Chapter 2
Politics of Nanotechnologies in Food and Agriculture

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Abstract The chapter discusses the reasons for the delay in the regulatory intervention concerning nanotechnologies used in the agriculture and food sectors. The main finding is that unregulated introduction of nanoinnovation into the food system is due to the current neoliberal food policy and to the power struggles that characterize the economic, social and political dynamics within the global supply chain. Therefore, it is necessary to put the 'question concerning technology' at the center of the regulatory debate in order to implement a regulatory system able to face nanorisks. Which means looking at the way in which technology controls power relationships within society. Attention should be shifted from efficiency to power issues, and new technologies should be assessed from a political rather than an economic or ethical perspective.

Keywords Nanotechnology • Food • Agriculture • Power • Technological change • Critical theory

2.1 Introduction

Over the last twenty years nanotechnology has silently entered the agrifood sector. Currently, worldwide consumers buy a plethora of nanofoods, unaware of the (incorporated) new technologies that have been used to produce and distribute them. While in the late nineties scientists and businessmen engaged in nanoinnovation praised the wonders and the benefits of nanotechnologies to the general public, at the dawn of the new millennium a curtain of silence was slowly dropped over the topic. Meanwhile, countless testimonies were collected of possible risks associated with the new technologies (Nikodinovska et al. 2015) and a debate has grown, at

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food policy and regulatory bodies level, on the need for specific regulation as regards nanofood (Ngarize et al. 2013; Mbengue and Charles 2013; Marrani 2013; Ehnert 2015; Sodano et al. 2016). Notwithstanding the growing attention on the part of academics and policymakers, though still ignored by the mass media and the general public, almost no regulatory action has been taken so far. This paper investigates the reasons for such a delay in the regulatory intervention with respect to a technology that seems to pose serious risks to human health and the environment. The main argument of the paper is that the unregulated introduction of nanoinnovation into the food system is the result on the one hand of the current neoliberal food policy and, on the other hand, of the power struggles that at various levels and between various actors characterize the current economic, social and political dynamics within the global supply chain. In particular, the paper discusses how nanotechnologies represent a useful weapon for those corporations which are trying to take over the control of the global food chain. An important objective of the paper is to uncover the hidden socio-cultural and economic dynamics that prevent nanotechnologies from entering the food market in a safer and more democratic way, so as to spur on changes that can put science and technology at the service of society as a whole rather than at that of corporate power.

The paper is organized as follows. The first paragraph offers a brief picture of the current state of application and regulation of nanotechnologies within the agri-food sector. The presentation is very concise since a large body of literature (Bouwmeester et al. 2007; Sozer and Kokini 2009; Neethirajan and Jayas 2011; Weir et al. 2012; Cushen et al. 2012; Qureshi et al. 2012; Mura et al. 2013; Kumari and Yadav 2014; Handford et al. 2014; Rossi et al. 2014; Mihindukulasuriya and Lim 2014; Sabourin 2015; Hannon et al. 2015; Dasgupta et al. 2015; Ranjan et al. 2014; Bhagat et al. 2015) now exists from which the reader can draw more detailed information. The second paragraph describes how the weak regulatory effort can be explained as stemming from the neoliberal attitudes that have been shaping food policy worldwide for about thirty years. The third paragraph delves into the business practices that function as drivers of nanoinnovation. The final paragraph shows how different understandings of technical change can affect the perception and the assessment of benefits and costs of innovations and how the embracement of the idea of technological determinism is a further factor explaining the lack of nanofood regulation.

2.2 Nanofoods, Risks and Regulatory Frameworks

In this paper the term nanofood is used to encompass all nanotechnology applications in agriculture, feed and food sector. Nanofood refers to "food that has been cultivated, produced, processed or packaged using nanotechnology techniques or tools, or to which manufactured nanomaterials have been added" (Joseph and Morrison 2006). Throughout the paper when speaking of nanomaterial used in food production it is implicitly meant that the reference is to engineered nanomaterials, such as defined by Regulation EU N. 1169/2011 of 25 October 2011: "engineered nanomaterial means any intentionally produced material that has one or more dimensions of the order of 100 nm or less or that is composed of discrete functional parts, either internally or at the surface, many of which have one or more dimensions of the order of 100 nm or less, including structures, agglomerates or aggregates, which may have a size above the order of 100 nm but retain properties that are characteristic of the nanoscale".[1]

There are several feasible nanotechnology applications along the food supply chain (Handford et al. 2014), many of which are already on the market. In agriculture some examples are: nanoformulation of agrochemicals; nanosensors for the identification of plant diseases; nanodevices for genetic manipulation of plants; nanobiocides for animal breeding (Sekhon 2014; Kumari and Yadav 2014). In the food processing industry nanomaterials are used as: nanocapsules to improve dispersion, bioavailability and absorption of nutrients; nanomaterials as color and flavor enhancers; nanotubes and nanoparticles as gelation and anticaking agents; nanoparticles for selective binding and removal of chemicals and pathogens from food; antimicrobic and nonstick cookware. In food packaging nanomaterials are primarily used to impart antimicrobial function and to improve barrier and mechanical properties; applications include: quantum dots for traceability, nanoclays as gas barriers, carbon nanotubes to improve strengthening, ultraviolet light filters, nanosilver as an antimicrobial (Hannon et al. 2015).

Since companies are not required to declare the presence of nanomaterials in their products, it is difficult to estimate the actual use of nanotechnology in the food chain. A publication (Peters et al. 2014) of the European Food Safety Authority (EFSA) provides an inventory of current and potential future applications of nanotechnology in the agri/feed/food sector based mainly on the review of the related literature. The inventory reports the use of 55 types of nanomaterials and 14 types of applications. The reported nanomaterials are: nano-encapsulates, silver, titanium dioxide, nano- composite, zinc oxide, clay, synthetic amorphous silica, carbon nanotubes, silicon dioxide, gold, iron, nanosilver, copper, quantum dot, chitosan, fullerene, nisin, selenium. The applications include: pesticides, fertilizers, food additives, food contact materials, novel foods, flavoring, enzymes, supplements, food ingredients, feed additives (Dasgupta et al. 2017; Shukla et al. 2017; Walia et al. 2017; Balaji et al. 2017; Maddinedi et al. 2017; Sai et al. 2017; Ranjan and Chidambaram 2016; Janardan et al. 2016; Ranjan et al. 2016; Jain et al. 2016; Dasgupta et al. 2016). Figure 2.1 synthetizes the data for the main nanomaterials and field of application.

[1] This definition of engineered nanomaterial stems from the general definition of nanomaterial previously in 2011 by the European Commission, with the Recommendation on Definition of nanomaterial: «Nanomaterial means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1–100 nm. In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50% may be replaced by a threshold between 1 and 50%».

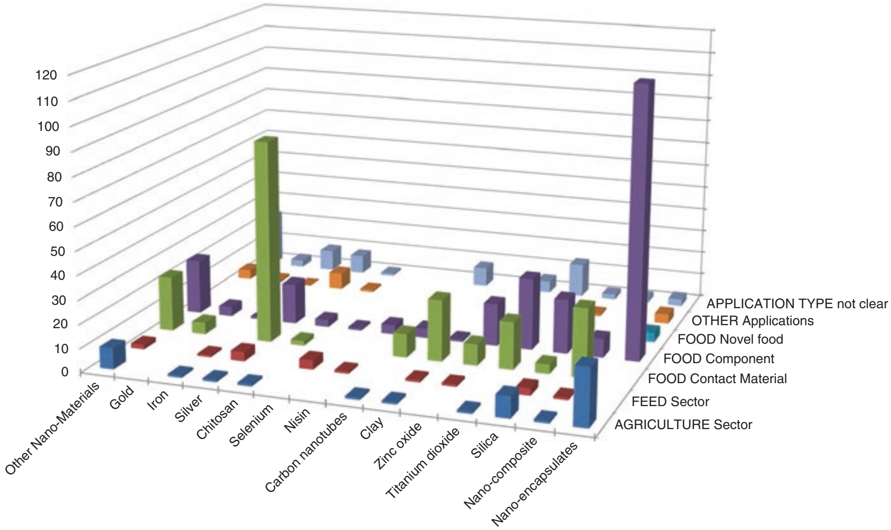

Fig. 2.1 Nanomaterials in current and future applications by type of applications and sector. Agriculture Sector include fertilizer and pesticide. Other Applications include biocide and veterinary drugs Application type not clear includes all applications without specified type. (Source: EFSA – Inventory of Nanomaterials: Current and future applications, 2014)

The EFSA inventory is rather inaccurate since it does not distinguish between feasible and actual (that is products that are already commercialized) nano applications. Information explicitly targeted to commercialized nanofoods is contained in the "interactive database of consumer food products containing nanomaterials" provided by the Center for Food Safety (CFS),[2] on the basis of various, rigorously quoted, sources of information. The CFS database includes: products claiming to contain nano; products positively tested for nano; products previously claiming to contain nano; Food and Drug Administration (FDA) approved additives believed to contain nano. For each product the type of nanomaterial, the country of origin, the product category, the commercial name and the producer/company are specified. Figure 2.2 reports the commercialized products for category and country of origin of the producer. Although the majority of the products belong to the categories of food supplements and food contact materials, it is worth noticing that many everyday food products sold by some of the most powerful corporations in the world (such as Nestlé, Kelloggs, Kraft food, Coca Cola, Unilever, General Mills) contain nanomaterials, generally for taste and flavor enhancement.

Nanotechnology application in the agro-food sector may produce many negative effects thus giving rise to various kinds of risks, such as health, environmental, economic, social and political risks. Health risks mainly depend on the ability of nanoparticles to bypass cellular membranes, to pass through biological barriers (as, for instance, the blood-brain barrier) and to bio-accumulate with severe toxicological

[2] Center for Food Safety (CFS) http://www.centerforfoodsafety.org/

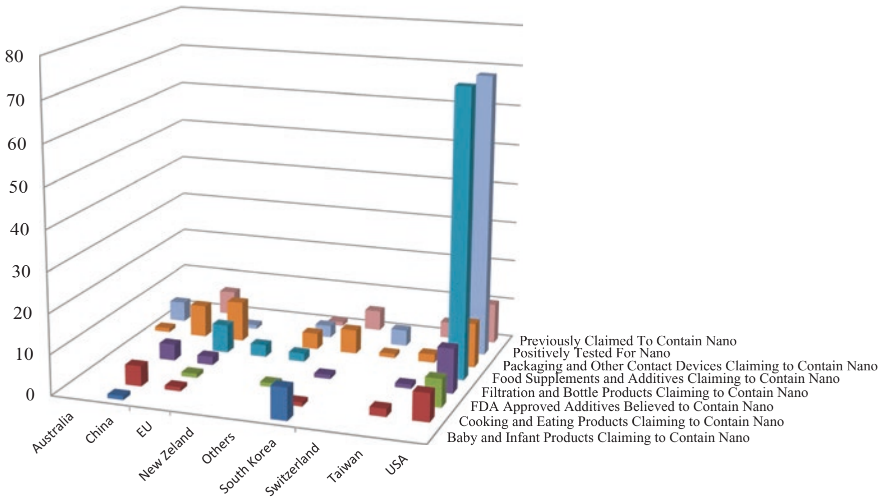

Fig. 2.2 Commercialized products for category and country of origin of the producer (Source: Center for Food Safety)

effects (Elsaesser and Howard 2012; Hubbs et al. 2013). Environmental risks are associated with the limited biodegradation of nanoparticles and their interaction with living organisms, soil and aquatic ecosystems. So far the following negative impacts have been reported: phytotoxicity, damage to soil structure and fertility, reduction of microbial biomass and diversity, toxicity for algae and daphnidis (Mueller and Nowac 2008). Economic risks arise from (Scrinis and Lyons 2007; Invernizzi et al. 2008; Miller and Scrinis 2011): (1) the possible disruption of markets (for those traditional products which are replaced by new nanoproducts); (2) the displacement of workers due to a more capital-intensive mode of production; (3) the further consolidation of food systems, with the largest corporations more able to exploit the profit streams from the patents on the new technologies. As regards socio-political risks, it has been argued that the proliferation of nanotechnologies in the food systems might exacerbate social injustice, deepen the North-South divide, and threaten the food sovereignty of local communities (Lyons et al. 2012). Finally, because nanotechnology is a dual-use technology (being developed for military as well as civilian purposes) there may be military and security risks, as in the possible case of nanofood being used to spread disease in scenarios such as war and terrorist attacks.

Despite the accelerated rate of innovation and the risks posed by new materials, nanofoods are still entering the market in a regulatory vacuum, and this in disregard of the many concerns raised by scientists and civil society (ETC Group 2010; Savolainen et al. 2010; Shatkin 2013; Takeuchi et al. 2014) So far, the choice of regulatory bodies all over the world has been to consider nanomaterials equivalent to their bulk form and as such not requiring specific provisions. The results of a 2015 overview (Amenta et al. 2015) of regulatory measures for nanomaterials in agri/feed/food in EU countries showed that EU and Switzerland were the only world regions where nano-specific provisions have been incorporated in legislation for agri/feed/food, which include specific information requirements for nanomaterials risk assessment and/or legally binding definitions of the term “nanomaterial”. Nevertheless, under closer scrutiny, apart from the effort to identify a standard definition of nanomaterials, even the EU has not yet set forth binding standards and regulations.

As regards the food sector, in the EU there are only a limited number of regulations which provide specific provisions for nanomaterials.[3] None of these interventions, however, set stringent inspection rules for the entry of new products into the market or for mandatory labeling. Overall, the choice of the European Commission seems to be to leave the sector completely unregulated and deprive consumers of the knowledge of the risks and the right to choose. In this regard, the story of Regulation (EU) No 1169/2011 on the provision of food information to consumers is emblematic. In its original form, this regulation contained an article (Article 18) stating that all food containing manufactured nanomaterials should be labeled accordingly. However, in 2013 the Commission submitted a proposal to amend this.

Regulation in order to eliminate the clause related to the mandatory labeling of nanomaterials, to “avoid confusion” among consumers. On February 2014, the Parliament approved a resolution rejecting the amendment, judging the Commission’s justification to be “erroneous and irrelevant”, but the Commission reiterated the amendment and the Regulation came into force in January 2015 without any provision on nano labeling.

2.3 Unregulated Nanofood: The Reasons of the Neoliberal State

The main response that states have given to civil society organizations concerned about the risks arising from nanofood is that there is still a lack of conclusive scientific evidence of the dangers of new technologies. As a matter of fact, currently there are many technical obstacles to carrying out a sound risk assessment for the novel nanomaterials (Elsaesser and Howard 2012; Shatkin 2013), since toxicological risk characterization is a challenging task. Nanomaterial characterization is difficult because of the multitude of variables in the parameter space, such as particle size, roughness, shape, charge, composition and surface coating. Exposure assessment, that is the estimate of how much of a nanomaterial comes into contact with humans, is also difficult to perform. The level of exposure depends on a variety of aspects (such as substance concentration, likelihood of contact, bioavailability) that are scarcely predictable in the case of nanomaterials, since there is still poor scientific knowledge of the way these materials behave when dispersed in the environment. Finally, estimation of nanoparticle “toxic dose” is complex, requiring a number of direct and/or indirect technologies to determine how many particles are reaching

[3] Namely: Reg. 1333/2008 on food additives; Reg. 1332/2008 on food enzymes, Reg. 450/2009 on active and intelligent materials and articles intended to come into contact with food; Reg. 10/2011 on food contact plastic materials; Reg. 1169/2011 on novel foods.

defined targets. Nevertheless, these difficulties, that somehow highlight the weakness of the science, should elicit more cautious stances on the part of the policy makers and should be an incentive for delaying the introduction of the new products into the market. In other words, they should not be an excuse for not regulating, but instead a strong incentive for higher standards, greater demands for toxicity tests on the firms and even moratoria, appealing to the precautionary principle. Therefore it is possible to argue that there is not an inability but rather an unwillingness to tackle nanofood risks. Such an unwillingness is the result of the economic policy approach embraced by many governments all over the world, which is neoliberalism (Sodano 2015; Sodano and Hingley 2016).

Neoliberalism is the new economic policy approach in liberal systems of modern capitalist societies, which has spread all over the world over the last 30 years. On theoretical grounds, neoliberalism is anchored in the political tradition of contractarianism and in neoclassical economic theory. Contractarianism, associated with Nozick's libertarian approach, states that a free society is one in which the state should have no power and duty other than that of securing private property rights and guaranteeing the proper functioning of markets. Neoclassical economics stresses that competitive markets are the best means to ensure an efficient resource allocation. On practical grounds, neoliberalism is a project aimed at the restoration of class power, where the capitalist class is eager to regain the economic and political power lost, to the benefit of middle and working classes, as a consequence of the welfare state policies carried out in three decades following the Second World War (Harvey 2005). In general, state intervention in the economy is warranted with reference to three goals: restore market efficiency; redistribute wealth to ensure social justice; protect citizens' health, and human rights and the environment (when the rights of future generations are taken into account based on sustainability principles). Given its theoretical stances, it is clear that a neoliberal state may pursue only the first objective and that, given its blind faith in the allocative efficiency of the market, only according to the Coase theorem (Coase 1960), that is tackling the inefficiencies due to public goods by assuring clear property rights (i.e privatization). No intervention instead is foreseen with respect to redistributive, health and sustainability goals. Moreover, a new goal arises in the neoliberal state: foster capital accumulation, i.e. a regressive wealth redistribution, transferring wealth from poor to rich people.

Table 2.1 synthetizes the effects of the endorsement of a neoliberal economic policy on the public management of the risks posed by nanofoods. The section a of the table shows how the choice under neoliberalism is to give up public regulation and promote private regulation instead, which gives corporations the power to set the institutional stage that best fits their vested interests. The securing of public research funds, the weakening of firms' liability with regards to nanofood adverse effects and the reinforcement of patent laws are the major consequences of such a choice, resulting in what I have called in the table "progress without people" using the title of a book which is a masterpiece in describing the role of state corporate power in the processes of technological innovation (Noble 1995). I will discuss the arguments developed by Noble with reference to nanofood innovation in the next

Table 2.1a How neoliberal policies affect nanofood regulation

Goals and related policy interventions in a neoliberal state	
Policy Goals allowed by neoliberalism	Restore market efficiency by establishing clear private property rights.
	Protect private property
	Foster capital accumulation.
Interventions	Deregulation.
	Substituting public regulation with private regulation (soft regulation).
	Privatization
	Tightening patent systems.
	Enforce private property rights.
	Promote innovation.
	Public funds to private research.
Effects on Nano innovation	Corporate lobbies setting regulatory rules.
	Low level of risk management and consumer protection.
	Science at the service of corporate profits.
	Innovation used as a competitive weapon.
	Abandonment of useful research patterns because not consistent with vested interests.
	In a nutshell: progress without people (Noble 1995).

Table 2.1b How neoliberalism prevents from tackling nanofood risks

Goals and policy interventions, consistent with nanofood risk effective management, which are not allowed in a neoliberal sates			
Policy Goals not allowed by neoliberalism	Fulfillment of human rights and sustainability	Economic justice	Global social justice
Entailed nanofood risks	Human health. Environment	Monopoly. Corporate power	Market disruption. Unemployment. North-South divide. Nanorisk dumping. Food sovereignty
(Not allowed) Interventions	Precautionary principle	Strong antitrust policy. Mandatory monitoring and reporting. Lobbying transparency	Trade policy
	Standard setting		Welfare policies (social security). International cooperation

paragraph of the paper. The second section of Table 2.1 calls attention to the goals excluded by neoliberal policies, showing how such excluded goals, and the related policy instruments, are the ones that would help tackle nanofood risks. The current regulatory framework in the EU, in the same way as in the United States and in most other countries, clearly reflects the outline sketched in the table. As a matter of fact, none of the regulatory interventions quoted among the "excluded interventions" in Table 2.1b have been implemented. The choice has been to set a plethora of non-binding suggestions and guidelines (that is soft regulation as quoted in Table 2.1a) and let the agribusiness, by endorsing the stakeholder approach in the regulatory decision processes, set the stage for future regulation. It has been pointed out (Bonnafous-Boucher and Porcher 2010; Sodano and Hingley 2016) how the consequence of soft regulation and the stakeholder approach has been the cooptation of the regulatory bodies by the most powerful stakeholders (namely agribusiness corporations), with the demission of democratic governmental regulatory institutions and the birth of a sort of corporatist state.

2.4 Unregulated Nanofood: The Reasons of the Agribusiness

Starting from the late seventies the agrifood sector has been affected by growing processes of consolidation and globalization. Currently, each stage of the food supply chain, from the agricultural input industry (seed, agrochemicals and agricultural machinery industry) to the food processing industry and retailing, presents a high rate of concentration, with huge corporations controlling large shares of the world market. In order to further accrue their market share and their profits, these corporations have to continuously gain competitive advantages over their competitors both at horizontal (i.e. towards firms operating in their same industry) and vertical level (i.e. towards firms operating in the other stages along the food supply chain). For example, a food manufacturer has to gain market share with respect to other food manufacturers but also has to gain bargaining power over its suppliers (for example, farmers supplying raw agricultural products) and its distributors (for example retailers) in order to appropriate larger shares of the added value of the entire food supply chain. The main source of competitive advantage is innovation, which allows the pursuit of cost reduction as well as differentiation strategies (Porter 1985). Nanotechnologies together with biotechnologies and information technologies are certainly among the most important sources of innovation within the food supply chain. Food nanoinnovations that have been introduced so far show how firms at any stage of the supply chain can benefit from them as a source of competitive advantage. Seed and agrochemical corporations are using nanoinnovations (nanoformulation of agrochemicals; nanosensors, nanobiocides and nanodevices for genetic manipulation) to complete the second green revolution initiated with seed bioengineering, and to make traditional farming techniques obsolete, further undermining peasant agriculture and agroecological practices. The processing industry is using nanoinnovation to carry out differentiation strategies to outperform competitors and exercise market power through price discrimination. Moreover, the focus on functional food is part of the attempt to change the attitudes of consumers towards high-tech food, overcoming their neophobia and increasing their trust in agribusiness. Modern retail can benefit from nanoinnovations in packaging and nanosensor, to extend shelf life and improve their logistics, lowering their distribution costs and snatching even more market share from traditional retailers.

A general outcome of nanoinnovation is to deepen the segmentation of the food market, starting from the breakdown of the market into four basic segments, namely:

low price/low quality industrialized products for the poor masses (a sort of huge junk food market), medium price/high tech food to capture the new induced needs of functional foods of low-medium income consumers; high quality "traditional/natural" food for high income consumers (this segment would capture what will remain of organic and/or local food and gourmet); high price/high tech/high quality foods for rich consumers. Such a segmentation would be consistent with the ever increasing polarization of wealth distribution produced by neoliberalism. As long as new tech food products require the joint effort of different actors along the supply chain (for example, new genetically engineered plants may be programmed to 'coordinate' with nanobiocides and/or the addition of supplements and/or better (nano) packaging to support longer shelf life and long distance transportation) besides horizontal consolidation, vertical consolidation processes may also occur, with the emergence of large conglomerates. Overall, nanoinnovations support and reinforce the techno-corporate agri-food paradigm (Scrinis and Lyons 2007) within the current neoliberal food regime (McMichael 2009). They serve, interalia, to change people's understanding of food and nutrition, separating ever-further the consumption from the production sphere (that is the notion of 'food from nowhere' introduced by: Bové and Dufour 2001, p. 55), severing the bond between nature and food, and accustoming the consumer to the new diets and lifestyles imposed by corporate marketing policies.

Given the many benefits corporations may have from nanoinnovation it is strikingly clear that they want to avoid any obstacle to the fast commercialization of nanofoods, and therefore oppose any form of intervention. Not only do they want to repeat the experience of the introduction of genetically modified organisms in the United States, where the dramatic diffusion of genetically modified crops has been made possible by choosing to consider them equivalent to their conventional counterparts, moreover they want people to remain completely unaware of the new technologies, in such a way as to avoid raising concerns and requests for regulation (as it has been from the beginning in the case of genetically modified organisms in the EU and successively of their diffusion in the US). It is not by chance that after the triumphant announcements of the first nano-innovations, a deafening silence has fallen over the nanofoods that have been rather constantly placed on the market. It is also not by chance that in almost every article addressing the issue of nanofood regulation, it is stressed that it is better (it is implicit on the part of governments and scientists) not to make too much noise about nanorisks, in order to avoid any controversy as to the social desirability of the new technology and prevent the request for regulation and mandatory labeling from coming from citizens who want to defend their right to know. A further motivation for firms to have nanofoods unregulated might depend on the difficulties encountered in clearly defining the private intellectual property rights (IPRs) of the new products. The patent regime for nanotechnologies faces some challenges. Notwithstanding the fact that a high number of nano-patents already exist worldwide (with the primacy of the USA, followed by Japan, Germany and China), there are some unsolved legal issues concerning the consistency among the patent systems of different countries and the verifiability and the acceptability of the claims contained in patent requests. Many nano-applications rely on nanotechnologies already patented and which have a necessary enabling function with respect to a wide array of nanoapplications. There are few nanotechnologies that are critical research tools for the development of further innovation (Barpujari 2010). The majority of these key patents are owned by the public sector, and in particular by the US universities which have benefited from the huge amount of public funds devoted to nanotechnologies in the US. The choice of these universities so far has been to exclusively license their discoveries to the industry, so that a handful of mostly USA companies currently have the control of large swathes of the new technologies. Given the still blurred system of intellectual property rights for nanotechnologies, it might be the case for firms selling nanofood to protect their innovation through trademark and industrial secrets, and therefore have no incentives to give clear information (including nano-labels) on their nanoproducts. Meanwhile, they can work behind the scenes in such a way as to gain future control (through patents of key enabling technologies and systems of licenses) of the most profitable nanotechnologies. The strategy of open innovation (Huizingh 2010; Duarte and Sarkar 2011) that has until now been embraced by many companies also makes the use of trademarks and industrial secrets more appropriate ways to protect their innovative products.

2.5 Unregulated Nanofood: Nano-innovation Backed by the Techno-scientific Ideology

Neoliberal policies and firms' strategies are strong drivers of the current unregulated nanofood development. Nonetheless, there is another important factor which is helping the relentless advance of the new technologies, namely the notion of technological determinism, and the generally accepted idea of technological change as an engine of progress.

The notion of technological determinism is grounded on the idea of autonomy and neutrality of science and technology. Autonomy means that scientific knowledge, and the subsequent technological innovations, proceed independently from the other forces that shape societies, such as norms, beliefs, political and ethical issues. They proceed as autonomous forces and intellectual enterprises, guided by an innate unbounded and value-free human rationality. Science and technologies shape society, triggering processes of modernization and progress, but are not themselves influenced by society.

Neutrality means that science and technology are not affected by any value judgement concerning the goals of society; neutrality also means that science and technology have no preferences as to the various possible uses to which they can be put (Feenberg 2002). As such, social changes are deterministically caused by science and technology, the latter viewed as autonomous forces of social progress. The notion of technological determinism dates back to the European Enlightenment of the eighteenth century when the traditional conception of society, where social institutions and beliefs were justified by taking for granted myths and customs, was substituted by the modern conception, where customs and institution were justified on the basis of an instrumental human rationality. Later, in the nineteenth century, it became commonplace to view modernity as an unending progress towards the fulfillment of human needs through technological advance. A consequence of the endorsement of technological determinism is that technical change, even when it entails high social and environmental costs, must never be delayed. At the dawn of the early industrial revolution the notion fueled the faith in progress, which in turn fueled the industrialization of western economies and capitalistic accumulation.

Precisely the negative consequences of the industrial revolution, despite the protests by the social classes adversely affected by industrialization, fed the rise of critical theory of technological change in the first half of the twentieth century. One of the manifestoes of the Frankfurt school of social theory, Adorno and Hokheimer's classic Dialectic of Enlightenment, explored the intertwining of the domination of nature, psychological repression, and social power. This work opened new perspectives in the study of the authority system of advanced society, on the technologies that integrate it, and on the forms of social struggle that resist its hegemony (Feenberg 2002, 2005). Central to the critical theory is the view that technical change is the product of the pursuit of its own interest by some group in society (generally the dominant class) who chooses, from among different feasible technological paths, the ones that better fit their personal goals. In this sense, science and technological systems are neither autonomous nor neutral, rather they are spheres of human activity embedded in the general social structure which shapes (and is shaped by) them. In other words, technologies develop in predetermined directions and determine social change (MacKenzie and Wajcman 1999). In the last thirty years of the twentieth century, the critical theory paved the way for a large body of technology studies that rejected the notion of technological determinism. Particularly successful was the constructivist theory, with the adoption of Thomas Hughes' notion of sociotechnical (1986) and the actor network theory of Bruno Latour. The main argument of the constructivist technology studies is that those who design technologies are by the same token 'designing society' (Latour 1988, 1992).

As regards economic science, the neoclassical theory embraced from its very beginning a deterministic stance. In the neoclassical model, science and technology are spheres separated from the economic activity; technology is an exogenous variable which is not explained by the behaviors of economic actors. Only after the work of Schumpeter has an economics of innovation been developed, embracing a large array of research themes, such as the study of firms' research and development policies, the development of technological systems, the dynamics of innovation, the study of public research policy and so on. However, it is important to stress that most economic literature only partially overcomes the notion of economic determinism. On the one hand, it acknowledges the embeddedness of the technoscience in the larger socioeconomic system and the influence that firms' strategies and public policy may have on research and innovation patterns, thus questioning the autonomy of technology. On the other hand, it does dispute the principle of neutrality, but from the point of view of substantivism, which argues that technology is a

Table 2.2 Alternative theories of technical change and economic and political thoughts

Technology is:	Autonomous	Not autonomous, human controlled
Neutral (complete separation of means and ends)	**Technological determinism**	**Instrumentalism (liberal faith in progress)**
	Modernization theory; neoclassical economics; traditional Marxism.Neoliberalism	*Liberal political thought; management studies; constructivism.Neoliberalism*
Not neutral. Value laden (means for way of life that includes ends)	**Substantivism (means and ends linked in systems)**	**Critical theory (choice of alternative means-ends systems)**
	Economic neo-institutionalism; evolutionary economics	*Technological change is power driven*

Source adapted from Quan-Haasen (2013)

force of its own that determines what our society will be like, on the basis of its own values (good or bad) which people cannot control. Therefore, technology itself determines how it will be used and towards what ends, but it moves autonomously along its own path and people have little influence on its socio-economic and political impacts. In short, economics either assumes that technology is autonomous and neutral, or it removes the two elements of the notion of technological determinism one at a time.

Table 2.2 reassumes the different conceptions of technical change on the basis of the endorsement of the two elements of technological determinism (i.e. autonomy and neutrality); for each of the four identified approaches (technological determinism, instrumentalism, substantivism and critical theory), some economic and political theories embracing them are mentioned. It is worth noticing that none of the most popular theories (within the orthodox, but also within the heterodox theories) simultaneously dispute autonomy and neutrality of technology. Only the critical theory fully challenges the notion of technological determinism; nevertheless, the dominant schools of political, social and economic thought do not endorse critical theory and, as a consequence, lose sight of power and class domination in the technological discourse. It is also worth noticing the position of neoliberalism which never questions the neutrality of technology, but is more flexible on the autonomy assumption, accepting that technological innovation can and ought to be financed and supported by the public and the private sector, on the basis of faith in progress, i.e. the assumption that technological change is always beneficial.

Technological determinism has been the best ally of the capitalist class since the early phases of the industrial revolution. In his books, Noble (1995) has masterly shown how the social negative impacts, in terms of labor displacement, unemployment and environmental and health effects, of the mechanical and chemical innovations throughout the nineteenth and twentieth century have been dismissed as trivial side effects by appealing to an almost religious commonly shared faith in progress. As pointed out by Noble, since the time of the Enlightenment, "science had come to be identified with transcendence, on the basis of the inheritance of the new medieval view of technology as a means of recovering mankind's original perfection"4[4] (Noble 1997, p.26). The faith in technology and faith in progress ideology served the dominant classes to create social consensus for the violent repression of riots against those new technologies, as in the case of the Luddites, or in the case of the Swing riots of the 1930s caused by the introduction of threshing machines. The true fact is that workers opposing the new machineries "were not against technology, rather they were against the efforts of capital, which was using technology as a vehicle, to restructure social relations and the patterns of production at their expense" (Noble 1995, p. 7).

Since the first industrial revolution until today, the notion of technological determinism has allowed capital to impose any technological change functional to the mere pursuit of profit. Nevertheless, in the first three decades after World War II, thanks in part to the critical theory and in part to the advent of the welfare state, the idea arose of the need for state intervention in order to direct scientific research towards goals of social justice and to mitigate the socially undesirable effects of new technologies. The victories achieved by labor unions and environmental movements in those years bear witness to this momentary rift of the notion of technological determinism. The raise of neoliberalism at the end of the seventies gave renewed strength to the notion of technological determinism leading to the establishment of the techno-scientific ideology (Levidow et al. 2012; Hess 2012), which preaches the ability of scientific knowledge to solve any problem of human societies, and pledges the ethical and political neutrality of science (and scientists). Such an ideology is used by business to impose their technological choices and to capture state regulatory and public research institutions in order to shape the institutional framework in such a way as to serve business interests.

The way in which the issue of nanotechnology regulation has been framed so far is an outstanding example of how the notion of technological determinism has given support to the new power relationships established by neoliberalism. Three elements in particular of the nanoregulation framing strategy, which is outlined in the majority of public documents and academic literature dealing with the issue of nanoregulation, help clarify this point.

The first element is the common stated presumption that scientific knowledge and technology can definitively solve the most important social problems (this is the myth of technological salvation, which is part of the faith in progress credence). The following statement opening a Communication of the European Commission on the Second Regulatory Review on Nanomaterials provides an insightful example; "the benefits of nanomaterials range from saving lives, breakthroughs enabling new applications or reducing the environmental impacts to improving the function of

[4] And Noble makes clear that the term mankind referred literally only to men, since the religion of technology was part of the myth of a masculine millennium, which served to shape the hierarchical organizational structures, in the economy and in society, and the mode of exploitation which formed the backbone of the processes of capitalistic accumulation (Noble 1995, ch. 7).

everyday commodity products".[5] Another example is the following statement from The OECD Working Party on Nanotechnology[6]: "Nanotechnologies are likely to offer a wide range of benefits, including in helping address a range of societal and environmental challenges, e.g. in providing renewable energy and clean water, and in improving health and longevity, as well as the environment".[7] Similar statements can be found in FAO documents: "nanotechnology offers considerable opportunities for the development of innovative products and applications for agriculture, water treatment and food production, processing, preservation and packaging, and its use may benefit farmers, the food industry and consumers alike" (FAO 2014).

Linked to the first is the second element which bears witness to the endorsement of technological determinism in the nanoregulation issue: the emphasis on risks when making judgments on the social desirability of the technology. The emphasis on risk reinforces the assumption of the indisputable benefits; the clear message is that we must not question 'whether or not" or 'for the benefit of whom' the new products have to enter the market, rather 'how' to deal with the associated risks. "For critics (Felt and Wynne 2007), framing technoscience issues in terms of risk means pre-empting any possible debate on the need and desirability of innovation, or its distributional effects. The assumption is that the benefits of innovation are unquestionable and general" (Pellinzzoni 2012). Moreover, besides shifting the discourse from assessing the benefits to dealing with risks, the issue of risk is understood in terms of risk perception. In this view, the real social issue associated with nanotechnologies is the fear and anxiety that their unknown health and environmental effects may raise, with people's concerns framed as inability to rationally understand science and technology. In such a way any skepticism about the new technologies is delegitimized and risk management intervention ends up being directed towards communication policies aimed at increasing consumers' willingness to take risks rather than protect them from hazardous products; the principal public intervention is therefore directed at increasing their social acceptance (Vanclay et al. 2013).

The third element of the nanoregulatory strategy which is strictly linked to the embracement of technological determinism is the shift from political to ethical discourse. Since the social benefits of the new technologies are certain and unquestionable, there may not be political conflicts about technology but only divergent ethical stances. When any resistance is viewed as consequence of the possible diverse ethical instances present in society, the role of the state is to smooth these divergences through various forms of governance under the guidance of experts in the field of ethics. The centrality of ethics in state regulatory activities has been associated with the spread of a flexible way of governing without law and have been indicated as

[5] Communication from the Commission to the European Parliament, the Council and the European Economic and social Committee. Second Regulatory Review on Nanomaterials (2012) {SWD(2012) 288 final}.

[6] https://www.oecd.org/sti/nano/oecdworkingpartyonnanotechnologywpnvisionstatement.htm.

[7] However, unlocking this potential will require a responsible and co-coordinated approach to ensure that potential challenges are being addressed at the same time as the technology is developing. The OECD Working Party on Nanotechnology.

'ethical legislation' in many EU policy documents (Felt and Wynne 2007). Ethical councils and participatory discussion settings led by experts are outstanding examples of such forms of intervention. Ethical councils are made up of appointed 'experts', allegedly capable of representing relevant viewpoints and concerns, or, in the case of public citizen dialogues, to interpret inputs from, and give proper guidance to, the reflections of 'lay' people. For critics, ethical councils are used to marginalizing non-negotiable standpoints (i.e. political struggles) as regards new technologies, by stigmatizing them as ignorance or prejudice. Ethics is presented as a neutral technique capable of producing 'a single, correct solution for each ethical problem and therefore ethics councils may be depicted as 'a "neutral" normative tool. Ethics, in other words, is framed as the equivalent in the normative realm of the function that 'sound science' performs in the realm of facts (Pellinzoni 2012, pp. 262–263). As a consequence, the legislative activity is severed from its linkages with politics and finds its new foundation in ethics, with the latter moreover assuming the character of an exact science. Such an alliance between science and ethics serves to further shrink the room for political and distributive questions about technological innovation and dramatically reinforce the ideology of technological determinism.

2.6 Conclusion

The way in which the issue of nanotechnology regulation has been dealt with so far by national and international regulatory bodies is at the same time grotesque and deceitful. The unanimous agreement on the possible risks of new technologies and on the need for their regulation, emerged in the countless reports and discussion forum on the subject, has been accompanied by an almost complete legislative inaction. With respect to the food and agricultural sectors, this state of affairs is well portrayed in the FAO/WHO technical report (FAO 2014) on the 'state of the art on the initiatives and activities relevant to risk assessment and risk management of nanotechnologies in the food and agriculture sectors'. Here the call for an international coordinated effort to face food nanorisk is not supported by real action programs and strong request of commitment to governments.

The paper has investigated the causes of such a paradoxical situation, with a focus on the political besides the technical reasons beyond the regulatory paralysis. Three main reasons have been discussed. First, the attitudes of the neoliberal state, which praises deregulation and the primacy of the economic over social and political spheres. Second, the lobbying activities of the business sector which wants to be free to use the new technologies, whatever their health and environmental negative impacts, for its profit seeking strategies. Third, the dominance of a techno-scientific ideology which, by praising the idea of technological determinism, helps to remove the technology question from public debate, namely the problem of the social and political effects of technological change. Together these three driving forces are contributing not only to the regulatory delay, but also to a subtle communication campaign directed at accommodating consumers' attitudes in such a way as to accept nanofoods and the related risks.

Nanotechnologies in the agri-food sector, also combined with biotechnologies, may dramatically change the way we conceive food and nutrition and may have unexpected negative effects on our lives. Main risks are associated with adverse health and environmental effects, but also with the restructuring of the food system in a way which, by further strengthening corporate power, weakens people's control over the food they grow and eat. Nanotechnologies are a core engine of the techno-corporate agri-food paradigm (Scrinis and Lyons 2007), leading to an increasingly globalized, export-oriented and corporate-dominated food system; a system which jeopardizes food sovereignty, local food diversity and democracy (Windfuhr and Jonsen 2005). The findings of the paper show that in order to oppose such a system it is necessary to put at the center of the regulatory debate the "question concerning technology", that is to look at the way in which technology affects power relationships within society. What is needed is to shift attention from efficiency to power issues and assess new technologies from a political rather than an economic or ethical perspective. The assumption of technology determinism should be avoided in order to reassert the fact that technology is a means to an end and that it is a human tool; as such, it is used to pursue the individual goals of those who control technology. Nanofood regulation should be tailored with the aim, above all, to socialize and democratize processes of technological changes, by ensuring that technology is not mostly privately owned and that all those affected by technology have their voices heard in the processes of technological change.

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