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Who rules the development of nanotechnologies? Expert knowledge challenging the flexible regulation of innovation – the perspective of two European regions

INGRID OTTA, CHRISTIAN PAPILLOUD, TORBEN ZÜLSDORF

Nanotechnologies (together with biotechnology, information and cognitive sciences) belong to the so-called converging technologies that are expected to move social modes of exchange towards a more functional, coarser mesh. The innovations they enable, are supposed to empower science, economy and society. However, research, development and diffusion of this sector depend on the adaptability of existing economic structures and on the social acceptance of its products and services. Moreover, because of nanotechnologies' features, externalities and risks of systemic divergences caused by potentially uncontrollable or unwanted interactions between sectors, actors, and environments may arise and disturb the efficiency of the corresponding innovation process. Converging institutions aim to manage these market imperfections and their resulting social risks in the long term. They rely on social groups specialising in the design, application, and diffusion of nanotechnologies within society, whose functioning is explored in this article using data from a comparative survey carried out in Grenoble (France) and Hamburg (Germany).

Ingrid Ott is an economist and works as Head of the group 'Innovation and Growth' at the Hamburg Institute of International Economics. She is also Research Associate of the Kiel Institute for the world economy

Christian Papilloud is professor of sociology at the French university of Caen Basse-Normandie and researcher at the French Center for the Study of Risks and Vulnerabilities, invited professor at the German university of Lüneburg and collaborator at the Hamburg Institute of International Economics

Torben Zülsdorf is junior researcher at the Hamburg Institute of International Economics, and PhD student at the Leuphana University in Lüneburg

1. INTRODUCTION

In the opinion of various experts, nanotechnologies will be the dominant general-purpose technologies of the next decades.(1) The notion 'nanotechnologies' denotes technologies applied on a molecular scale. Aside from intensified miniaturization (so called top-down approach), the generic function nanotechnologies provide includes the possibility to manipulate atoms and molecular structures by building completely new and unexpected ones (so called bottom-up approach). Nanotechnologies frequently are also referred to as 'enabling technologies' thereby indicating that they provide the basis for many possible applications, including implantations in the human body, in microelectronic components or in chemical gas.

Additionally, nanotechnologies form part of the so-called *converging technologies* that unify a web of technological developments from several, diverse fields in order to create new technologies with their own characteristics and fields of applications, such as germanium chips or bacteriological hard disks in the field of microelectronics. As converging technologies, nanotechnologies lead to newly-emerging linkages between various economic sectors as well as social structures and promise possible societal benefits as well as posing potential systemic risks.

In scrutinising current literature on converging technologies and risk analyses in order to understand the relationships among technology, economy and society, we observed a paradox. Although almost all contributions more or less explicitly mention possible growth barriers on the one hand, and risks related to the development and embedding of nanotechnologies on the other, these arguments are almost never integrated. Even though the converging character of nanotechnologies is well recognised, its full potential seems hardly to be taken into account. Convergence, however, does not only cover the technologies embedded in nanotechnologies. It also includes the actors involved in nanotechnology's diffusion and embedding. In other words, aside from possible technological frictions, converging technologies also have to overcome structural divergences among the actors involved in the diffusion and application of nanotechnologies. We give an example of such a challenge in our comparative investigation in Grenoble (France) and Hamburg (Germany) by summarizing and evaluating expert opinions. We selected actors who explicitly assert a materially or symbolically rewarded activity within the field of nanotechnologies, e.g., individuals working within a prestigious association or as scientists, or actors who have an almost daily involvement with nanotechnologies. We also explore how these actors position themselves in order to accommodate the challenges of regulating nanotechnologies as converging technologies. In few words: Who takes part and from which perspective in the innovation processes that are connected to nanotechnologies? Who rules the development of nanotechnologies?

2. INSTITUTIONS AND CONVERGING INSTITUTIONS

The actors mentioned above are not single acting individuals but are integrated in national and regional innovation systems. In this context they are also related to innovation promoting institutions. According to North (1990, p. 3) institutions provide structures and restrictions on human actions. They can be described as symbolic, human, or material-related entities that mediate, control and support relationships between actors, their activities and their representations in different fields of society during different phases of societal transformations. Institutions secure functions in both economy and society and, in addition, adapt their functions and decisions with respect to changing environments, diversifying themselves as a 'complex of status-role relationships' (Kaplan, 1960, p. 179). From a traditional perspective, institutions can be described as guardians: they establish borders by differentiating and grouping societal actors. On the other hand, they also act as bridges, meaning they stimulate new linkages and networks. This active bridging feature of institutions is a key function when it comes to the field of nanotechnologies and its relational structures.(2) This does not only specify the institution's profile; it also suggests their importance of for the public at large and stresses the necessity for institutions also to evolve over time. Finally, institutions almost always implicitly embrace a general societal aim or a universal ideal, which is communicated in each of their acts. These aims and ideals also often have philanthropic characteristics (e.g., the improvement of human knowledge), and they thereby provide a basis for the embodiment of institutions as converging institutions.

As stressed in some research papers on 'converging technologies and institutions', the converging character of nanotechnologies supposes that an institution dealing with them and their universe is not only a reactive structure administrating the synergies between actors involved in the development and application of nanotechnologies. Rather, their place is not outside the convergences enabled by nanotechnologies, but inside. Such a kind of institution must assimilate convergences within technology, science, economy, and society as enabled by nanotechnologies. Converging institutions are thus responsible for the development and application of nanotechnologies just as much as any other actor involved in the innovation process of nanotechnologies. Correspondingly, they have to be:

- Collaborative: Converging institutions have to animate involved actors to communicate even if they do not use the same language and even if they do not evolve at the same speed, in the same direction, at the same time and for the same reasons regarding the development and application of nanotechnologies.

- Responsive: Converging institutions have to work towards integrating the particular technological, scientific, industrial, economic, social, and political stakes of nanotechnologies.

- Flexible: Converging institutions have to be sensitive to changes between actors involved in converging technologies. This enables converging institutions to quickly react to possible inconsistencies in possible convergences and to better identify, manage and communicate the risks involved in introducing nanotechnologies in society.

3. CONVERGING INSTITUTIONS IN GRENOBLE AND HAMBURG

As argued before, the general purpose of the converging institution is to shape relationships between converging technologies and all actors involved in nanotechnologies, particularly those who may benefit from the outcomes of nanotechnologies but who fear the related uncertainty of their introduction in economy and society. More than one prototype of converging institution structure can be expected. This is one result of our inquiry about possible types of regional converging institutions in Grenoble (France) and Hamburg (Germany). Although there are lots of stakeholders involved in the innovation process of nanotechnologies we concentrated our investigation so far on one type of actor involved in nanotechnologies, namely the experts, who are:

a) *scientists* (7 interviews): the developers and designers of nanotechnologies, including the scientific research and development centres *MINATEC* (Grenoble) and *Hansenanotec* (Hamburg);

b) *representatives of technological culture* (2 interviews): the promoters and optimisers of nanotechnologies within society, such as CCSTI-Grenoble (*Centre de Culture Scientifique, Technique et Industrielle*) and CAN-Hamburg (*Centrum für Angewandte Nanotechnologie*);

c) *representatives of civil society* (2 interviews): public organisations, civilian associations or citizens' movements that stimulate the public discussion about nanotechnologies, such as *Vivagora*, an NGO located in Paris, and opponents to the nanotechnologies such as *Pièces et Main d'Oeuvre* (or PMO). This type of actor was only found in Grenoble. In Hamburg, there is no association or group of citizens that has a clear purpose of stimulating public discussion on nanotechnologies.

We were in close contact with the experts mentioned during a six months period (from November 2006 to April 2007). At that time, we made our first contacts with the experts, conducted interviews with them, and summarised the most important results. The interviews took about one and a half hour for each expert and were recorded. They were carried out face-to-face and structured using a semi-directed questionnaire of 10 questions.

In order to compare the discourses of our experts, we performed a statistical analysis of the discourses collected. We drew a single list of key words appearing in

all interviews comprised of words at least four letters long that were expressed three times or more. This list of common key words served as a grid to filter and then reconstruct the clusters of main themes and sub-themes in the experts' discourses. We used a significance level of p=0.05 in order to build the clusters. One issue discussed by all experts was the term 'danger' thereby mostly referring to three interrelated themes, namely a) the toxicity of the nanotechnologies and an evaluation thereof. This was usually followed by a discussion regarding b) the role of expertise within the field of nanotechnologies, e.g., the expert's activity and her/his role in the field, and c) the risks regarding the widespread introduction of nanotechnologies in society.

a) Toxicity

If the scientists often speak about the toxicity of nanotechnologies, they also point out that there are lots of debates on the topic and that it is very difficult to define the toxicity of these new technologies with any precision. Moreover, toxicity is not only a challenge for experts; it also is a societal challenge. According to one scientist, «Again, for me we have not to communicate in order to explain what nano is good for. This is first about understanding the world into which they pull us, and then about structuring this world. Thus, this is broader than the question […] of the risks of toxicity, of the economic externalities.» According to the scientists, toxicity presupposes their intervention insofar as they are able to analyze and control it. But this is not enough to address the entire issue of toxicity, which involves political questions, questions regarding the public health, and the management of environmental challenges. Thus, the scientists agree with the general tendency to consider toxicity as a hybrid problem of a scientific *and* public nature.

The representatives of the technological culture speak more and most unilaterally about toxicity. For them, the problems related to the toxicity of nanotechnologies are – and should primarily be – a concern of actors possessing an adequately specialised knowledge of nanotechnologies. For the representatives of civil society, toxicity does not appear to occupy a significant component of their discourse on nanotechnologies. This does not mean that they do not think about the danger of nanotechnologies. Rather, they simply do not focus on toxicity when they speak about the danger of nanotechnologies. Because the danger of nanotechnologies is an important problem, the representatives of civil society consider that it goes beyond the unique problem of toxicity and involves concerns about scientific and collective knowledge of nanotechnologies and public risks. In fact, discourse on the theme of expertise is articulated by all actors.

b) Expertise

In Grenoble as well as in Hamburg, the theme of expertise allows actors the opportunity to describe their most important strategic partner. For the scientists, expertise is a composite knowledge that takes into account the individual qualities of scientists, the upstream research results, and sometimes several forms of applied and collective knowledge. For the representatives of technological culture, this is above all an applied knowledge, one that is typically found in industries and companies. The partners provide scientists the means needed in order to optimise their technical work so that, as a consequence, the resulting products can be spread throughout society with the blessing of science. For the representatives of civil society, knowledge is essentially collective before it is scientific, but this is a partnership that is often seen to be ambivalent. Collective knowledge must be tied to a debate about the societal stakes of nanotechnologies. Thus, all actors support the idea that the possible danger of nanotechnologies requires an investment in expertise and, more generally, in the development of a deep and wide-ranging understanding of nanotechnologies. However, each actor tends to look for this knowledge where it is relatively most accessible, namely either in his/her own group or among partners close to his/her interests in light of the standpoints that the group promotes and defends. Thus, our actors think it is possible to better discuss the risks related to nanotechnologies, particularly the societal ones.

c) Risks and societal vulnerabilities

Scientists mention the problem of risks more often than the representatives of technological culture and of civil society. They do so in order to relativise the expected benefits of nanotechnologies and point out that it is hard to describe and explore what exactly is at stake in the societal changes brought by nanotechnologies: «If we remain with it, it seems that we only see things with the lorgnette because these technologies have such a capacity to transform our environment. […] We should not stick at the technique; instead, we have to understand its effects, and to anticipate them.» In this sense, the category of risk is denounced as an a priori answer to the still largely unknown world of nanotechnologies: «Indeed, we are here in a world which is not at all logical, which is also a world of the imaginary, of belief, and actually these are joined together today.» In a similar way, the representatives of technological culture do not see how the convergences of economic sectors that nanotechnologies could engender would necessarily bring risks: «That is simply too broad. You can take each kind of industry, and you can consider each kind of possible industrial improvement, too. Finally, the question is always: Does it have to stay on the market? The market decides this, and that's all.» Yet, the scientists and the representatives of technological culture and of civil society share a very similar position on the risks related to the danger of nanotechnologies. For the scientists, the type of risks does

not call for a scientific interrogation of the impact of nanotechnologies within society. The representatives of technological culture also think that these types of risks do not allow us to take into account the impact of the developments of nanotechnologies on various economic sectors in a relevant way. The representatives of civil society observe that speaking about risks does not enable critical questioning about the impacts of patents on innovation and about the possible restrictions of civilian and personal liberties resulting from their implementation within society.

These critical considerations regarding risks result in a double strategy. On the one hand, they provide each group with the possibility to reaffirm its own interests and the importance of the stakes each one projects in the development of nanotechnologies. The representatives of technological culture highlight it even more. They see nanotechnologies as a point of primary importance for socio-economic development. The representatives of civil society highlight the importance of taking a critical look at the consequences of technological development within our society. The scientists strike the greatest balance when they view nanotechnologies both as supporting societal change and as accelerating systemic risks. For them, the problems raised by nanotechnologies are still largely unknown. This, of course, supports further scientific research in this field. More generally, this relativisation of risks meets a common aim for the three types of experts. The risks, they say, do not suggest the framework for an adequate investigation regarding the possible danger of nanotechnologies. Risks have to be questioned. They have to be broken down and contextualised within society, where it is necessary to be dispassionate about this. In light of this, the experts hope for more relevant debates about the supposed danger of nanotechnologies, while the specific stakes of each actor have been preserved in order to delimit a space for possible collaborations on this topic.

Let us summarise. Taken together, the experts agree on basic elements when they discuss the dangers of nanotechnologies: the reliability of knowledge and the transparency of actors' involvement are two required elements. However, the solution to this problem has to be found initially within the scientific community, after which this information has to be spread within society. The representatives of civil society emphasise the lack of information and of its reliability. However, this is due to the fact that citizens do not have information adequate to develop knowledge about nanotechnologies and to open a dialogue with other actors involved in the field, particularly with the scientists. The representatives of technological culture recall that it is certainly important to improve scientific and collective knowledge of nanotechnologies. However, one should pay attention to the manufacture of technologies on the nano scale, which has to be taken into account in order to understand their impact on the economy and on society. Here too, debate is important. Do agreements on the importance of reliable knowledge and the

transparency of actors' involvement solve this ambivalence regarding communication about nanotechnologies?

4. MISTRUST IN NANOTECHNOLOGIES

All experts fear that the 'spectre' of GMOs motivates public opinion to be wary of nanotechnologies and/or to support a moratorium to stop the scientific and industrial developments in this field. A scientist explained the opinion of most experts by summarising the relationship between GMOs and nanotechnologies as follows: «First let's take the GMOs, then we take the nanos.» During the past few years, this expert discourse has been echoed in the specialised literature on nanotechnologies. Certain parallels with the GMOs have also been denounced by actors who criticise the development of nanotechnologies (3) as well as by actors supporting it.(4) All fear that this kind of joint project will prevent us from dealing with the socio-political, socio-economic, and socio-cultural stakes involved in the development of nanotechnologies, whether they are defined in terms of chance or risks.(5) All of this underlines laxity of the public authorities in terms of the legislation and standardisation of nanotechnologies.

Such a policy initiative is very important, not only because such norms are not to be expected before 2009, but also because the standardisation of nanotechnologies will increase the available information about nanotechnologies. This could provide a first step in developing reliable knowledge and promoting the transparency of actors' involvement within the fields of production and societal introduction of nanotechnologies. It would be the first step in fostering a basis for the development of converging institutions.

5. CONVERGENCE/MEDIATION

The interviewed experts are cautious about suggesting that nanotechnologies could bring science to the public in a way that builds a harmonised society and sustainable knowledge as can be seen in the following statements. Once more, scientists and the representatives of civil society defend similar arguments by taking into account this gap between science and society: «You can ask a researcher, or you do not need to ask him, because he does it for himself, he is not locked up in his test tubes, he is aware of it. But you cannot ask him to explain these things to people. It is definitely not his job.» For the representatives of civil society, scientific specialisation has a bad image among the public, which is related to a persistent, public mistrust in the sincerity of scientists. These arguments reflect in a typical way the importance of reliable information and communication within the field of nanotechnologies.

In contrast, the representatives of technological culture do not view the reliability of information and the transparency of actors' involvement as the most important

factors for fair, trustworthy communication in the field of nanotechnologies: «Actually, the more one learns, the more one doubts.» Consequently, the representatives of technological culture advocate less convergence, such as the direct collaboration of several complementary actors within the fields of nanotechnologies, and more mediation, such as the positioning of one organisation between actors involved in the fields of nanotechnologies in order to facilitate mediated communication and collaboration.

Convergence and mediation represent the different viewpoints of the scientists and the representatives of technological culture and civil society. At the same time, they point to the challenges that they share the danger of nanotechnologies: namely, the risks associated with an open debate on nanotechnologies that takes the form of a public discussion open to multiple actors and requires their collaborative engagement. For the scientists and the representatives of civil society, the idea of convergence expresses their ambivalence regarding this kind of debate, its organisation, the exchange it might encourage between specialised knowledge and collective knowledge. For the representatives of technological culture, the idea of mediation expresses the same ambivalent feeling, because for them, to have an exchange about nanotechnologies means more than simply building a shared language in order to support a sustainable dialogue between two different forms of knowledge. Rather, it is to communicate these forms of knowledge with industrial cultures engaged in the practical production of nanotechnologies. In other words, this entails finding a bridge between two worlds that cannot coincide, even if they might encounter and valorise each other.

6. CONCLUSIONS

The scientists and the representatives of technological culture and civil society are not only ambivalent regarding the contents of the communication about nanotechnologies. They are also ambivalent regarding the modalities of the exchanges that this communication could favour. Mediation carries the ambivalence about "working together" and collaboration (*cum laborare*). Convergence leads to an involvement in the debates about nanotechnologies. But these debates should not be forced on people who do not want to communicate about nanotechnologies, who do not care about it, or who communicate merely in order to stop the further development of nanotechnologies. Could these kinds of debates support the building of converging institutions? Will this rule the development of nanotechnologies? Or should it remain purely informational? Should it be normatively framed within a corpus of laws, or should it rest on the initiatives of the civil society, i.e., on the exchanges between experts and non-experts of nanotechnologies?

The experts interviewed see the vulnerability of the communication on nanotechnologies as a necessary preamble to more deliberate public debates on nanotechnologies. In other words, this is a necessary condition of the emergence of

converging institutions. Indeed, the scientists and the representatives of civil society embrace a conservative strategy. They do not seek to ensure their socio-institutional position by limiting their communication according to their interests and stakes. Rather, they try to modify their individual and mutual involvements in order to reshape their understanding of convergence. They want to deal with the vulnerability of their own communication about nanotechnologies, and they want to avoid having their actions wield a perverse effect in accord with the motto, "the more one speaks, the less one gets along with the other." In a similar way, the representatives of technological culture try to escape their position as intermediaries in order to play a more active role within the debates on nanotechnologies, which is not only about (specialised and non-specialised) knowledges but also about (techno-scientific and industrial) practices. In other words, experts in Grenoble and Hamburg try to use their vulnerabilities as a resource in order to find an appropriate way to collaborate and to create a dialogue between convergence and mediation that could define the future ways in which nanotechnologies are developed.

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NOTES

(1) See e.g., BMBF (BMBF, 2004). In our paper, we use the label 'nanotechnologies' instead of 'nanotechnology'. Nanotechnology denotes a conceptual frame used to define the process of developing technologies at nano-scale. In contrast nanotechnologies refers to various technologies developed at nano-scale.

(2) As an example, one can consider the concept of 'institutional entrepreneurs' developed by Maguire (Maguire et al., 2004), accentuating this active component of institutions, and applied to nanotechnologies by Mangematin (Mangematin et al., 2005)

(3) See the special issue 97 of the ecological initiative "Chain Reaction" started by the Friends of the Earth in Australia, and entitled *Size Does Matter* (2006). This gives a good overview of the information on the relationships between GMOs, and nanotechnologies, which is considered to be too fragmented, and not reliable enough. Same statements can be found in this report about the relationships between nanotechnologies and nuclear research, or nanotechnologies and social surveillance.

(4) See the report of the National Risk on Governance Council *Survey on Nanotechnology Governance* (2006), edited by Roco and Litten. See also the report of the 4th European forum on nanotechnologies, which states: «Fears which emerge must be calmed by implementing a real discussion between the different actors. The dialogue between scientists and the general public must avoid past mistakes, as was the case for GMOs, where the absence of distinction between various techniques, contempt of information and an incomplete study of the risks, legitimately caused a massive rejection by the general public and a great mistrust with respect to the 'agro-business' 90» (European Nanotechnology Gateway, 2005, p. 37).

(5) The ethical committee of the UNESCO on nanotechnologies expressed this concern clearly, and in relationship with GMOs when its members met in Paris in July 2005: «It was also said that the scenario that was presented seems so scary that public opinion may be mobilised against nanotechnology, like

with GMOs, preventing possible benefits. Is this technology intrinsically dangerous or is it only its possible use? One should avoid that some sort of paranoia prevents public benefits. Mr. Gordijn emphasised the strong influence of the gray-goo scenario in the public debate, despite its recognised obsolescence. Even if it was possible, molecular engineering in other ways would be more efficient. Some publications such as the novel Pray had a huge influence anyhow, as had already been the case with genetics» (UNESCO, 2005, p. 4).