional and regulatory policy analysis (Renn and Klinke), science and technology studies (Rip), risk assessment and environmental appraisal (Stirling).

Troyer, Ronald J., and Gerald E. Markle, *Cigarettes. The Battle over Smoking*, New Brunswick, N.J.: Rutgers University Press, 1983.

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010
ISSN: 1861-3675

STI
Studies
www.sti-studies.de

How to make the mode 2 thesis sociologically more robust?

A comment on Monika Kurath and Janus Hansen

Peter Wehling (University of Augsburg, Germany)

Over the last years, the intense and vivid debates which had developed around the so called mode 2 thesis after the publication of "The New Production of Knowledge" (Gibbons et al. 1994) and "Re-Thinking Science" (Nowotny et al. 2001) seem to have significantly abated. Nevertheless, the controversial issues that were raised in those disputes are, of course, far from settled or out-dated. Quite to the contrary, the questions concerning the changing relations of science and society and the potential emergence of new forms of knowledge production and expertise, termed "socially robust knowledge" and "socially distributed expertise" by Nowotny et al. (2001), still are highly relevant for STS. Given this background, the publication of Monika Kurath's (2009) and Janus Hansen's (2009) papers in the last issue of STI-Studies offers a good chance to reconsider these issues from some temporal distance. In my comment, I will make some remarks on how the mode 2 thesis is addressed and criticised in each of the two papers and then, in my short conclusion, argue for a primarily heuristic use of this thesis and the concepts mentioned above.

Nanotechnology governance – without socially robust knowledge?

In her paper on "Nanotechnology Governance", Monika Kurath, uses the concept of "socially robust knowledge" in order to examine to which extent the alleged "governance turn" in recent science and technology policies is actually linked with greater accountability and public participation. While there is obviously much talk of "public engagement" or "responsible technology development" in the field of nanosciences and nanotechnologies (NST), Kurath's comparative analysis of 14 self-regulatory and soft law schemes and six public engagement projects presents rather disillusioning results. With regard to the mode 2 thesis it appears to be particularly alarming that the soft law and self-regulatory initiatives "considered little societal knowledge (…) and were rarely subject to external evaluation, testing, and improvement" (Kurath 2009: 101) and, similarly, most of the public engagement projects were still shaped by "the notion of a boundary separating science and the public into two societal actors on either side of an expert/lay divide" (Kurath 2009: 101-102).

These findings seem to explicitly contradict or even refute one of the core assumptions of the mode 2 thesis: the assertion of a shift from the production of scientifically reliable to socially robust knowledge. The latter is characterised by Nowotny et al. (2001: 167), besides other criteria, as "infiltrated and improved by social knowledge" and subject to frequent testing, feedback and evaluation by a variety of actors. I would, however, suggest that what is undermined by Kurath's findings is first and foremost a certain evolutionist interpretation of changes in the relationships of science and society, of expert and lay actors. This reading which apparently is supported by the mode 2 authors themselves relies on the *co-evolution* of "mode 2 science" and "mode 2 society" (Nowotny et al. 2001: 30-49) which is held to result in convergent trends within the two spheres. It thus underestimates the essentially political, i.e. contingent and contested nature of new modes of producing and evaluating (scientific) knowledge.[1] If one abandons the questionable background assumptions of co-evolutionary "coincidences and correspondences" (Nowotny et al. 2001: 30) between science and society, one gets a more differentiated understanding of the shift from reliable to socially robust knowledge and its limitations. It becomes clear then that the extent to which environmental and consumer organizations or "ordinary" citizens are involved in the production and assessment of knowledge primarily depends on the openness of institutional settings and policy arenas as well as on the power relations of different actor groups. Thus, even in the field of NST, where upstream public engagement recently became "a fashionable term in science communication" (Kurath 2009: 89), it seems to be the rule rather than the exception that established actors only pay lip service to the rhetoric of public participation. Nevertheless, Kurath's analysis also shows that some of the employed governance mechanisms, mainly in the UK, actually did "provide a substantial level of exchange and mutual learning" (Kurath 2009: 101). In addition, the fact that – after the GMO disaster in Europe – governments in almost all Western countries feel obliged to adopt at least the rhetoric of dialogue and public engagement in their NST programmes is striking. This exemplarily highlights that the legimitation and acceptability of new science and emerging technologies become increasingly dependent on wider social processes in which a great variety of actors potentially play an important role.[2] Since the concept of socially robust knowledge reflects such dynamics, it proves to be a useful heuristic and analytical tool to study how new constellations of social actors emerge in relation to the production of knowledge.

But the extent to which scientific knowledge is in fact "infiltrated" by social knowledge and subject to external evaluation cannot be not predetermined on a theoretical level but has to be established empirically. Kurath's study thus confirms the heuristic fruitfulness of a central concept of the mode 2 thesis while her findings simultaneously challenge an interpretation of this thesis in terms of an evolutionary master-trend from mode 1 to mode 2, from reliable to socially robust knowledge.

Rectifying mode 2 with Lumann?

Janus Hansen raises two more theoretically demanding objections to the mode 2 thesis. He, firstly, questions the assumption of a convergent and homogeneous transformation of all modern societies towards "mode 2 societies", an assumption which according to Hansen is at least implicitly suggested by the work of Nowotny, Gibbons and colleagues. He rightly asks "how this implicit assumption of convergence can be transformed from

[1] See for more detailed criticisms of this point Pestre 2003; Wehling 2006a.

[2] Beyond the massive social conflicts over GMOs, there are indeed many more examples of the involvement of social actors in the production and assessment of (scientific) knowledge. An illuminating case in point is the engagement of patients' associations and health movements in medical research; see for instance Epstein 1996; Rabeharisoa/Callon 2002; Brown 2007; McCormick 2009, and for an overview Epstein 2008.

a conceptual a priori into a question suitable for theoretically grounded, empirical examination" (Hansen 2009: 72) and argues for comparative, especially cross-national research in order to account for variations in different social contexts.[3] It should be clear from my comments on Kurath's paper as well as my earlier criticism of the model of co-evolution underlying "Re-Thinking Science" (Wehling 2006a) that I largely agree with Hansen's suggestion. Likewise, I have little doubt that the concept of "political culture" recently re-adopted by Sheila Jasanoff might prove fruitful in order to capture variations in the ways different societies deal with the challenges posed by scientific knowledge and novel technologies (see Hansen 2009: 79-81). I would, however, like to add one qualification: cross-national comparisons will certainly remain important but no longer seem sufficient to fully understand the variety of forms in which knowledge is produced, legitimized and evaluated in different cultural and political contexts. This is due not only to the diminishing influence of nation-states on globalizing economies and sciences, but also to the fact that international or transnational institutions play an increasingly important role in shaping research and innnovation policies and in regulating science and technology.[4] Cross-national comparisons therefore have to be complemented with comparative research into the institutional cultures of different transnational organizations as well as with what I would term "cross-technological" comparisons. Nanotechnology, for instance, is framed and institutionally dealt with similarly in many countries, but quite differently from other technologies such as agrobiotechnology or human genetics and biomedicine.

Hansen's second criticism of the mode 2 concept is in my view much less convincing than his call for comparative research. Opposing the mode 2 claims of "dissolving boundaries between science and society" or even societal de-differentiation, Hansen resorts to Luhmann's theory of social systems with a twofold aim: On the one hand, he adheres to "socially significant distinctions" which, according to Hansen (2009: 74) "should not be overlooked or abandoned for both analytical and normative reasons", namely the distinctions between science as a functionally specialised (sub-)system and society or other subsystems such as politics or economy. As is well known, according to Luhmann, science constitutes an autonomous subsystem by exclusively referring in its communicative operations to the binary distinction of true vs. false. On the other hand, Hansen calls for greater attention to the differences between "two levels of social reality", namely science as a subsystem of society and organizations such as universities or industrial R&D departments which operate with reference to more than one subsystemic code (Hansen 2009: 76). While it is certainly true that in "New Production of Knowledge" and "Re-Thinking Society" de-differentiation often is too hastily proclaimed and levels of analysis are not clearly separated, I have serious doubts whether Luhmann's theory provides a perspective to adequately capture the complex and flexible relations of science to the state, the economy, the media and the public in contemporary societies. I rather suspect that systems theory draws too static a picture of science as a self-referential communication system the "core" of which (the true-false distinction) is by definition immune to transformations.

Although this point would certainly deserve much more detailed elabora-

---

3 One could reasonably argue that this is exactly what Kurath does in her paper. I presume, however, that Hansen argues for more detailed, qualitative research than Kurath's rating of social robustness along a numerical classification.

4 Among the sample of 20 nanotechnology governance projects analyzed by Kurath five are launched by supranational (EU) or international bodies (OECD) and another five by private actors.

tion, I can only very briefly sketch the argument here. Even if one admits that scientific communication "in the final instance" (Hansen 2009: 75) recurs upon a distinction between true and false, one should acknowledge that this conception of scientific communication is equally restrictive and selective. In particular, it remains unspecific with regard to a great number of issues which are exceedingly important both for the dynamics of science and the relations of science and society but cannot be meaningfully expressed in terms of true or false – and, at the same time, offer various opportunities for the engagement of non-scientific actors. A pertinent example is the choice of research questions and priorities which obviously cannot be judged as true or false but merely as more or less interesting, promising or relevant. Therefore it is hardly surprising that a broad range of actors (from politics, economy, civil society and the like) strive to influence, often successfully, the research agenda of science. A second case in point is the scientific creation and subsequent diffusion of new entities such as GMOs, embryonic stem-cells, nanoparticles or human-animal chimaeras. Again, the question is not whether these entities are "true" or "false" but whether it is considered acceptable, in terms of risk or ethical justification, to create, utilize and release such entities. And again, social actors massively intervene in discussions on such issues, as the fierce conflicts over agro-biotechnology or stem cell research show. Further examples are the debates on unknown and unforeseeable risks which result in a remarkable "politicization of non-knowledge" (cf. Wehling 2006b; Böschen et al. 2010) or conflicts over the design of clinical drug tests and safety research on GMOs. In all these cases, important areas of scientific communication (or scientific practice, as I would prefer to say) are (potentially) opened to negotiations with a variety of actors, thus confirming the heuristic and analytical relevance of concepts such as "socially robust knowledge" or "socially distributed expertise". Yet, what is not contested in all these cases is that scientific communication is (or should be) about truth; what *is* debated and transformed, however, are the social contexts and the ways in which questions of true or false are addressed.

To put the argument briefly: With regard to the relations between society and science and to emerging new modes of knowledge production in contemporary modernity, the question of whether or not de-differentiation occurs on the very general level of binary codes of communication is less important than most Luhmannians as well as many of their critics usually believe. Instead, the focus on functional differentiation or de-differentiation tends to distract our attention from the far more significant developments on the "lower" levels of social reality. Thus the occasional talk of de-differentiation in the work of Nowotny and colleagues is sociologically less informative than the many examples they give of how the institutionally fixed and stabilized "boundaries" between science and society are contested, permeated, transgressed, and reconstructed.[5]

Conclusion

Both papers inspiringly contribute to renewing the debates on the mode 2 thesis. They do not only point to its limitations but also sketch out promising perspectives to overcome some of these limitations, for instance by comparative research focusing on how the supposedly new relations between science and society differ across national, cultural, or institutional contexts. I suggest to conclude that the

[5] I agree with Hansen that the differences between science (or scientific practices) and, for instance, economic or political action are also normatively significant; yet it is far from self-evident what practical consequences should be drawn from this fact.

mode 2 thesis should be understood and used as a "tool-box" of inspiring and sensitizing concepts (such as "socially robust knowledge") rather than as a (sociological) theory of "mode 2 science" and "mode 2 society". Nevertheless, contrary to Hansen, I do not see the need nor the benefit of remedying the weaknesses of the mode 2 thesis by resorting to Luhmann's systems theory, for this theory with its focus on the utterly abstract distinction of true and false has little to offer to adequately understand those new modes of interaction between science and society to which the mode 2 thesis has successfully drawn our attention.

References

Böschen, Stefan/Karen Kastenhofer/Ina Rust/Jens Soentgen/Peter Wehling, 2010: Scientific Non-Knowledge and Its Political Dynamics. The Cases of Agrobiotechnology and Mobile Phoning. In: *Science, Technology and Human Values* 35 (in press).

Brown, Phil, 2007: *Toxic Exposures. Contested illnesses and the environmental health movement*. New York: Columbia University Press.

Epstein, Steven, 1996: *Impure Science. AIDS, Activism, and the Politics of Knowledge*. Berkeley: University of California Press.

Epstein, Steven, 2008: Patient Groups and Health Movements. In: Edward J. Hackett et al. (eds.): *The Handbook of Science and Technology Studies*. Third edition, Cambridge, MA./London: MIT Press: 499-539.

Gibbons, Michael et al., 1994: *The New Production of Knowledge*. London: SAGE Publications.

Hansen, Janus, 2009: Mode 2, Systems Differentiation and the Significance of Politico-Cultural Variety. In: *Science, Technology & Innovation Studies* 5(2): 67-85.

Kurath, Monika, 2009: Nanotechnology Governance. In: *Science, Technology & Innovation Studies* 5(2): 87-110.

McCormick, Sabrina, 2009: *Mobilizing Science. Movements, Participation, and the Remaking of Knowledge*. Philadelphia: Temple University Press.

Nowotny, Helga/Peter Scott/Michael Gibbons, 2001: *Re-Thinking Science*. Cambridge: Polity Press.

Pestre, Dominique, 2003: Regimes of Knowledge Production in Society: towards a More Political and Social Reading. In: *Minerva* 41: 245-261

Rabeharisoa, Vololona/Michel Callon, 2002: The involvement of patients' associations in research. In: *International Social Science Journal* 54(3): 57-65.

Wehling, Peter, 2006a: Sozial robuste Wissenschaft in der Modus 2-Gesellschaft? In: *Soziologische Revue* 29: 257-264.

Wehling, Peter, 2006b: *Im Schatten des Wissens? Perspektiven der Soziologie des Nichtwissens*. Konstanz: UVK.

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI
Studies
www.sti-studies.de

Social robustness as analytical tool or normative standard?

A comment on Monika Kurath „Nanotechnology Governance. Accountability and Democracy in New Modes of Regulation and Debate“

Janus Hansen (Copenhagen Business School, Denmark)

A recent issue of STI-Studies (vol. 5, no. 2) contained two articles, which both addressed the so-called 'Mode 2-diagnosis' by Nowotny et al. (2001). In particular, they both made reference to the affiliated concept of 'social robustness'. Given this topical overlap, the editors of STI-Studies encouraged the authors of the two articles to provide comments on each other's paper. My own paper (Hansen 2009) is concerned primarily with the theoretical consistency and analytical value of the concept of 'social robustness' for comparative analysis of public engagement processes, and was conceived as an attempt to lay a conceptual ground for ongoing empirical work. In this respect, Monica Kurath's paper is ahead of mine, as it presents a completed comparative study of nano-science governance based on the concept of social robustness (Kurath 2009). In my view, Kurath's paper thus constitutes a fruitful step beyond my own reflections. I am pleased to note that her analysis indeed addresses a number of the dimensions I suggest as central for empirical inquiries in the final pages of my paper, such as institutional embedding, procedural design, and discursive dynamics, and does so in a grounded and hands-on manner. However, her more operational approach to questions I pose only at an abstract and analytical level also illustrates some of the caveats I believe are entailed in applying the concept of 'social robustness' for comparative empirical analysis. I shall discuss some of these in the following. However, I should emphasize that I am keenly aware that Kurath has faced the more challenging task of leaving the academic office and confront theories with actual, social practice. This inevitably makes matters more complicated compared to isolated theoretical reflection. Therefore, the following comments should be read as constructive suggestions for further work, not as a polemic against the work done by Kurath.

I divide my comments in three sections: The first one deals with the epistemological status of the concept of 'social robustness'. The second pertains to the comparability of the cases presented in Kurath's paper. The third regards the question of how more explanatory or interpretive value can be gained from analyzing this kind of material. However, I shall start with a preliminary observation on Kurath's adoption of the concept of social robustness.

Originally, the term 'social robustness' in the Mode 2 diagnosis pertains to novel demands made on (academic) knowledge production from the surrounding society (claiming that the borders between scientific knowledge production and 'society' are eroding). Kurath moves the application of the concept from the domain of (scientific) knowledge production to the realm of (nano-science) governance. She argues that "The openness of social robustness well matches the analytical needs of a study of societal processes or activities beyond science and academic knowledge production that include regulation, deliberation, public engagement and governance" (ibid. 90). I consider this move unproblematic. In fact, perhaps the concept is more suitable in the realm of governance than in knowledge production per se. However, with this move the concept also loses its radical edge, when compared to other conceptualizations of the interface between science and society. Some of the appeal – but also much of the provocation – of the Mode 2 thesis lies in the claim that the 'epistemological core' of contemporary science is empty (Nowotny et al. 2001; 179). This claim is important as normative underpinning of the calls for a reconfigured and less hierarchical interaction between experts and lay-people. Kurath thus navigated around some of the epistemological intricacies affiliated with the Mode 2 diagnosis by looking 'only' at governance, as it is much less controversial to claim that governance of science – as opposed to science proper – must be open to inputs from the outside, in order to be 'socially robust'. Nonetheless, my first comment regards the epistemological status of the concept of social robustness, but from a slightly different angle.

Social robustness – empirical reality of normative standard?

Some of the criticism that has been leveled against the Mode 2 diagnosis pertains exactly to its epistemological status (e.g. Shinn 2002). The authors have been criticized for oscillating between, on the one hand, claiming to describe a shift from a Mode 1 to a Mode 2 knowledge production, as a set of ongoing social processes (empirical reality), on the one hand, and presenting a normative standard on the other, an ideal to be aimed for in order to stimulate innovation, mitigate risks and enhance legitimacy of techno-scientific development.[1] Kurath decisively opts for the second option and makes 'social robustness' the normative standard against which her cases are measured. She constructs a social robustness-index composed of measures of five analytical dimensions ('contextualization', 'stability', 'acceptability', 'social knowledge' and 'evaluation'). Also, this choice is a perfectly legitimate move, although the methodological aspects of the index construction and scores can be discussed.[2] In my eyes, however, this use of the concept of social robustness raises two questions, which are not addressed in Kurath's paper. The first has to do with how we interpret the performance or 'compliance' with the standard. The second has to do with why this particular standard in this particular operationalization is selected and how it relates to other possible standards, which could perhaps be applied in an equally meaningful manner to assess the cases.

Out of the total of 20 either 'regulatory' or 'public-engaging' events or processes analysed in the paper, most score rather poorly on the social robustness-index. According to Kurath

[1] As I noted in my paper, the Mode 2 thesis seems in particular to be embraced by policy makers for its normative implications, rather than its empirical substantiation, a point that seems to be supported by Kurath's findings.

[2] The social robustness index consists of 5 components, which are each assigned one of three values (-1, 0, 1, but also at some point 0.5) and summed. The score system, the fact that the five dimensions are given the same weight and the principles of score assignments, are all issues that could be given further consideration. However, I accept that for the sake of simplicity pragmatic choices need to be made.

this is a cause for concern regarding the democratic accountability of the resulting governance of nano-science. I concur this is a valid and pertinent concern. However, this result could also lead us to question the viability of the concept of social robustness from an analytic rather than a normative angle. We could ask empirically whether 'social robustness' is in fact a good tool to grasp the empirical reality of those processes. The very mixed scores on the index could thus be used to question the empirical viability of Nowotny et al.'s claim that we are moving towards a Mode 2 relationship between science and society. Perhaps some of the processes were instigated with entirely different purposes than achieving 'social robustness' as envisioned in the Mode 2 thesis. In that case, a low score on the social robustness-index may not be an entirely fair or relevant evaluation of the processes and organizations examined, and we may need other tools to get an analytical grip on the intrinsic dynamics and external effects of these processes.

When it comes to public engagement with technology alone (a subset of Kurath's cases) there is a lively discussion on how best to evaluate such processes.[3] Kurath's social robustness index might benefit from being confronted, compared or supplemented with other evaluative criteria discussed in the literature (see e.g. discussions in Rowe and Frewer 2000, Renn et al. 1995, Abels and Bora 2000, Horlick-Jones et al. 2007). When it comes to evaluation of 'governance' in the broader sense of processes that move beyond conventional 'government', the number of frameworks and approaches on offer are even more abundant (to name just one contribution to this discussion, see Borrás and Conzelmann 2007). The point is not that the social robustness index is flawed, but it appears somewhat arbitrary and could be qualified through a more elaborate confrontation with normative and conceptual alternatives, which might reorder the scores of the cases.

Rendering cases comparable, managing diversity

My second comment pertains to the comparability of the cases entailed in Kurath's study. In my own paper I suggest that comparability is not an intrinsic characteristic of cases. Rather comparability must be established through the researcher's calibration of the distinctions through which selected aspects of the social world are observed. Comparative research therefore needs to balance the need for similarity (selecting cases of the same phenomenon) and distinctiveness (ensuring enough variation is observable), in order to establish worthwhile comparisons. Kurath argues that her cases are similar-in-kind in so far, as they are all examples of a novel approach to the regulation of nano-science. As such, all the cases allegedly embody or express a general shift from (hierarchical) 'government' to (network-like or deliberative) 'governance'. I find this overall framing of the cases convincing enough for the present purpose. Yet, one may nonetheless wonder, if perhaps there is too much diversity among the selected cases to make analytically fruitful comparisons. The cases are not only drawn from four different national, one supranational and one international context, they also span both public and private initiatives (or what should perhaps more appropriately be labeled corporatist) and seem from the description in the annexes to have quite different aims, serve quite different purposes for their sponsors

[3] Personally, I think that there has been a tendency for the discussion on normative standards to take precedence over actual empirical analysis of public engagement activities, which means that the accumulation of knowledge and experiences across cases are less than satisfactory.

and comprise very different modes of communication. As a consequence, Kurath furthermore distinguishes between cases as 'soft law measures', 'self-regulatory initiatives' and 'public engagement projects'. All in all, this amounts to quite a lot of variation on quite a lot of dimensions among the 20 cases included in the study. As a consequence, it is not entirely clear what kind of lessons can be drawn from the performance scores assigned to the cases. In a next step it may perhaps be recommendable to focus on a smaller subset of the cases, holding some of this variance constant, which would allow for more in-depth analysis, including more contextual features. This brings me to my third and final comment.

Learning from comparative analysis

In my paper I comment critically on the fact that a lot of research on public engagement is either dealing with normative reflections or focusing narrowly on single cases, thus ignoring the potential of comparative research. In my view, one strength of Kurath's paper lies in the fact that it presents and compares a significant number of cases. However, processing such a rich material in a journal article comes at a price. In this case, the price is that the empirical sections of the paper have a largely descriptive and classificatory nature. This is perfectly respectable, but hopefully the effort will not be terminated here. In a next step it would be nice to see more of an explanatory or interpretive effort, to account in more detail for (perhaps selected aspects of) the similarities and differences among the cases. How can the variance covered by the cases be interpreted or explained? For instance, what difference does it make for a governance initiative whether it is organized by a private organization/association compared to a state agency or an international organization? This will likely impinge on both the public legitimacy and the policy impact of the procedure. Similarly, is it possible to establish any (systematic) effects of the national context, in which the procedures are embedded? It seems reasonable to expect that they are both shaped by and play into different institutional settings and political cultures. It is mentioned in a footnote (note 8, p. 91) that the aim of the study was to undertake a transatlantic comparison. But this comparative perspective does not really appear in the analysis. In my own paper I argue that systematic comparative analysis of processes of public engagement should form an important way forward in our understanding of the pros and cons of public engagement. Therefore, I would welcome an attempt to further examine differences and similarities across the cases in a more interpretive and/or explanatory fashion. The ambition is already present in the paper as Kurath argues that

"Questions will focus on the ways governance has been embedded in social, cultural, political and historic contexts, and their relations with current policy and technology discourses, which include environmental, health and safety (EHS) issues" (p. 91).

However, one may wonder whether the operationalization of this dimension in questions about whether the regulatory schemes are based on 'standards' or 'principles', and whether the public engagement processes are focused on 'information provision' or 'deliberation', actually provides enough information to address the question of contextualization satisfactorily. In any case, the measurement stops short of making any kind of causal inferences, which in my view should form a desirable next step. This may, however, require conceptual and methodological tools beyond what the Mode 2 framework delivers.

Concluding remarks

Kurath summarises her analysis in the following manner:

"These findings contest the idea that deliberative governance projects and public upstream engagement in NST exemplify a paradigm shift in techno-political discourse and will lead toward the more democratic development of technology that is advocated by proponents of the upstream engagement approach … In fact, governance projects still appear to limit public engagement to values, and social and ethical matters, rather than to expose expertise to scrutiny…" (p. 102).

I believe this conclusion is warranted and it corresponds well with my own observations and concerns regarding the actual impact of the discourses about expanded public engagement (e.g. Hansen 2010). It certainly should give rise to normative concerns when "political responsibility is distributed and deliberated among a variety of actors in different societal domains" (ibid.), but no actor or institution can be held democratically accountable. Indeed this would appear as an empirically grounded example of Ulrich Beck's catch phrase of 'organized irresponsibility' (Beck 1999).

However, looking only at cases which supposedly embody this alleged new mode of governance we do not learn anything about what remains of conventional 'government' in the field of nano-science. Do these novel processes of governance replace conventional government completely, or are they rather layered on top of a more conventional regulatory structure? If so, is this a good or a bad thing, given the somewhat questionable performance of the processes surveyed for their ability to establish social robustness?

This last question may also serve as a call for conceptual and methodological self-reflection. If we find that governance processes do not deliver what some expect in terms of legitimacy and rationality gains, is it then necessarily a sign that democratic control of techno-scientific dynamics is being undermined? Or is it perhaps an indication that existing institutions and organizational arrangements of governance are more resilient than some scholars currently suggest.[4] While we should certainly be aware of the kind of democratic problems identified by Kurath, we should also ask whether the government/governance distinction constitutes mutually exclusionary categories and whether the concept of social robustness is an adequate and sufficiently sensitive tool to analyse the ongoing developments at the interface of techno-science, politics and the larger public.

References

Beck, U. (1999) *World Risk Society*, Polity Press, London

Bora, A. and Abels, G. (2004) *Demokratische Technikbewertung*, transcript Verlag, Bielefeld.

Borrás, S. and Conzelmann, T. (2007) Democracy, Legitimacy and Soft Modes of Governance in the EU: The Empirical Turn', in *Journal of European Integration*, Vol. 29, no. 5, pp. 531-48.

Hansen, J. (2009) 'Mode 2, Systems Differentiation and the Significance of Politico-Cultural Variety. Reflections on the theoretical foundation of comparative analysis of public engagement practices', in *STI-Studies*, Vol 5, pp. 67-86.

Hansen, J. (2010) *Biotechnology and Public Engagement in Europe*, Palgrave-MacMillan, Basingstoke.

Horlich-Jones, T. et al. (2007), *The GM Debate. Risk, politics and public engagement.* Routledge, London.

Kurath, M. (2009) 'Nanotechnology Governance. Accountability and Democracy in New Modes of Regulation and Deliberation, in *STI-Studies*, Vol. 5, pp. 87-110.

[4] Kurath herself seems to be leaning towards this interpretation, when she argues that,"… the notion of a boundary separating science and the public into two societal actors on either side of an expert/lay divide, and the focus on old contrast structures that further set a unified science and an illiterate public in opposition, persist in most of the projects" (Kurath 2009: 102).

Nowotny, H., Scott, P. and Gibbons, M. (2001) *Re-Thinking Science*, Polity Press, Cambridge.

Renn, O., Webler, T., Wiedemann, P. (eds.) (1995), *Fairness and Competence in Citizen Participation: Evaluation Models for Environmental Discourse*, Kluver Academic Publishers, Dordrecht/Boston/London.

Rowe, G. and Frewer, L. (2000) 'Public Participations Methods: A Framework for Evaluation', *Science, Technology & Human Values*, vol. 25, pp. 3-29.

Shinn, T. (2002) 'The Triple Helix and New Production of Knowledge: Prepackaged Thinking on Science and Technology', *Social Studies of Science*, vol. 32, pp. 559-614.

Science, Technology & Innovation Studies
Vol. 6, No. 1, August 2010

ISSN: 1861-3675

STI
Studies
www.sti-studies.de

Mode 2: Theory or Social Diagnosis?

A Comment on Janus Hansen „Mode 2, Systems Differentiation and the Significance of Politico-Cultural Variety"

Monika Kurath (University of Basel, Switzerland)

Janus Hansen's essay examines in how far the Mode 2 concept (Gibbons et al. 1994, Nowotny et al. 2001) is applicable as a theoretical or analytical concept for a cross-national comparison of public engagement practices. Influenced by reflections on socially robust knowledge production and the role of science in society by Gibbons and Nowotny et al., Hansen begins his essay with the observation of a rising demand for public engagement (Gibbons et al. 1994, Nowotny et al. 2001). In the course of the article he confronts the Mode 2 concept with competing sociological approaches, in particular Luhmann's systems theoretical approach (Luhmann 1984) and Jasanoff's concept of political culture (Jasanoff 2005).

The article mainly focuses on a broad-critical discussion of Mode 2, drawing upon the arguments of earlier diagnoses (see e.g., Weingart 1997, 1999, Pestre 2000, 2003). In accord with them, Hansen argues that the Mode 2 approach lacks a sufficient social-theoretical grounding as well as a conceptually sharpened and sensitive tool for the analysis of politico-cultural variety in science/society interaction. Hansen claims that Mode 2 conveys an implicit thesis of convergence, seemingly suggesting that all modern societies are affected by similar transformations. Relying on basic principles of systems theory (e.g. Luhmann 1984), Hansen considers two aspects of the Mode 2 approach intrinsically problematic:

1) Mode 2 contests the theoretical assumption of social differentiation and instead observes a transgression between different societal systems.
2) It fails to distinguish analytically between changes on the sub-systemic and organizational level by relying on categories it claims are dissolving.

Although agreeing with the authors of Mode 2 and their observations of a transformation of science and academic knowledge production in the last 50 years—like Weingart and Pestre—Hansen doubts whether the empirical material Novotny et al. (2001) provide is sufficient to abandon well established basic principles of systems theory. While discussing Mode 2 as a theoretical and analytical concept in the first part of the article, Hansen later suggests that Mode 2 might be conceived as a diagnosis of social transformation, which implies a normative claim for engaging the public in techno-scientific decision-making, rather than a conceptual basis for theoretical and empirical analysis.

Hansen's vague differentiation in looking at Mode 2 both as a theoretical concept and as a social diagnosis remains a core problem throughout the whole article. To initially define Mode 2 as a social diagnosis rather than a theoretical concept would have made most of the aspects criticized by Hansen less essential. Considered as a social diagnosis, speculative ideas such as the observation of converging social systems might have been discussed in more detail. By reading Mode 2 as a theoretical concept instead, Hansen's contention is correct that minimal consistency with basic principles of neighbouring social theories are necessary. However, in my reading of Mode 2 (Nowotny et al. 2001, 28, 32) the authors remain rather open to the question whether different social systems would really converge, or whether—according to Weingart's observations—transformations such as a scientification of politics and a politicization of science would take place within the systems (Weingart 1983, 2001).

In order to avoid these conceptual inconsistencies, Hansen suggests considering public engagement processes as poly-contextual organisations. Conceived in this way, engagement procedures can be compared by identifying similar overlying social trends having different local manifestations. As a theoretical tool which allows comparing engagement processes within the specific logics of their particular social systems and domains, Hansen introduces the concept of political culture developed by Sheila Jasanoff (Jasanoff 2005). He considers this concept a more fruitful analytical approach to a comparative analysis of legitimating practices in public engagement procedures. Accordingly he claims that Jasanoff's understanding of political culture corresponds to systems-theoretical assumptions. Furthermore, Hansen regards the concept as a helpful tool to observe and explain variation in the way public engagement is institutionalized and used in different national contexts and to empirically address questions of convergence or continued variety. Jasanoff's use of political culture consists of three relevant analytical dimensions, along which a comparative analysis of public involvement in techno-political decision making can be designed (Jasanoff 2005, 281):

1) Representation: how voices are made audible in the political and policy process and how political inclusion in turn affects the framing of issues
2) Participation: who actually takes part in politics, and who does not
3) Deliberation: the discourses in which political debate is conducted, together with their limits and achievements

Hansen suggests that these three dimensions of political culture could serve as a tool to compare public engagement procedures. This analytical approach, with which I agree, allows a comparative analysis of the specific patterns of interaction between different societal domains, depending on their national and sectoral contexts. It distinguishes between societal subsystems as relatively stable discursive environments and organizations, which may be more easily reconfigured by analyzing representation, participation, and deliberation.

To analyze public engagement processes—focusing on how they are shaped by their politico-cultural environments and in some cases consciously tailored to fit the politico-cultural contexts in which they unfold —Hansen suggests further comparison of public engagement procedures across different politico-cultural contexts. Because the success of engagement processes is likely to depend upon their compatibility with the politico-cultural context in which they operate, Hansen applies Jasanoff's (2005) three analytical dimensions to specific research designs. But he suggests furthermore that comparative analysis of public engagement processes, with regard to their ability to generate socially robust innovation, should be based upon three additional analytical dimensions (Hansen 2009, 83):

1) Institutional embedding: where and how public engagement procedures are institutionally anchored
2) Procedural design: which actors have been included/excluded from participation, and how interaction is organized and roles are defined and distributed
3) Discursive dynamic: the communicative resources relied upon and how they condition each other

However, as Jasanoff's dimensions are already supposed to work as tools for the analysis of public involvement in technopolitical decision-making (Jasanoff 2005, 281), the added value of these latter dimensions remains unclear to me. From my point of view, Hansen's institutional embedding somehow narrows the analytical perspective from organizations to institutions and, at the same time, links it to neo-institutionalism, thereby inducing analytical difficulties which result from these multiple theoretical bases. The wording 'procedural design' implies a focus on the organization and procedure of the participatory process but does not address Jasanoff's original question of inclusion/exclusion. What exactly is to be compared within the procedure and organization needs further specification. In addition, the concept of discursive dynamic lacks specificity and I do not see the value it adds to deliberation.

Summing it up I consider Hansen's efforts to further develop existing analytical approaches in order to use them for the comparative analysis of public engagement procedures interesting and fruitful. I would, however, have appreciated a more comprehensive discussion of Jasanoff's (2005) political culture approach and its applicability to the analysis of public engagement procedures across different politico-cultural contexts. In particular, a more extensive discussion of Hansen's three analytical dimensions is missing. Being clearer with respect to their exact focus, content, and compatibility with the suggested perception of public engagement processes as organizations might have offered interesting insights and hints at their added value compared to Jasanoff's (2005) categories. This, instead of revisiting familiar criticism of Mode 2, could have fostered the progress of the still underutilized and arguably underdeveloped theoretical and analytical tools of comparative analysis in STS.

Prologue: Mode 2 as a theory or as a social diagnosis?

In the article following Hansen's essay on Mode 2, I used social robustness from the Mode 2 framework as an analytical concept, following Hansen's suggestion to compare different international governance and engagement procedures in Nanotechnology. I found the criteria for social robustness (Nowotny et al. 2001, 167) quite helpful and I did not encounter in my analysis conflicts of Mode 2 with basic assumptions of systems theory as described by Hansen. The criteria of social robustness seem sufficiently openly designed to allow a comparison of governance and engagement practices within their particular social, political, and cultural contexts. But using social robustness as an analytical tool did not facilitate a more in-depth analysis of the discourses, practices, and implications of these new forms of governance and engagement processes. Also, their role in science and technology policy and their ability to frame techno-political decision-making in different social, cultural, and political environments remained dissatisfying. From the rather narrow social robustness perspective, most approaches I analyzed did not meet their purpose of generating a more democratic and responsible science and technology policy. Thus, the empirical test of using Mode 2 and particularly the related idea of social robustness as an analytical category in a comparative study produced some interesting results, but their utility did not necessarily exceed that of a deficit analysis.

This supports the proposal of several critics, including Hansen, to treat Mode 2 and the idea of social robustness as a social diagnosis rather than a theoretical concept. In this respect, I agree with Hansen's suggestion to base comparative analysis on related, but further developed theoretical and analytical approaches. Jasanoff's concept of political culture clearly offers a more comprehensive and elaborate tool than Mode 2 and social robustness.

References

Gibbons, Michael et al., 1994: *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies.* London: Sage.

Hansen, Janus, 2009: Mode 2, Systems Differentiation and the Significance of Politico-Cultural Variety: Reflections on the Theoretical Foundation of Comparative Analysis of Public Engagement Practices. In: *Science, Technology & Innovation Studies* 5 (2): 67-85

Jasanoff, Sheila, 2005: *Designs on Nature: Science and Democracy in Europe and the United States.* Princeton: Princeton University Press.

Luhmann, Niklas, 1984: *Soziale Systeme: Grundriss einer allgemeinen Theorie.* Frankfurt am Main: Suhrkamp.

Nowotny, Helga et al., 2001: *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty.* London: Polity Press.

Pestre, Dominique, 2000: The Production of Knowledge between Academies and markets: A Historical Reading of the Book The New Production of Knowledge. In: *Science, Technology & Society* 5: 169-181

---, 2003: Regimes of Knowledge Production in Society: Towards a More Political and Social Reading. In: *Minerva* 41: 245-261

Weingart, Peter, 1983: Verwissenschaftlichung der Gesellschaft — Politisierung der Wissenschaft. In: *Zeitschrift für Soziologie* 12: 225-241

---, 1997: From ‚Finalization' to ‚Mode 2': old wine in new bottles. In: *Social Science Information* 36 (4): 591-613

---, 1999: Neue Formen der Wissensproduktion: Fakt, Fiktion und Mode In: *Technikfolgenabschätzung - Theorie und Praxis [formerly: TA-Datenbank-Nachrichten]* 3/4: 48-57 <http://www.itas.fzk.de/deu/tadn/tadn993/wein99a.htm>.

---, 2001: *Die Stunde der Wahrheit? Vom Verhältnis der Wissenschaft zu Politik, Wirtschaft und Medien in der Wissensgesellschaft.* Weilerswist: Velbrück Wissenschaft.