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## Converging institutions: shaping the relationships between nanotechnologies, economy and society

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by  
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# Converging institutions. Shaping the relationships between nanotechnologies, economy and society

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## **Abstract**

This paper develops the concept of converging institutions and applies it to nanotechnologies. Starting point are economic and sociological perspectives. We focus on the entire innovation process of nanotechnologies beginning with research and development over diffusion via downstream sectors until implementation in final goods. The concept is applied to the nano-cluster in the metropolitan region of Grenoble and a possible converging institution is identified.

Keywords: converging institutions, converging technologies, nanotechnologies, systemic risks.

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# 1 Introduction

Up to the opinion of many experts, nanotechnologies will be the dominating general purpose technologies of the next decades (see e.g. BMBF (2004)). In contrast to 'simple' product or process innovations, a general purpose technology is characterized by (i) pervasiveness, i.e. it may be adopted to a multitude of uses, (ii) innovational complementarities, i.e. it affects the innovation process in upward and downward industries and at the same time is itself affected by these innovations, and (iii) induces reorganization of working processes and with this of societal structures. The notion 'nanotechnologies' unifies technologies that work at the molecular scale. The generic function they provide includes the possibility to manipulate molecular structures, to assemble single atoms and to build completely new structures. There exist lots of application possibilities, e.g. the implantation in the human body, in microelectronic components or in chemical gas. Therefore nanotechnologies are frequently called 'enabling technologies'.

Aside from this, nanotechnologies form part of the so called 'converging technologies' which refer to a composition of technologies that are all likewise used to pursue a common superior goal. As a converging technology and due to their further characteristics, nanotechnologies do not only influence the organization of economic sectors but also the civil society in which nanotechnologies are or shall be implanted. Nanotechnologies do not only require that the borders between the established techno-industrial developments fade, thus requiring strong interdisciplinarity. They also lead to newly emerging linkages of various economic sectors as well as social structures in several fields within society thus also incorporating possible systemic risks.

Looking at the current literature about converging technologies and risks' analyses in order to investigate the relationships between technology, economy and society, we observe a kind of paradox: although almost each contribution mentions more or less explicitly possible growth barriers on the one hand and risks related to the development and applications of nanotechnologies on the other hand, both arguments are nearly never brought together. Though well recognized, the converging character of nanotechnologies seems hardly to be taken into account in its complete sense. Convergence does not only cover the network of technologies embedded in nanotechnologies. It also includes the network of actors involved in diffusion and implantation. Or said in other words, aside from possible technological frictions,

converging technologies also have to overcome structural divergences in the network of actors involved in their diffusion and applications. In order to tap the full potential of nanotechnologies, the growth barriers as well as possible risks emerging from such structural inconsistencies seem to be of major importance. They directly depend upon the level of acceptance and adaptation nanotechnologies in economic and social contexts diffusing and using them. Managing such situations requires high competencies related to the collective collaboration and communication about these externalities and risks, to identify and to describe them adequately, bringing together specialists and non-specialists of nanotechnologies.

Thus, the typical characteristics of nanotechnologies induce coordination requirements as well as coordination failures, not only between firms and sectors but also at the level of the entire society. To reduce or even to eliminate these frictions is the task of what we call *converging institutions*. How these institutions have to be embellished in order to accommodate the particularities of nanotechnologies is the main concern of this paper.

The paper is organized as follows. Section 2 brings together the most important building blocks required for the subsequent argumentation. These parts are embedded in economic and social perspectives within Sections 3 and 4. Section 5 analyzes stumbling blocks within the innovation process. Subsequently, converging institutions are detailed and applied to the case of nanotechnologies within Section 6. We then apply the concept of converging institutions to the already existing nano-cluster in the metropolitan area of Grenoble/France in Section 7. The paper closes with a short summary and some questions and remarks for future work.

## 2 Institutions and technologies: some building blocks

### *Institutional approaches in economy and sociology*

According to North (1990, p. 3) 'Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction. [...] In consequence they structure incentives in human exchange, whether political, social, or economic.' They provide structures but also impose restrictions on human actions. Economic institutions frequently focus on the structure of property rights and the presence and perfection of markets. Accordingly, institutions affect

the structure of economic incentives in society, influence investments in physical and human capital, technology, and the organization of production. Recent discussions highlight the necessity of 'appropriate institutions' covering the idea that different institutional arrangements are appropriate at different stages of economic development and societal change (see Eicher and García-Peñalosa (2006)).<sup>1</sup> Acemoglu et al. (2005) also argue that institutions are, at least in part, determined by society, or a segment of it and thus are endogenous. This also stresses the interaction between economy and society.

A more sociological view emphasizes the role of institutions as mediations of various sorts (symbolic, human, material-related) controlling and supporting the relationships between actors, their activities and representations in different fields of society, and at different phases of its transformations. Hence, institutions mediate regulation of practices and representations: based on first reflections of ethnologists and anthropologists on the concept of institutions as 'a group of people united for the pursuit of a simple or complex activity' (see Malinowski (1945, p. 40)) analysts of institutions concentrate on the relationships between actors in order to define institutions as mediative regulators between activities, practices and representations (see MacIver and Page (1949, p. 16)). Institutions secure functions in society which have been more or less restructured and redefined in the process of regulation thus leading to an internal diversification of the 'complex of status-role relationships' which is concerned within an institution (see Kaplan (1960, p. 179)). In addition, institutions adapt their functions and decisions with respect to changing environments. This does not only precise the profile of institutions; it also makes its interventions in the public more appropriate and stresses the necessity for institutions to evolve over time. To sum up: On the one hand, institutions can be understood as acting as a bridge: they stimulate linkages and networking. On the other hand, they can be seen as a guardian: they establish borders in form of frames of rules differentiating and grouping societal actors and activities.

Sociological and economic interpretations of institutions do not contradict but complement one another. Both stress the fact that institutions almost always embed a general societal aim or an universal ideal that has to be communicated when an

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<sup>1</sup>Note that these analyses compare alternative institutional arrangements between economies near the technology frontiers to less developed economies whereas institutions in the context of our paper explicitly focus on institutional settings that evolve along the technology frontier.

institution acts. These aims and ideals have often philanthropic characteristics (e.g. participating in the improvement of human knowledge) and thus provide the basis for the embodiment of institutions as converging institutions. Until now, these properties and objectives consider institutions mostly as being reactive and with this only to define responsive rules in order to reduce uncertainties of all kind which may happen in societies' life.<sup>2</sup>

*Nanotechnologies, converging technologies and technological platforms*

Another building block of this paper refers to the linkages, (possible) coordination failures and technology platforms of the so-called converging technologies. These refer to the convergences on a common global goal by insights and techniques of basic science and technology: converging technologies are enabling technologies and scientific knowledge systems that add to each other for the achievement of a shared aim. For example, singly or together, NBIC-technologies (nano, bio, info, cogno) are likely to contribute to such convergences as e. g. for improving human performance (see Nordmann (2004, p. 19) or Roco and Bainbridge (2002, p. 282)).<sup>3</sup> Hence nanotechnologies form part of the converging technologies. Nevertheless, some authors noticed that this converging property of nanotechnologies may also be its most controversial one once related to the existing structures within society.<sup>4</sup>

In addition to this, nanotechnologies are frequently interpreted as being a general

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<sup>2</sup>One exception is the concept of 'institutional entrepreneurs' as developed by Maguire et al. (2004) and applied to nanotechnologies by Mangematin et al. (2005).

<sup>3</sup>NBIC-convergence for Improving Human Performance is the name of a prominent agenda for converging technology research in the US. In Canada, 'Bio-Systemics Synthesis' suggests another agenda for converging technology research while Converging Technologies for the European Knowledge Society (CTEKS) designates the European approach. It prioritizes the setting of a particular goal for converging technology research. This presents challenges and opportunities for research and governance alike, allowing for an integration of technological potential, recognition of limits, European needs, economic opportunities, and scientific interests (see again Nordmann (2004) for details). Defending a strict technological classification of the expression 'converging technology', Roco refers it to the combination of four major NBIC provinces of science and technology, namely: (i) nanoscience and nanotechnology; (ii) biotechnology and biomedicine, including genetic engineering; (iii) information technology, including advanced computing and communications; (iv) cognitive science, including cognitive neuroscience (Roco and Bainbridge (2002, p. 282)). For a broader application of this expression, cf. the description given by Wood et al. (2003, p. 23): 'Many of the applications arising from nanotechnology may be the result of the convergence of several technologies.'

<sup>4</sup>See e. g. Dupuy (2004, p. 75ff.) or Berne and Schummer (2005).

purpose technology thus providing generic functions that may be adopted to a multitude of uses. In case of nanotechnologies these functions include the possibility to manipulate molecular structures or to assemble single atoms.<sup>5</sup> According to Lipsey et al. (1998) or Bresnahan and Trajtenberg (1995) general purpose technologies involve huge potentials for improvement at the beginning of their development, a multitude of possible uses and hence an impact on nearly every part of the economy and induce major changes of production structures, network relationships and the organization of entire societies. Another main attribute is given by the strong complementarities to already existing technologies. As such, nanotechnologies form part of technological platforms that organize further actions (e. g. R&D), enable and constrain them (see Robinson et al. (2006, p. 4f.)). In this sense, traditional sectors can be interpreted as the interaction of several technological platforms, giving the network character of the involved actors more importance.<sup>6</sup>

Figure 1 demonstrates the interdependencies between several sectors, firms and/or actors that include nanotechnologies within the production process. Using the simplest case, the hierarchical interdependencies as well as the network character may be most suitably illustrated by a technology tree. Nanotechnologies represent the sector of the general purpose technology and are denoted by  $GPT$  whereas  $AS_i$  reflect the downstream industries that actually or potentially use the general purpose technology or augmented products as intermediates. Aside from vertical relationships, there exist also horizontal linkages between actors at the same level of the value creation chain. These horizontal as well as possible newly emerging vertical linkages are indicated by the dashed lines. Note that such a conjunction of horizontally and/or vertically linked actors could also be interpreted as building a joint technological platform.<sup>7</sup> The interaction requires a lot of coordination and consequently failures may arise.

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<sup>5</sup>Other generic functions and the corresponding general purpose technologies are the rotary motion in the case of the steam engine or binary logic in the case of ICT.

<sup>6</sup>According to the *European Union* technological platforms are being set up which bring together companies, research institutions, the financial world and the regulatory authorities at the European level to define a common research agenda which should mobilize a critical mass of – national and European – public and private resources (Robinson et al. (2006, p. 8, footnote 8)).

<sup>7</sup>Figure 2 shows such a technological platform that includes the linked firms.

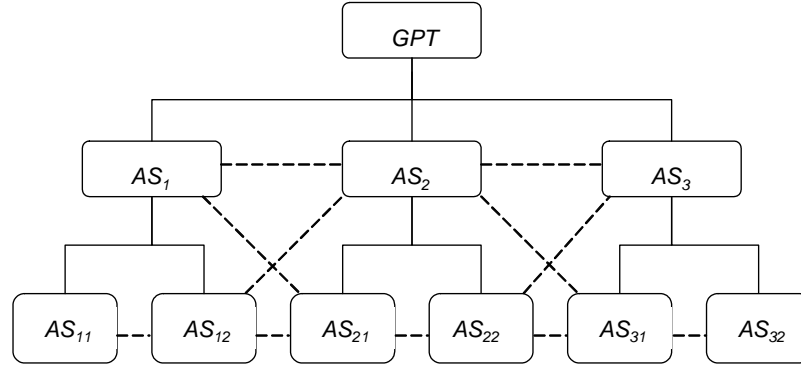


Figure 1: Technology tree: horizontal and vertical linkages

Applying these rather general arguments to the peculiarities of nanotechnologies, merging it with institutional aspects and analyzing the corresponding economic and social implications makes clear that mediation could improve the outcome of these interactions. This results in the concept of what we denote by 'converging institutions'.

### 3 Nanotechnologies as a general purpose technology

Within Figure 1 nanotechnologies correspond to universities and research institutions that continually develop the general purpose technology. As already argued, nanotechnologies may be implemented in a multitude of uses in applying sectors thus reflecting the *pervasiveness* of the technology.<sup>8</sup> Applying sectors could be e. g. the chemical industry ( $AS_1$ ), microelectronics ( $AS_2$ ) or pharmacy ( $AS_3$ ). New materials may be demanded by further downstream sectors such as aviation industries ( $AS_{11}$  which uses fire resistant materials for inboard equipment) or automobile industries ( $AS_{12}$  which utilize scratch-resistant lacquers). Analogously, ICT industries make use of nano components to augment the calculating capacity of computers. Again, these are used by downstream sectors as e. g. automobile industries ( $AS_{21}$ : board

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<sup>8</sup>Roco (2001, p. 355) underlines this, seeing in the converging property characterizing nanotechnologies a possible 'synergism among the converging fields play[ing] a determining role in the birth and growth of new technologies.' There are lots of examples of such applied synergisms as the implantation of nanotechnologies in the human body, in microelectronic devices, in chemical gaz, cars' brine, liquid cleaning agent (see also BMBF (2004).

computers) or medicine technics ( $AS_{22}$ : magnetic resonance tomograph). Both fire resistant materials and scratch resistant lacquers may not only be used within aviation but also in automobile industries. Similar relationships may be identified for other downstream sectors. Note that sometimes, these relationships between two downstream sectors do not exist until they make use of nanotechnologies.

Another feature of general purpose technologies are *induced technological dynamics*. Due to continuing innovation and learning effects, the generic function of the general purpose technology may be provided at less costs and/or in a better quality. The use of the general purpose technology in downstream sectors becomes more attractive, and profits there increase. As a consequence, the application of the (augmented) general purpose technology becomes interesting also for other sectors, and the fields of uses increase. Applied to nanotechnologies, the production of continuously improved nano-particles, and thus decreasing costs, may be mentioned. As consequence nano-particles are now used in a wide range, e. g. in suntan lotion or lacquers.

The third constituent property of general purpose technologies is the existence of *innovational complementarities* between the sectors of the general purpose technology and the application sectors. This reflects the phenomenon that technological progress in one sector also spurs progress in the other sector and vice versa. Both sectors are linked by their innovating activities wherefore the profit in one sector also depends on the technological conditions in the other sector. Applied to nanotechnologies, these interdependencies may be illustrated together with micro-electronics or information technologies as applying sectors. It is undoubted that due to their calculation capacities information technologies have contributed significantly to the emergence of nanotechnologies. All illustrations of nanoscale effects and structures are based on electronically constructed pictures. Since more than 30 years the capacity of computers doubles every 12–18 months (Moore’s law). But within the next several years, physical boundaries will interrupt this development since at nano-scales, the technological characteristics of solid state physics cease to hold and the usual transistor will be unusable. Then quantum physics become relevant and molecules – manipulated by nanotechnologies – could replace the well known transistor. Consequently, technological progress in nanotechnologies become a pre-condition for future innovations in microtechnology which anew spurs technological progress in the nanotechnologies’ sector.

Fourth, general purpose technologies induce major *changes of production processes and work-life organization*.<sup>9</sup> Applied to nanotechnologies, this argument is until now undifferentiated since these technologies are still at the very beginning of their development. But just to get a vague idea, one could imagine how for example functional materials that measure functions of the human body and transmit the results to the medicine makes lots of sick people much more independent compared to their situation today thus allowing for restructuring daily life.

To sum up: nanotechnologies incorporate all characteristics of general purpose technologies as defined by Bresnahan and Trajtenberg (1995) and Lipsey et al. (1998). Consequently, the 'usual' implications of general purpose technologies, particularly coordination failures, externalities as well as the reorganization of economic and social networks, also become relevant in the analysis of the implications of nanotechnologies for economy and society.

## 4 Ambivalence of nanotechnologies

The emergence of nanotechnologies incorporates lots of benefits for economy and society. Technological process reduces production costs, provides new and/or improved products and is accepted to be the main source of ongoing economic growth.<sup>10</sup> But as any other technological innovation, nanotechnologies often induce a process of 'creative destruction':<sup>11</sup> on the one hand, they create unusual development possibilities.<sup>12</sup> But on the other hand, they also enforce strong modifications or even destructions of older processes and habits.<sup>13</sup> Since the emergence of nanotechnolo-

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<sup>9</sup>An example of the implications for work-life-organization can be illustrated in the context of the general purpose technology 'electricity'. Its development and diffusion made people independent from daylight and with this had a very strong impact on the organization of daily life.

<sup>10</sup>See Barro and Sala-I-Martin (2004) for this argument and an overview over the most essential growth determinants.

<sup>11</sup>This expression draws back on Schumpeter (1950) who describes destruction of the old as being an inherent part of the innovation process.

<sup>12</sup>Examples are genetically modified organisms for the production of food, improvement of health care for people suffering of cancer or diabetes, improvement of the efficiency and the safety of vehicles by the use of 'on-board' supercomputers (see e. g. Silverstein et al. (1995) or SwissRe (1998, p. 6)).

<sup>13</sup>For example, the secondary effects of new molecules improved with nanotechnologies in order to make people awake during a week or the use of nanotechnologies in medicine which could

gies enables unlimited linkages between every element in economy and society, they may also reinforce the sources of loose connections within the networks built. Thus, nanotechnologies bring us in a more complex world where increasing growth opportunities and decreasing structural consistencies in society have to be balanced. Besides, the entire potential may only be realized if all adjustment processes going along with creative destruction are completed. Thereby the development and diffusion of nanotechnologies may favor the emergence of systemic risks by de-structuring all dimensions of already existing networks thus affecting entire spheres of society.

Altogether, does this mean that we have to fear nanotechnologies or do the chances prevail? Actually, the circumstances are more complex. First of all, it has to be noticed that nanotechnologies are *not an innovation in itself*. They get their real innovative character as embedded at the nanoscale in all possible (i.e. biological, mineral, chemical, mechanical) media, thus realizing sometimes also unexpected convergences between people, social systems and environments.

Second, these convergences do *not* have *only positive effects*. While relying on lots of actors involved in its development, diffusion and the use of nanotechnologies, they also multiply the risks of network-inconsistencies and network-failures. This could hinder or even interrupt the innovation process of nanotechnologies, thus reinforcing possible breaks and ruptures between the involved actors. Indeed, the convergences growing out of the diffusion and implantation of nanotechnologies in society are based on existing functional and structural dependencies but also create new ones. These so called path dependencies in the sense that earlier investments and competencies shape what can be done later, once being established, hardly can

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push medicine to abandon open-minded, holistic caring for patients (see e. g. Timmermans and Angell (2001)). Indeed, as Branscomb et al. (2001, p. 26) observe 'in various segments of the public there is confusion and ambivalence about the mission of research in science and technology.' See also Douglas and Isherwood (1979) or Rosenberg (1982). At the opposite side, Roco and Bainbridge (2002, p. 282) defend the view of a radical functionalization of society understood as the progress due to the application of nanotechnologies: 'This progress is expected to change the main societal paths, towards a more functional and coarser mesh instead of the less organized and finer one we have now.' The duty to involve the public in the largely unknown consequences of the applications of nanotechnologies in economy and society is that of public media: 'The public media should increase high-quality coverage of science and technology, on the basis of the new convergent paradigm, to inform citizens so they can participate wisely in debates about ethical issues such as unexpected effects on inequality, policies concerning diversity, and the implications of transforming human nature' (ibid. page 294).

be revised. In extreme, given that a critical point within the innovation process of nanotechnologies is reached, path dependencies can lead to the impossibility to develop nanotechnologies anyway further in a given area. This could have disastrous consequences for existing economic sectors (as e. g. bankrupts that are due to the impossibility to sell nano products and services for which there is no need any more) or individuals engaged in the innovation process or in the use of nanotechnologies (e. g. medicaments which can't be provided any more).

Third, another cardinal property of nanotechnologies, their size, makes it impossible to deliver them directly in the public. They require to be implemented in media (human body, objects, liquid, gas, natural environment) thus reflecting the characteristic of an *on-board technology*. This explains why the economic sectors are often considered as the prime actors to be taken into account in the development and diffusion process of nanotechnologies. Actually, economic sectors do not only support the development but also the diffusion of nanotechnologies by interacting with each other (developers, scientists, technicians, engineers). The public is more likely considered as 'public of end users', whose concerns are the applications and related uses of nanotechnologies. This distinction between the development, diffusion and the applications' areas is more than only a pedagogical one, even if in practice, there are no impermeable borders between both sides. The distinction allows us to identify coordination failures and thus economic growth barriers related to the actors of the technology platform on the one hand, as well as risks emerging out of the diffusion and implantation of nanotechnologies in the public on the other hand. As a consequence the innovation process of nanotechnologies, as well as nanotechnologies on their part, are deeply ambivalent.<sup>14</sup> Thus, the question asked by Kearnes

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<sup>14</sup>This particular signification of the ambivalence of technologies has already been given attention (see Silverstein et al. (1995, p. 12)): 'the complexity of the relationship [which technologies embody; IO&CP] comes out as a kind of ambivalence of the public toward the whole science-technology complex. The public may be positive on things like improvements in their quality of life and at the same time fearful of the changes in values, with a sense perhaps of social disintegration that may be vaguely tied to what's going on here.' Bennett and Sarewitz (2005, p. 1) observe that 'people have converged around the notion that, whatever nanotechnology is, and whatever it will become, its implications for society are going to be transformational, perhaps radically so, in social realms as diverse as privacy, workforce, security, health, and human cognition.' For Roco and Bainbridge (2005, p. 282), 'converging technologies integrated from the nanoscale could determine a tremendous improvement in human abilities and societal outcomes.' Cf. also in the same vein, the report of the European Commission (2004) as well as Whitman (2006). Dupuy (2004, p. 60)

et al. (2006, p. 14) in their report on nanotechnologies in the UK remains of urgent actuality: 'How are individuals and institutions, confronted with rapid technological change, to imagine new social possibilities, and choose among them wisely? And how may all of this pan out [...] for the development process generally?'

## 5 Stumbling blocks in the innovation process

According to the specific conceptualization of both economics and social sciences, we use the term 'externalities' in order to describe prior economic risks related to coordination or markets failures. We refer to the term 'systemic risk' to take into account the more general societal risks related to the use of nanotechnologies in the public which could unstructure their individual life and social habits thus also reshaping societal relationships (see Roco (2005)).

### *Economic level*

As already illustrated in the context of Figure 1, lots of interactions between upstream and downstream sectors exist. These interdependencies do not only arise in a production context but also during the innovation processes within the firms, and they incorporate two fundamental externalities (see Bresnahan and Trajtenberg (1995)):

- *Vertical externalities*: Due to the innovational complementarities, the innovation activities in upstream and downstream industries are related, and both sectors have linked payoffs. The familiar problem of imperfect appropriability of the social returns arises, except that here it runs in both ways. This bilateral moral hazard problem implies that neither side will have sufficient incentives to innovate. Altogether, both sectors innovate too little and too late.
- *Horizontal externalities*: Applying sectors include actual and possible users of the general purpose technology. Their demand depends positively upon the quality and negatively upon the price of the general purpose technology. At

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points it out dexterously when he shows the ambivalence of the slogan 'Bringing Nanotechnology to Life' used by any research center in the field of nanobiotechnology. It expresses the will to use nanotechnologies in order to make progress in human biology; but, so Dupuy, it is impossible not to imagine that it remains related with the old utopia to fabricate life using these technologies.

the same time, the quality within the general purpose technology sector depends upon marginal production costs and upon the (aggregate) technological level of all applying sectors. Hence, if one single applying sector innovates to increase its own technological level (with the goal to reduce own production costs) also the aggregate level of the applying sectors will increase. This leads to improvements of the general purpose technology and hence to reduced costs not only in the originally innovating sector but also in the other (non-innovating) downstream sectors. Consequently all applying sectors benefit from innovations of a single applying sector. Again, this characteristic induces a moral hazard problem: why should one applying sector innovate if it could benefit at zero costs from the innovation in another sector?<sup>15</sup>

*Societal level:* Until now, societal risks generated through the uses of converging technologies are hardly discussed in the literature, and if so, they mainly concern the application in areas dealing with life sciences or biotechnologies. It is often unnoticed that there is a deep lack of independent safety assessments and regulations concerning the implantation of nanotechnologies in consumption goods.<sup>16</sup> Until now, little attention is given to risks that directly threaten the social acceptance of nanotechnologies in the areas in which they are or shall be implanted.<sup>17</sup> It is thus of major importance to understand and to assess these risks, and given this, to analyze possible communication strategies about these risks and their transfer between techno-science, economy and society (see e. g. Oriordan et al. (1989)). It would then be possible (i) to transmit information about risks, which requires (ii) mediations that (iii) shape trust in the public about the transmitted information, and could afterwards (iv) prepare individuals to get involved in the control of the implantation and the use of new technologies. The management of risks successes at both levels of

- *Stereotypes associated with nanotechnologies:* They rise up strongly in the case

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<sup>15</sup>This phenomenon is summarized by the term 'dual-inducement hypothesis' thus describing the interrelationships between the innovational activities in the sector of the general purpose technology and the applying sectors (see Bresnahan and Trajtenberg (1995)).

<sup>16</sup>An exception is given by genetically modified food. First analysis are conducted by the (see European Commission (2005) ) or Mehta (2002).

<sup>17</sup>Note that there already exist several anti-nanotechnologies' movements, see e. g. <http://pmo.erreur404.org/Necrotechnologies.htm> or <http://pmo.erreur404.org/>. Growing systemic risks in the late modernity are in detail discussed Beck (1986) or Luhmann (1991, 1990).

of nanotechnologies because of their invisibility and their character of an all purpose technology. This may bring the feeling in the public that everybody will be under surveillance always and everywhere. The communication about nanotechnologies pursues the goal to manage the stereotypes associated with these technologies in order to facilitate their acceptance and thus leading to a successful implantation in the public;

- *Control of the implantation and use of nanotechnologies*: The feeling of loose of control by private individuals could lead to the technocratic vision of experts that manipulate nanotechnologies at their convenience (and in secrecy) in order to robotize the population.<sup>18</sup> This may create severe gaps between the developers of nanotechnologies, the economic sectors diffusing nano products and the public. Another discrepancy may arise within the public itself between those people who want to benefit and make use of nanotechnologies, and those who won't be contacted by nanotechnologies. Thus, the management of control is an important social challenge in order to shape trust in the public where nanotechnologies will be implanted.

To sum up: nanotechnologies are not new on their part but because they enable unexpected interactions between expert knowledge developing nanotechnologies, economic sectors diffusing them and the civil society in which nanotechnologies are implanted and used. These interactions are not automatically spontaneous results of the development, diffusion and implantation of nanotechnologies but bring about possible risks of systemic divergences that are caused by non-controllable or unwanted interactions between involved actors, technological objects and embedded environments. Supporting these interactions means first not to take the convergences that nanotechnologies may favor in society as obvious, but instead to understand how to regulate their ambivalence and oscillation between expected growth and risks of systemic inadequacy. Following analogous intuitions, some authors already suggested that 'Governments and civil society organizations (...) should establish an International Convention for the Evaluation of New Technologies (...), including mechanisms to monitor technology development' (ETC-Group (2003, p. 6)). Other

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<sup>18</sup>This is one of the most current objection raised by interest groups that decline against nanotechnologies. One example is the group 'Opposition Grenobloise aux Nérotechnologies' in Grenoble/France.

authors signalized that organizations experiencing uncertainty as well as organizations dealing with innovations in general and with nanotechnologies in particular 'will be more likely to adopt new institutions that will help them deal with the uncertainty they are experiencing.' (Guthrie (1998, p. 477)).<sup>19</sup> Bresnahan and Trajtenberg (1995, p. 3) argue: 'However, where there is potential for coordination failures there is also room for coordination, and which ultimately prevails depends upon the institutional arrangements that are developed, alongside or *in lieu* of market arrangements.' We focus on this last more explorative recommendation without totally declining the first one, considering the regulation of nanotechnologies development and applications under the viewpoint of converging institutions. How could they support the convergences which nanotechnologies undertake in the environments in which they may be implanted?

## 6 From nanotechnologies to converging institutions

As argued above, nanotechnologies incorporate huge potentials for improving welfare. But due to the interdependencies of the various actors, technological complementarities and the dynamics within the innovation process, frictions at the economic and the societal level are in all probability. Since coordination failures and social risks may disturb the innovation process of nanotechnologies and hence reduce maximum possible welfare, room for improvement is given. We now analyze how dedicated institutions, henceforth called converging institutions, contribute to improvements of the decentralized decisions.

Figure 2 illustrates the interdependencies between all stakeholders involved in the innovation process of nanotechnologies: the interdependencies between upstream and downstream firms are adopted from Figure 1 and assembled to an exemplary technology platform, embedded in the rest of the economy, and interacting also with society. Converging institutions may be assigned to the two lines of argumentation from above:

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<sup>19</sup>Heinze (2006, p. 22) observes in analogous terms: 'For describing and analysing the formation of new science-based fields of technologies, it is essential to understand the interface between different institutional settings, such as companies and public research institutions.'

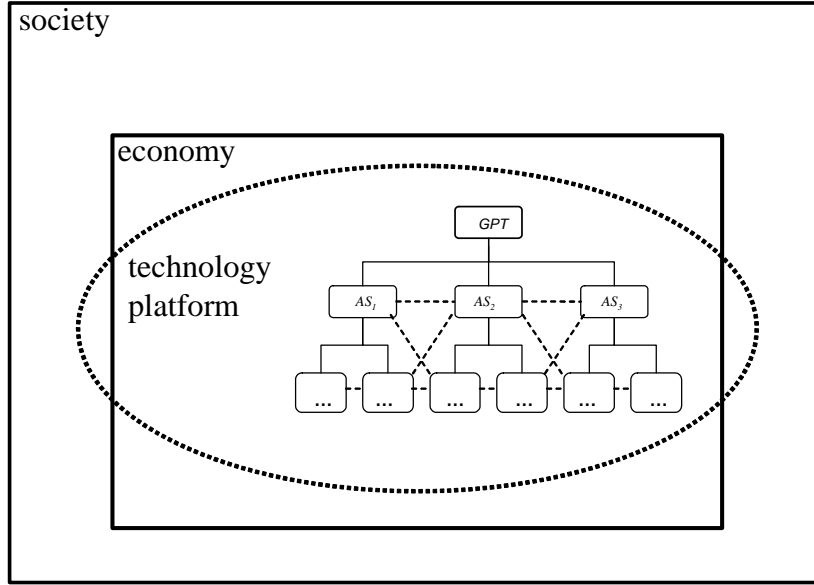


Figure 2: Technological, economic and social levels.

Starting points for converging institutions

- *Economic level:* Due to the innovational complementarities the innovation activities of one single actor affects the outcomes of the other agents. Consequently existing sub-optimality affects all involved agents. Converging institutions are thus interpreted as institutions that reduce or remove coordination failures that arise due to the interrelatedness between the firms. Starting points for concrete intervention at a vertical level could be performed e. g. by technology-push strategies. At a horizontal level, coordination of individual demand of the general purpose technology could increase aggregate demand, thus reflecting a demand-pull strategy.
- *Societal level:* A converging institution mediates the processes by which (i) nanotechnologies are integrated into society in the form of nanotechnological innovations, and by which (ii) society integrates nanotechnologies in diffusing them, e.g. in selling, using, considering or not considering or debating about them.<sup>20</sup> As many other institutions, a converging institution may be basically

<sup>20</sup>The need for such kind of institution is not new (see Sarewitz (2004, p. 29)), although nobody

interpreted as involving actors dealing together with various organizational structures and processes. Their main task is to decompose systemic risks and preferably to harmonize the communication about them.

However, as stressed by some workings on the couple 'converging technologies and institutions',<sup>21</sup> the converging character of nanotechnologies supposes that an institution dealing with them and their universe is not only a reactive structure administering the synergies between the actors involved in the development and in the application of nanotechnologies. Their place is not outside the convergences nanotechnologies enable, but inside of them. This kind of institution has to assimilate the convergences between technology, science, economy, and society which nanotechnologies enable. Converging institutions are thus responsible for the developments and applications of nanotechnologies just as any other actor involved in the innovation process of nanotechnologies. Correspondingly, they have to take initiatives in the planning of and the communication about the possible inconsistencies in the development and the application of nanotechnologies, as well as of the related public fears, economic externalities and systemic risks which nanotechnologies could enable. Such specialized institutions can be labelled as *converging institutions*. They do not only have to fulfil responsive functions in supporting and regulating nanotechnologies. They also have to actively act as one actor within the convergences that nanotechnologies favor in order to support and develop them. To put it metaphorically: a converging institution is not only a transmission instance enabling the unproblematic development and delivering of nanotechnologies from science and industry to economy and society; rather, it is a translation instance, which actively constructs exchange possibilities between all actors involved. As an interactive agent within the nanotechnologies' networks, converging institutions are then<sup>22</sup>

- *Collaborative*: Converging institutions have to make involved actors commu-

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seems to refer it to the specifics of nanotechnologies, which is their converging property.

<sup>21</sup>See e. g. the project description concerning the Center for Nanotechnology and Society at Arizona State University (<http://cns.asu.edu/network/asu.htm>).

<sup>22</sup>Our focus differs from the institutional approaches of Maguire et al. (2004), which define institutional entrepreneurship as activities of the actors who have an interest in particular institutional arrangements, and who leverage resources to create new institutions or to transform existing ones. See also Mangematin et al. (2005) who discuss cluster-institutionalizing entrepreneurs as those who promote the creation and the institutionalization of clusters in the context of nanotechnologies.

nicate even if they do not use the same language, and even if they don't evolve at the same speed, in the same direction, at the same time and for the same reasons regarding the development and applications of nanotechnologies. As a consequence, converging institutions neither follow a bottom-up nor a top-down approach but rather fulfil the characteristics of a network on their parts.<sup>23</sup>

- *Responsive*: Converging institutions have to act for the encounter of technological, scientific, industrial (more concerned with the first point of the definition), economic, social, and political stakes which nanotechnologies carry (more concerned with the second point of the definition) considering their respective specifics.
- *Flexible*: Converging institutions have to be directly sensible to the changes in the convergences between actors involved in converging technologies. This gives converging institutions the possibility to quickly take into account possible inconsistencies of these convergences, and to better identify, manage and communicate about risks which the implantation of nanotechnologies in society carries with itself. The general purpose of the converging institution is then to shape relationships between converging technologies and all actors involved in nanotechnologies, particularly those who may benefit from the outcomes of nanotechnologies but also have to assume the related uncertainty of their implantation in economy and society.

The concept of converging institutions can be seen as an example of the so called 'churn theory' of knowledge value and innovation (Bozeman (2005, p. 5f)). The word 'churn' implies no particular direction of scientific innovative outcomes. They may be positive, negative, neutral, or, most likely, mixed. This is almost what we are facing with nanotechnologies and this is what converging institutions assume as an actor involved in the convergences which nanotechnologies favor. As Bozeman (2005, p. 6) observes, the position of converging institutions can be defined as it considers all parties and itself 'as part of the knowledge value collective because each is producing

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<sup>23</sup>Bottom-up and top-down concepts in the context of nanotechnologies are analyzed by VDI (2005) with a more technological focus, and by Robinson et al. (2006) with a more sociological focus.

knowledge, using it or enabling its use.’<sup>24</sup> Converging institutions, then, have a major role in reflecting that the converging capacity of nanotechnologies doesn’t only depend on the whole fields of science, but also on the whole fields of societies bringing science to the multiple uses which characterize converging technologies. If one says about the development of technologies in cold-war that ‘Codeword science engendered a codeword community’ (Cloud (2001, p. 244)), converging technologies prepare a new era for a collaborative society in which converging institutions are of central stake, shaping the relationships between nanotechnologies, economy and society. Therefore, it is to expect that converging institutions will become increasing attention in the research agenda on nanotechnologies as well as in the management of externalities and societal risks related to their implantation in society.

## 7 La Maison des Micro– et Nanotechnologies (MMN). An emerging converging institution?

Considering the innovation processes of nanotechnologies, it becomes obvious that increasing attention to the management of externalities and societal risks related to their implantation in society. Besides, converging institutions play a central role in this context. One example of a potential converging institution is the ‘Maison des Micro- et Nanotechnologies (MMN)’ developed at the ‘Pôle d’innovation en Micro et NAnoTEChnologies (MINATEC)’ in Grenoble (France).<sup>25</sup>

MINATEC exists as a project since 2000 in the metropolitan area of Grenoble. It has been planned and supported by the French state, the region Rhône-Alpes, the Dpt. Isère, the public institutions Grenoble Alpes Métropole and the Caisse des Dépôts et Consignations, the city of Grenoble, the Centre d’Energie Atomique (CEA) and the Institut National Polytechnique (INP) in Grenoble. The region Rhône-Alpes has been chosen for the construction of the pool because of its economic excellence and the prevailing industrial structures. The convention of the 18.01.2002 and the

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<sup>24</sup>In this sense, converging technologies and converging institutions lead to more complex (loosed coupled) networks of diffusion and application of innovations as, e. g. those envisaged by Etzkowitz (2003) within the Triple Helix Model declining the various possible relationships between university-science-government in the promotion of technological innovations.

<sup>25</sup>Note that there exist various regions that also develop nanotechnologies strategically. An overview can be found at the homepage of the nanodistrict project, [www.nanodistrict.org](http://www.nanodistrict.org).

first financial support of 150 billions Euros led to the realization of the project (see INP-Communiqué de Presse (2002), p. 12). MINATEC has been inaugurated on the 1<sup>st</sup> of June 2006.

MINATEC is a mixed structure made of public and private research and investments. It has been organized in three platforms, namely (i) the platform *education*, (ii) the platform *research* focusing on microtechnology, biochips and microsystems for applications in the fields of communicating objects (clothes, robots for kitchen, etc.), and (iii) the platform *economy* for the developments of start-ups or bigger industrial conglomerates which work together with the platforms education and research. In this context, the MMN has been developed as a center for the getting together of these platforms, and more generally of nanotechnologies, economy and society (see *ibid.*, p. 11). The main aims of the MMN are:

- to accelerate and optimize the process of innovation;
- to build transdisciplinary and international networks;
- to favor the encounter between the old and the new in order to adapt the identity of the region at the changes brought by nanotechnologies (see INP-Communiqué de Presse (2002), p. 11).

In order to perform these goals, the MMN works together with the Observatoire des Micro- et Nano Technologies (OMNT) developed at the initiative of the CEA and the CNRS, and built in February 2005. The OMNT is unique in Europe. It provides information about nanotechnologies and their applications in order to communicate about possible externalities and risks related to nanotechnologies and to prevent the stereotypes associated with nanotechnologies.<sup>26</sup> As such, the MMN gives an example of a typical converging institution structure. Its work faces the main challenges of converging institutions which can be summarized as follows:

- *Economic level*: efficiently support the diffusion of nanotechnologies so that the economic sectors may benefit from the convergences between developers

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<sup>26</sup>This is one of the motivation often associated with the arguments underlining the necessity of the build of the MMN at MINATEC (see also cf. also Gutierrez (2004) at <http://www.epic.org/privacy/nano/default.html>

of nanotechnologies and firms at the same level of the value creation chain to reach the expected economic growth potential that nanotechnologies are attempted to bring about.

- *Societal level*: manage the stereotypes associated with nanotechnologies in order to communicate about them and to shape trust in the public regarding the implantation and the use of nanotechnologies in civil society.

Since converging institutions are innovative institutional structures on the making, as the example of the MMN shows, and since such structures haven't been studied until now, it is an exciting challenge to observe closer their emergence related to the centers developing nanotechnologies in order to know how they will act as a mediation instance in the network of actors involved within the entire innovation process, from the development over diffusion up to the implantation in civil society. Converging institutions have to proof their capabilities to manage the structural externalities and systemic risks related to possible inconsistent convergences in this network and the resulting consequences for economy and society.

To sum up: until now it has been shown that form and content of the concept of converging institution, and having underlined its major role not as a reactive instance beside the network of actors involved in nanotechnologies, but as an interactive, responsible and flexible mediative structure within this network, let us conclude with three observations bring the theory nearer to the practice. First, as the MMN illustrates, it is to expect more than one prototype of converging institution–structure particularly regarding the specificity of the region in which nanotechnologies have to be developed. Therefore, one main stake of the investigation of converging institutions is to identify types of converging institutions corresponding to the area where nanotechnologies are developed. In this respect, an investigation of converging institutions should provide a differentiated analysis of specific functions and structures growing out of converging institutions that are of special interest in a given region, with which these converging institutions manage systemic risks and market failures related to nanotechnologies. In this sense, it is possible to empirically differentiate the concept of convergence which nanotechnologies induce in order to investigate the specifics of the network of actors involved in nanotechnologies in which converging institutions have been embedded. This first step in the investigation of converging institutions enables a second one, leading to isolate shared properties that each con-

verging institution develops in its context in order to be efficient in its proper action. This delivers empirical elements in order to get an empirically informed concept of converging institution. Third, the investigations have to focus on the most important institutional determinants resulting out of the analyses developed in the former two steps in order to give an evaluation of the changes they could enable in the economic and sociocultural sectors given the regions in which converging technologies have to be developed and diffused. Following these steps, it will then be possible to investigate instruments that stimulate the public discussion about nanotechnologies thus leading to a global and an unequivocal exploitation of the entire innovative potentialities of nanotechnologies.

## 8 Conclusions

This paper derives the concept of converging institution as consequence of economic and social considerations of nanotechnologies as part of the so called converging technologies. This concept is based on the entire innovation process beginning with research and development, diffusion (here mostly interpreted as the diffusion between upstream and downstream industries) up to the implantation of nanotechnologies in society. The paper merges both economic and social perspective and thus results in the interdisciplinary concept of converging institutions. Three constituents characteristics that define the type of a converging institution are derived: they are responsive, collaborative and flexible, that is, converging institutions evolve along the development process of nanotechnologies. Then the concept is applied to a possible converging institution, namely the MMN in Grenoble/France. However, there are several caveats that have to be analyzed during future work, among them answers to the following questions. How may converging institutions be divided from traditional institutions that also arise in the context of newly emerging technologies? How may converging institutions be implemented in regional, national and supranational levels? From where do converging institutions get their knowledge to act in a welfare enhancing manner? Thus there is much work left to be done.

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