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Emerging technologies and waiting games:

Institutional entrepreneurs around nanotechnology in the food packaging sector

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Abstract

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

1 Introduction

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

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

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

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

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

technologies, through reducing uncertainties.

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

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

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

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

2 Distributed institutional entrepreneurship and sectoral changes

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

2.1 Distribution of institutional entrepreneurship in a sector

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

Studies in the literature have analyzed institutional entrepreneurship as a phenomenon in its own right, rather

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

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

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

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

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

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

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

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

2.2 Sectoral changes associated with emerging technologies

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

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

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

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

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

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

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

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

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

2.3 Real time analysis of sectoral developments and institutional entrepreneurship

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

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

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

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

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

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

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

3 The domain: nanotechnologies & the food packaging sector

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

3.1 Nano enabled food packaging technologies

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

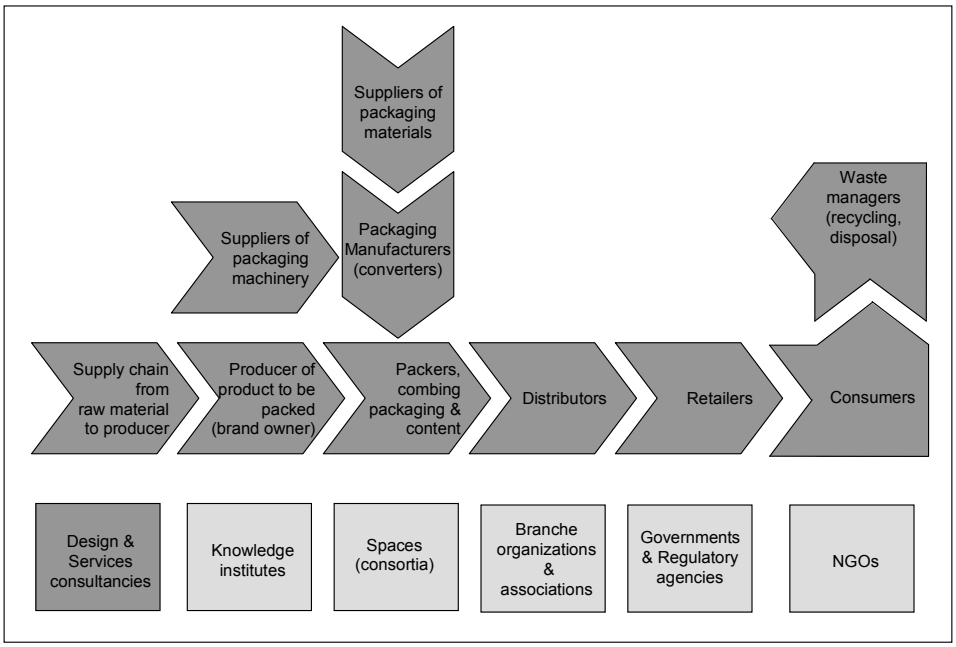
As to the distribution of firm size, large firms can be found, although not exclusively, at the beginning and end of the food packaging chain: Large packaging material suppliers, big food production companies (brand owners) who 'fill' the packages and at the other end, large retail chains, which can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

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

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

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

Table 1: Players in the food packaging sector



hesitant to initiate activities to introduce such packaging materials.

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

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

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

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

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

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

Table 1: Overview and characterization of distributed institutional entrepreneurs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.3 Third round of initiatives: resolving the impasse

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

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

One such initiative explicitly aiming to address the general impasse is the institutional entrepreneurship activity of DuPont together with Environmental Defense. Already in 2005, DuPont and Environmental Defense published an article, which discussed the need for more research and regulatory practices related to potential risks of nanotechnologies (Krupp/Holliday 2007). They compared nanotechnologies with earlier emerging technologies, which had unintended effects,

such as the impact of the release of CFCs on the ozone layer. In their advocacy piece they argued that early assessment of possible risks and enactment of safety standards can "reap the benefits while minimizing the risks." DuPont and Environmental Defense called for 'a collaborative effort' between firms, academia, governments and public interest groups that "could set interim standards for nanotechnology around the world while regulations are under development." Later, their 'collaborative effort' would meet resistance by NGOs, exactly because of the 'interim' character of their approach (Civil Society-Labor Coalition 2007).

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

Governmental authorities also became entrepreneurial by trying to resolve the impasse through voluntary measures rather than top-down policy making. The Department for Environment, Food and Rural Affairs (DEFRA) in the UK was pro-active concerning the uncertainties associated with health and environmental safety issues of nanomaterials (including packaging), through launching a voluntary reporting scheme.[21]

The occasion was provided by the UK Food Standards Agency (FSA) 2006 Report, which argued that although there were no major gaps in regulations, there nevertheless existed gaps with respect to risk assessment and information of manufactured nanotechnology products (Food Standards Agency 2006). Following the FSA, DEFRA launched a voluntary scheme in September 2006, a form of 'soft law' (Dorbeck-Jung 2007), to provide the UK government with information on properties and characteristics of new 'free' nano-engineered materials. In particularly it was expected to generate information to test existing regulatory measures. In this way, UK DEFRA aimed to bridge the gap between firms and regulators, with respect to uncertainties related to compliance with regulations. Responses to the scheme were relatively low and UK DEFRA had to put effort in getting responses. In March 2008 the UK Minister for Environment concluded that responses were disappointing and urged firms and researchers to commit to the scheme. The UK Minister hinted that more compulsory measures would be necessary when there was too little commitment to the scheme (Woolas 2008).[22]

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

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

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

[23] See also (Bowman/Hodge 2008).

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

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

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

4.4 Exploring future developments in the food packaging sector

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

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

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

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

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

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

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

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

5 Conclusions

Through the lens of tracing institutional entrepreneurs and their activities, I was able to show a pattern of development in the food packaging sector where rules and practices emerged before the envisaged nano-enabled technologies entered the market. Anticipation on eventual embedding of these technologies drove the institutional entrepreneurs. Over time, further aspects of eventual embedding became important, and other kinds of institutional entrepreneurs became involved, including NGOs and regulatory agencies introducing voluntary schemes. The net effect is the emergence of a patchwork of rules

and practices which extend further than industry structures as traditionally conceived. It is this patchwork which will act as a 'soft' framing condition for further developments in the uptake and embedding of nanotechnologies in the food packaging sector.

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

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

The nature of the reduction of uncertainties between supply and demand, and with respect to regulation up to broader societal acceptance will depend on the composition of the value chain and articulation of regulations (formal and informal) at the level of a sector. In the case of food packaging, intersecting value chains introduced specific complexities and uncertainties (such as the world of food, sensitive to public acceptance). In other sectors, such as micro/nano-electronics, public acceptance is not a prominent issue. For new nano-enabled materials and surfaces, there appears to be broad public acceptance, but some consideration of risk, with reference to nano-particles. Particularly important, given the enabling character of nanotechnologies, is that intersecting value chains will occur more often, as with nano-engineered delivery systems for pharmaceuticals (drugs) and nutriceuticals (food). Preliminary data of my ongoing research in the drug delivery sector show a first wave of institutional entrepreneurship to promote and legitimize a link

between the promise and possible use, but no second wave (yet).

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

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

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