From objective to constituted risk: an alternative approach to safety in strategic technological innovation in the European Union

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Abstract

Safety is a legitimate means of limiting technological innovation in our societies. However, the potential socio-economic impact of curtailing techno-industrial progress on the grounds of safety means that risk governance policies tend to restrict the range of legitimate approaches to safety on the principle that it can only be discussed in the frame of an allegedly objective scientific representation of risk. In European risk governance, socio-economic factors such as the underlying innovation rationales and goals are not openly considered to be related to the constitution of safety, but tend largely to be treated as factors of subjective reaction toward risk and technology. This paper seeks to overcome that approach by proposing a "constitutive" understanding of how risk and socio-economic factors and dynamics relate, focusing in particular on the "safe and responsible" development of nanotechnology in the European Union (EU). I argue that risk is *constituted* according to socio-economic considerations, and that the controllability of the environmental and health risks of nanotechnology in the EU are assumed on principle in the very strong institutional commitment to the industrial exploitation of nanotechnology R&D. Using a constitutive approach, we may legitimately conceive a broader set of potential safety scenarios, while at the same time highlighting major obstacles to implementing more critical constitutions of techno-industrial risk in the framework of a highly competitive knowledge-based global economy.

Keywords: objective risk; constituted risk; EU risk governance; nanotechnology; uncertainty

1. Introduction

Policy-making has instituted risk as a legitimate means for discussing and debating technological innovation in our societies on the basis of risk analysis (e.g. European Commission, EC 2007a). As technological innovation is considered the cornerstone of economic growth and competitiveness (Marklund, Vonortas, and Wessner 2009), the issue of risk has the potential to undermine the legitimacy of regulatory policies and, subsequently, to endanger techno-industrial progress and the economy alike. For instance, the food crises in the European Union (EU) in the 1990s (i.e. food and mouth disease, "mad cow" disease, and dioxin-contaminated chicken) provoked the social perception that risk governance was seriously limited and that regulators favored the interests of industry to the detriment of the public interest, which *"undermined public confidence in expert-based policy-making"* (EC 2001, 19). Arguably fueled by such growing public skepticism and criticism of regulators and techno-industrialism, social resistance to agri-food biotechnology in the EU can in part be interpreted as a reaction against the promotion of a technology whose environmental and health risks may have been under-analyzed and under-regulated (Gaskell 2008).

Prompted by such experiences, the EU now claims to be strongly committed to factoring in public interests and concerns regarding the industrial development and regulation of science and technology. According to the European Commission (EC): *"For Europe to become the most advanced knowledge society in the world, it is imperative that legitimate societal concerns and needs concerning science and technology development are taken on board"* (EC 2007b, 4). However, to what extent are *"legitimate societal concerns and needs"* likely to be "*taken on board*" in the context of a highly competitive knowledge-based global economy, in which very restrictive regulations might lead to a substantial loss of competitive advantage?

In the present paper I argue that the range of legitimate safety scenarios in EU risk governance is seriously curtailed by the principle that safety can only be discussed on the basis of an allegedly objective scientific representation of risk, meaning that socio-economic factors and dynamics such as the underlying innovation rationales and goals are not openly considered to be related to the issue of safety constitution, but are mainly treated as factors of subjective reaction to risk and technology (e.g. EC 2009, 7-13).

However, I claim that the relation between risk and socio-economic factors is "constitutive": risk is *constituted* according to a heterogeneous set of factors, including socio-economic ones, which means that safety scenarios are constructed on the ways in which those factors are understood, valued and interrelated. I propose that under a constitutive approach, we may legitimately conceive a broader set of potential safety scenarios.

To this end, in section 2 I argue that the strong demarcation between (scientific) "assessment" and (politico-social) "management" functions of risk analysis, which restricts alternative discourses on risk and legitimizes techno-industrial progress, is indefensible because scientific processes of risk selection and interpretation are embedded with non-epistemological values and interests. Section 3 characterizes and compares "objective risk" and "constituted risk", and claims that the latter provides a better account of how safety is built in our societies with regard to technological innovations of strategic economic significance. In section 4, which looks in some detail at European nanotechnology R&D risk governance policy, I argue that the potential for alternative constitutions of safety is severely constrained by a strong institutional commitment to industrial progress and economic competitiveness, by which the controllability of the environmental and health risks of nanotechnology is assumed on principle. Section 5 presents the paper's main conclusions and includes a discussion of the implications of "constituted risk" for risk governance policies and the possibility of creating alternative socio-technical safety scenarios.

2. Limiting safety: scientific knowledge and "objective" risks

Industrialized countries consider technological innovation a basic factor in social progress and problem-solving, as well as a key competitive element in the framework of a global knowledge-based economy (Marklund, Vonortas, and Wessner 2009). In its Communication on the 8th EU R&D Framework Programme, "Horizon 2020", the EC declared that "*Smart investment, notably in research and innovation, is vital in order to maintain high standards of living while dealing with pressing societal challenges"*, and added that the EU *"faces increasing competition from traditional competitors and emerging economies alike and must therefore improve its innovation performance"* (EC 2011, 2).

However, technological innovations are not valued only in terms of promises of social well-being and economic development. They also have the potential to damage the environment and human health, which is why policymakers also place great store by risk analysis. Such analysis assesses and manages the risks and uncertainties of techno-industrial developments (Luján and López Cerezo 2004).

In addition to determining and warranting acceptable levels of techno-industrial risk, risk analysis legitimizes techno-industrial progress in the eyes of society. First used in the 1960s in the USA, in a countercultural context increasingly hostile to industrial society and its evils, risk analysis represents the institutional attempt to control and legitimize scientific and technological innovations without renouncing the basic assumptions of economic growth, industrial development and consumption (Dickson 1984, 261-306).

Nevertheless, the controlling and legitimizing capacity of risk analysis is limited. The behavior of technological systems and toxic substances often cannot be accurately determined. As a result, risk frequently continues to be shrouded in uncertainty, which, together with the control and safety narratives of experts and regulators, can trigger social mistrust and cause anxiety about technology and the controlling bodies (Wynne 2006). Furthermore, the social perception that institutions prioritize the economic benefits of the industrial development of technology over environmental and human health is relatively widespread (Shrader-Frechette 2007).

In Europe, the limits and partiality of risk regulation were made clear by the public backlash against agri-food biotechnology (Gaskell 2008). Presumably prompted by that experience, the EU has openly admitted that the legitimizing capacity of the scientific and political risk governance dynamics and decisions on techno-industrial developments is limited. For instance, the EC claimed a decade ago that *"Risk governance – embracing risk identification, assessment, management and communication – has become a crucial but often highly controversial component of public policy"* (EC 2002, 23). In consequence, EU risk policy has evolved into more accountable, participatory and precautionary forms over the last two decades (EC 2000, 2002, 21-6, 2009), in an attempt to improve public uptake of technological innovations in the framework of a knowledge-based economy (Todt 2011).

Nevertheless, the coexistence of regulatory efforts and a major commitment to technological innovation must be taken into account in any attempt to understand and assess institutional attitudes and measures towards more drastic social demands on safety. For example, safety-related public resistance in Europe to transgenic food was considered by the then European Commissioner for Health and Consumer Protection David Byrne as something *"inconsistent if not completely irrational"* (Byrne 2003, 2), namely as something not based on facts, or objective risks, but on scientific ignorance and/or cultural and political prejudices.

Such attitudes appeal to science to discredit criticism of techno-industrial progress and, consequently, minimize the range of possible scenarios concerning the relationships between science, technology, society and nature. In other words, scientific knowledge works as *possibility* and *limit* of what can be criticized and regulated in regard to technological progress. According to Paola Testori Coggi, Director-General for Health and Consumers at the EC, *"Policy-making based on* sound science *is the main principle underpinning risk governance and regulation in the European Union. This is complemented by the* clear separation *of risk assessment and risk management"* (Coggi 2013, 3). Therefore, science, conceived as objective knowledge representing reality with no value-interferences, is the main legitimizing element of safety-related technology regulation.

However, scientific representation of risk should not be considered as a mere objective mirroring of a given reality. In what follows I present two dimensions of the scientific assessment of risk which question the ideal of "value-free" science:

To begin with, what is considered to be worth theorizing about, namely the complexity of the risk system in question, is constituted on largely pragmatic criteria (Sarewitz 2010). The EU initially addressed the regulation of risks relating to agri-food biotechnology from a "genetic deficit" perspective, taking as valid an intensive model of agriculture in which the possible ecological impact of transgenic crops was not seen as relevant. Thus, levels of uncertainty associated with the technology were lowered: only a limited causal space in which risk became controllable was considered as relevant for analysis (Levidow 1998, 217, 220, 223-4). In fact, the progressive tightening of European regulation on genetically modified organisms (GMOs) from the early 2000s was provoked by social pressure seeking consideration of a broader set of environmental risks associated with an industrial model of agriculture (Levidow and Murphy 2003, 52, 62-4, 67).

Furthermore, non-epistemological considerations also have a role in the internal processes of science, where the evidence on risk is characterized and interpreted. The science of risk has to deal with the possibility of erring in the evaluation of hypotheses, which are formulated to a great extent on the basis of incomplete evidence. When the consequences of error are non-epistemological (e.g. when they affect human health or the environment), decisions about how to deal with uncertainty are *necessarily* embedded with non-epistemological considerations (Douglas 2000). To put it another way, when evidence is incomplete, and with regard for instance to the toxic effect of a given substance on humans, the decision between erring on the side of health by accepting a positive research hypothesis (i.e. “the substance causes harm”) that turns out to be false (false positive, or Type I error) or erring on the side of economy by accepting a negative research hypothesis (i.e. “the substance causes no harm”) that turns out to be false (false negative, or Type II error) will be ultimately taken according to the way in which the different types of consequences are valued, or prioritized.[1]

In other words, the complete separation of the scientific determination of risk from the socio-economic considerations and dynamics by which certain techno-industrial innovations are promoted, needs to be called into question. However, my intention is not to address the specific problem of the relationship between science and

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[1] The fact that there are systemic, epistemological and practical limits for uncertainty reduction does not imply that decisions about Type I and II errors have nothing to do with science. The application of stricter criteria by which, for instance, statistical significance is granted to the differences between organisms exposed and organisms not exposed to a given dosis of a substance, produces a smaller amount of false positives (and, consequently, more false negatives) than do less stringent interpretations of statistical bases (Douglas 2000, 566).

non-epistemological values, but to relate risk to a broader set of social dynamics and considerations by which safety is constituted and determined. By adopting a conceptual framework in which risk is not simply understood as a technological characteristic whose regulation and limitation achieve legitimacy on the basis of objective scientific knowledge, but as a reality that is also constituted by a heterogeneous group of socio-economic considerations, a broader set of perspectives and strategies about how safety should be constituted in our societies becomes more visible, robust and legitimate.

3. Risk and society: from objectivity to constitution

As we saw in the previous section, in addition to being an instrument for regulating safety, the scientific assessment of risk acts as a legitimizing element of the critique of technological development. It represents the "objectivist limit" of what society can criticize regarding the negative socio-environmental impact of techno-industrial progress.

Rather than seeing risk as a controllable side-effect of uncriticized and highly promoted industrialism, the sociological theory of the "risk society" (Beck 1992) conceives risk as the most characteristic element of the configuration and dynamics of modern industrialized societies. Risk is presented as a constitutive element of the modern institutional framework and its limits—i.e. as the main tool for thinking critically about modernity.

Other social theories of risk, in contrast, have addressed the social meaning of risk from a more dichotomic perspective. For instance, Ortwin Renn seems to restrict the influence of values and socio-cultural factors to the issue of risk acceptability (i.e. if risk is imposed or not, if it is more or less familiar, if it is justified or not, etc.), while separating the issue of safety constitution from such socio-cultural dynamics. As he puts it: *"If all society would care about is to reduce the amount of physical harm done to its* *members, technical expertise and some form of economic balancing would suffice for effective risk management"* (Renn 1999, 3050). On this understanding, the author develops a "cooperative" risk governance model based on a strict functional differentiation between stakeholders, scientists and society (Renn 1999, 2004). In this model, the publics play the role of *"value consultants"* (Renn 1999, 3052), appraising various technological options in the light of a previous scientific assessment of their risks, measured against criteria established by stakeholders (Renn 1999, 2004).

Although the EC has made claims (theoretically based on proposals such as Renn's "cooperative" model) to the effect that it regulates techno-industrial risks according to an *"inclusive risk governance"* scheme (EC 2009) requiring *"a dialogue among experts, stakeholders and decision-makers"* (EC 2009, 7), such control is always based on the idea that scientific and socio-political factors and criteria come into play in different stages of the risk governance process. According to the EC, *"Risk management can be understood as a process of weighing the outcome of the risk assessment with political and socio-economic factors"* (EC 2009, 11).

Such strict functional differentiation, in itself a reflection of the separation of risk assessment and risk management processes, limits the range of elements and considerations that might legitimately be used to address the risks of scientific-technological progress. Indeed, given the dichotomy between social and scientific factors, this model implicitly assumes that an acceptable risk scenario is viable without renouncing the basic dynamics of industrial progress or economic growth and competitiveness. Thus, the relationship between the more critical socio-political considerations and safety is conceived in conventional, or symbolic terms, as expressed by Renn himself:

> (...) actors in risk arenas are not always interested in the risk issue per se, especially if it has become a symbol for other issues. The best example of such

> symbolization is the struggle over nuclear power. Groups in this arena are not only concerned about risks of nuclear power, but view the debate over nuclear power as a surrogate for larger policy questions about desired life-styles, political structure (e.g., centralization vs. decentralization), and institutional power. Fighting against nuclear power gives the protagonists social resources they need to fight their "real" battle. In highly symbolized arenas, evidence about actual impacts is almost meaningless for the actors, but is still a desired resource to mobilize support (Renn 1992, 191).

The relation of a symbol with what it denotes is conventional, namely the result of an agreement (Sebeok 1994, 33-7). Therefore, when the relationship between risk and social issues is understood in symbolic, conventional terms, a more direct relation between safety and more critical socio-political concerns and points of view is not considered. In contrast, I suggest risk should be understood mainly as a *symptom*, i.e. as something that maintains a natural, or causal relation with what it indicates (Sebeok 1994, 43-60).

Risk may thus be understood as an indicator of the relations and tensions between science, technology, society and nature. But the "risk-indicator" is open to a variety of interpretations; it is not an *"objective counter-force"* (Beck 1995, 99), which automatically questions the institutional design and capacities of our societies. As seen in the previous section, the value of the risk object under analysis influences how evidence available about that object is selected and interpreted: risk representations do not just represent "potential negative consequences", but the actual state of the socio-natural relations whose re-equilibrium may be "demanded" by those representations (Mitchell and Cambrosio 1997).

Therefore, the transforming potential of risk depends on the socio-economic relevance, or *pervasiveness*, of risky systems. For instance, in spite of its catastrophic potential, and the problem of permanent, safe storage of wastes whose toxic lifetime spans up to hundreds of thousands of years, nuclear energy is being advocated by some governments as a necessary step to reduce greenhouse gas emissions and, consequently, to attenuate anthropogenic climate change without renouncing economic growth or massive and growing energy consumption (Shrader-Frechette 2011). In 2010 the United States government approved an $8000 million loan guarantee to construct a new nuclear power plant there in three decades, arguing that *"To meet our growing energy needs and prevent the worst consequences of climate change, we'll need to increase our supply of nuclear power. It's that simple"* (US President Obama).[2] More recently (October 2013), the British Government announced the construction of two nuclear power stations in Britain, in similar economic and environmental terms,[3] despite the 11 March, 2011 Fukushima Daiichi nuclear disaster in Japan.[4]

In that sense, some safety demands can hardly be assimilated by regulators (Dryzek 2000, 112). Socio-economic imperatives constrain the action of governments regardless of the desires or preferences of the political representatives. The first task of a democratic liberal State is to reach and maintain adequate conditions for economic growth (Dryzek 2000, 83-4, 94, 142-3, 165).

So the issue of safety in techno-industrial progress goes straight to the foundations of our societies and their degree of transformability. In that respect, certain safety scenarios will only be reached by the reconfiguration of particular socio-institutional practices, including citizens' habits and commitments (Light 2003). For instance, one way of dealing with the contamination produced by urban waste

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[2] "Remarks by the President on Energy", IBEW Local 26, Lanham, MD, Feb. 16, 2010: www.whitehouse.gov/the-press-office/remarks-president-energy-lanham-maryland. Accessed May 13, 2014.

[3] Euronews: "UK and EDF agree deal on two new nuclear reactors": www.euronews.com/2013/10/21/uk-and-edf-agree-deal-on-two-new-nuclear-reactors. Accessed May 13, 2014.

[4] In contrast, in the aftermath of this accident, Germany has decided to phase out all nuclear power plants by 2022. Source: "Roadmap for the Energy Revolution: Germany to Phase Out Nuclear Power by 2022", *Der Spiegel*, 5/30/2011: www.spiegel.de/international/germany/roadmap-for-the-energy-revolution-germany-to-phase-out-nuclear-power-by-2022-a-765594.html. Accessed May 13, 2014.

incinerators—whose "real", or "objective" risks are under discussion—is to design and implement very strict selective waste collection systems that would maximize the use of waste and make incineration unnecessary. This would require an active commitment from citizens, who should be willing to forego comfort (Casado da Rocha 2013).

In the next section I focus on the European governance of the risks of nanotechnology, considered to be a socio-economically strategic R&D area, to argue that, although the EU is adopting strict regulations for nanotechnology, it is doing so on the assumption that a fundamental reconsideration of the economic and industrial exploitation of nanotechnology based on safety considerations would be inconceivable.

4. Constrained safety: EU risk governance of nanotechnology

The tension between technology promotion and regulation is evident in the European governance of the risks of nanotechnology. Having the capacity to manipulate matter at atomic and molecular levels, nanotechnology is an *"enabling"* R&D area, applicable to all technology-based industrial sectors (EC 2004, 4-5).[5] As a strategic R&D area for economic growth and competitiveness, the EC considers nano-R&D an activity that *"should not be delayed, unbalanced or left to chance"* (EC 2007c, 2).

At the same time, the capacity to manipulate matter at atomic and molecular sizes, by which the behavior of materials on larger scales in terms of properties such as lightness, resistance or conductivity is transformed, may expose people and the environment to new risks *"possibly involving quite different mechanisms of interference with the physiology of human and environmental species"* (EC 2008, 3). The behavior

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[5] This means that *"if you have one breakthrough in nanotechnology you can use it across sectors. And that's why everybody, including Europe, is working hard in the nanotechnology area"*, as stated by Janez Potočnik, former European Commissioner for Science and Research (2004-2010) (as quoted in Garkov, Bontoux, and Martin 2010, 418).

of a chemical in nanoparticle form cannot be extrapolated from the behavior of the same chemical on a larger scale. The toxicity of nanomaterials relates to physical properties that only occur at molecular and atomic sizes. For instance, nanoparticles have a greater surface-area-to-volume ratio than larger particles, which increases their surface energy and catalytic capacity and, consequently, their toxicity. Also, nanoparticles, being so small, are picked up by the human body and other organisms more readily than larger particles, and are able to penetrate through biological barriers inside the organisms more easily (e.g. Oberdörster 2010).

Prompted by safety concerns surrounding nanotechnology—and techno-industrial innovations in general—the EU claims to advocate *"safe and responsible"* development of nanotechnology (EC 2004, 3). The EU has thus become the first government in the world to develop and implement specific regulations about nanomaterials, due mainly to the European Parliament's legislative initiative, which has compensated for the EC's reluctance to develop special regulations for nanotechnology.[6] Regulation 1223/2009 on cosmetic products mandates, among other things, labeling of products that contain nanomaterials and a special risk assessment for these products (The European Parliament and the Council of the European Union 2009).

European regulatory efforts are based on the fundamental assumption that a massive industrial development of nanotechnology in a context of a highly competitive economic system is controllable and compatible with adequate levels of health and environmental safety. However, according to the Scientific Committee on Emerging

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[6] In spite of the novel properties of nanomaterials compared to their bulk counterparts, the EC concluded in a regulatory review conducted in 2008 that the pre-nanotechnology regulatory framework *"covers in principle the potential health, safety and environmental risks in relation to nanomaterials"* (EC 2008, 11). In a second review, the EC claimed, similarly, that *"all environmental legislation reviewed could be considered to address nanomaterials in principle"* (EC 2012, 9).

and Newly Identified Health Risks (SCENIHR), a body of experts who advise the EC, the underlying causal mechanisms for toxic effects of nanomaterials remain mostly uncertain, meaning that *"there is not yet a generally applicable paradigm for nanomaterial hazard identification"* (SCENIHR 2009, 10). In other words, the basic parameters that should frame the new knowledge about nanomaterial toxicology with regard to human health and the environment remain basically unknown: the behavior of nanomaterials in the environment, exposure routes and the metrics by which that exposure should be measured, the translocation mechanisms by which nanomaterials enter different parts of the body, or the exact mechanisms by which toxic processes are activated all remain uncertain (Kandlikar et al. 2007; Oberdörster 2010; Jamier, Gispert, and Puntes 2013).

Informed of the strong epistemological limitations concerning the fundamental, or characteristic causal mechanisms determining the risks of nanotechnology, the EC claims that the risk assessment of nanomaterials *"should be performed on a case-by-case basis"* (EC 2012, 11). However, in the context of a massive introduction of nanotechnology-based products onto the market, a thorough assessment of every nanomaterial may not be realistic: even if the number of nanomaterials causing concern is limited (nanotubes, quantum dots, metal oxides, carbon fullerenes, dendrimers and nanoscale metals, principally), differences concerning size, shape, surface area, surface chemistry, etc. will lead to thousands of variations, which will determine the environmental and health impact of those nanomaterials (Walker and Bucher 2009, 252; Oberdörster 2010, 93).[7]

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[7] Leaving aside the issue of whether some uncertainties are non-reducible, Choi and colleagues calculated in 2009 that comprehensive hazard testing of nanomaterials then available on the market would take between three and five decades and an investment of $1188 million (Choi, Ramachandran, and Kandlikar 2009).

However, in spite of the complexity and high degree of uncertainty regarding the behavior of nanomaterials, knowledge gaps are not seen as a profound inability to manage or control the molecular and atomic transformation of the world—as suggested, for example, by Nordmann (2005)—but as a temporary, solvable situation. In 2002 the Canadian non-governmental organization ETC Group (Action Group on Erosion, Technology and Concentration) demanded, on grounds of safety concerns and a prudent interpretation of uncertainty, a *"moratorium on commercial production of new nanomaterials"* (ETC Group 2002, 1), which the EC rejected, appealing to science and its alleged capacity to objectively and precisely represent the risks of nanotechnology. Only in the event *"that realistic and serious risks [were] identified"* (EC 2004, 19) could drastic regulatory measures as such be enforced.[8] In similar terms, the European Parliament also assumes that an appropriate scientific effort will *"close the knowledge gaps"* (The European Parliament 2009, paragraph K).

This regulatory optimism is based on a strong political commitment to the industrial development of nanotechnology. Given such a commitment, any questioning in the future of the promotion of nanotechnology on the grounds of safety issues and concerns is assumed to be an inconceivable scenario. According to the EC, *"Without a serious communication effort, nanotechnology innovations could face an unjust negative public reception"* (EC 2004, 19). Here we see that potential social resistance to nanotechnology on the grounds of safety is simply dismissed, being considered "unjust" on principle (i.e. as something that would need to be tempered by educating the ignorant through *"a serious communication effort*").

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[8] In fact, more than 1600 manufacturer-identified nanotechnology-based consumer products have already (as of December 2013) been launched on the market worldwide, according to the Project on Emerging Nanotechnologies (PEN): www.nanotechproject.org/cpi. Accessed December 5, 2013.

This kind of narrative assumes *de facto* that techno-industrial progress is controllable by science and law without renouncing the main goals of economic growth and competitiveness. The governance of the safety of industrial applications of nanotechnology thus transcends the exercise of assessing and managing a set of "objective" risks: governing the risks of nanotechnology also means dealing with the socio-economic factors by which safety scenarios are established and made acceptable in a knowledge-based economy. This in turn implies that the constitution of safety is severely constrained by socio-economic dynamics and imperatives guiding nanotechnology R&D.

Therefore, the relation between socio-economic factors and risk is "constitutive", in the sense that the way in which those factors are interpreted and valued will determine what type of safety can be constituted and, accordingly, the extent to which socio-technical relations can be re-thought and re-built. Risk governance should thus be explicitly understood and conducted from an ampler *"innovation governance"* perspective, meaning that the rationales and commitments behind technological innovations, instrumentally concealed by the dominant "objective risk" framing, cannot be immune to open criticism and scrutiny concerning safety constitutions (Felt, Wynne et al. 2007). For instance, very speculative expectations about future socio-technical scenarios, which represent a constitutive part of the legitimization and shaping of strategic technological innovations such as biotechnology (Brown 2003) or nanotechnology (Selin 2007), *"tend to be insulated from wider recognition and debate, accountability and negotiation"* (Kearnes et al. 2006, 293), and that arguably constrains the emergence of more critical, or skeptical policies of techno-progress and its safety. Forecasts about the economic size of nanotechnology, for example, were overtly exaggerated (e.g. a world market for nanotechnology worth between €750,000 million and €2 billion by 2015 according to the EC)[9], based on calculations about the total value of products containing any nanotechnology rather than on the actual nanotechnology part of the product, which would represent less than 1% of estimated total product sales (Shapira and Youtie 2012, 9).

Aware of that lack of reflexivity, inclusivity and precision surrounding the justification and promotion of strategic technological innovations, the EC is currently claiming the adoption of a "Responsible Research and Innovation" (RRI) approach for R&D activities under the next EU Framework Programme "Horizon 2020" (2014-2020), which would *"allow all societal actors (...) to work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of European society"* (EC 2013, 4). As such, RRI can be characterized as an attempt to justify and guide innovation not on the basis of taken-for-granted macro-economic visions and promises, but on grounds of societally-beneficial objectives (*"right impacts"*) as openly and deliberatively defined by a heterogeneity of stakeholders (von Schomberg 2013). From this perspective, *"inclusive risk governance"* (EC 2009) might be arguably broadened as to also include *"upstream"* public appraisal of socio-technical assumptions guiding innovations and their safeties (Sykes and Macnaghten 2013).

In this regard, recent European policy claims on the development of nanotechnology in society have tended to be more nuanced and complex in comparison to claims made in the past, something that could affect the way in which nano-safety is approached. For instance, according to Christos Tokamanis, Head of Unit for Nano and Converging Sciences and Technologies of the EC, *"the proposal that we are making*

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[9] http://ec.europa.eu/nanotechnology/faq/faqs.cfm?lg=en&pg=faq&sub=details&idfaq=28821. Accessed April 28, 2014.

compared to six years ago is that nanotechnology is not simply about creating or improving products" (Tokamanis 2011, 10). Nanotechnology is characterized here as a *"socio-political project"* that involves controversial socio-economic, cultural and ethical aspects and, as such, should try *"to engage citizens as early as possible in all developments and processes"* (Tokamanis 2011, 10). However, in spite of the progressively increasing emphasis by European research policy during the last two decades on promoting more responsible science and technology, evidence shows that the actual demand for integrating socio-ethical issues and perspectives into specific research projects and practices has been relatively modest compared to efforts to integrate economic and industrial considerations and goals (Rodríguez, Fisher, and Schuurbiers 2013). The possibility that an RRI approach will contribute to a substantial transformation of nano-safety constitution should therefore be treated with some skepticism.

5. Discussion and concluding remarks

Risk, institutionally considered to be a legitimate issue by which techno-industrial progress can be debated and limited, is framed and appraised by regulatory bodies as a reality that must be regulated only on the basis of its allegedly objective scientific representation, meaning that risk governance should respond to a "clear separation *of risk assessment and risk management"* (Coggi 2013, 3).

In the present paper I argue that in European risk governance socio-economic factors and dynamics framing technological innovations are not considered to be legitimate concerns in risk constitution. Instead they are seen as factors through which societies react, resist and adapt to objective risk. In contrast to this vision, I claim that the relationship between risk and society is "constitutive": socio-technical safety is constituted according to a set of socio-economic factors and dynamics by which certain techno-industrial safety scenarios are erected while others are not.

Taking as a main example the *"safe and responsible"* development of nanotechnology in the EU (EC 2004, 3), I argue that nano-safety is regulated in Europe under the framework of a strong institutional commitment to nanotechnology, by which the controllability of the environmental and health risks of nanotechnology in a context of a highly competitive knowledge-based global economy is assumed on principle. An appraisal of the economic imperatives grounding technological innovations as well as of the scientific and technical resources and capabilities by which those imperatives are argued to be safely "satisfiable", would facilitate the creation of alternative safety scenarios for techno-industrial progress. Seeing techno-industrial risk as "constituted risk" implies approaching the risks of techno-industrial progress on a more critical basis.

Far from understanding risk governance as an objectively grounded process by which techno-industrial progress should be regulated while avoiding the influence of subjective *"overreactions"* (Sunstein and Zeckhauser 2011), it may be argued that risk constitution—including the scientific and technical capabilities by which risks can be known and controlled—should be debated on grounds of political, economic and cultural considerations. This does not mean science should not have a crucial role in risk regulation and constitution; rather, it means that the role and capacities of science have to be analyzed and valued according to the complex set of political, economic and cultural interests and concerns by which dangerous technologies are promoted and regulated.

But the extent to which more profound economic imperatives guiding techno-industrial innovations such as nanotechnology will be drastically revised remains doubtful. In spite of the application of precautionary policies (EC 2000), inclusive risk governance settings—where a fundamental differentiation between scientific and socio-economic criteria is established—(EC 2009), or broader frameworks for responsible science and technology such as RRI (EC 2013; von Schomberg 2013), the strong commitment of R&D policies in Europe—and around the world—will arguably continue to constrain alternative scenarios of socio-technical safety, assuming on principle that the risks of market-oriented technological developments in a context of global economic competitiveness are controllable and regulatable according to established normative safety narratives and criteria.

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