Case Study:

Risk governance of food supply chains

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August 2012

This paper was prepared for the International Risk Governance Council (IRGC), as part of project work on Public Sector Governance of Emerging Risks

1. Introduction

Food supply disruptions, whether due to natural calamities or human action, have been widely reported on in the media. Various business literature has noted the increased vulnerability to such shocks due to deepening dependency on globally dispersed food chains. The ongoing trend to seek efficiencies means a reduction of 'system slack' and counteracts a chain-wide risk culture. Government interventions in response to shocks can have a considerable effect on market dynamics elsewhere in an interdependent global food market.

Various disasters, but especially the 2008 price explosion have moved transboundary food supply up the national policy agendas. The Dutch, UK, Australian and other governments have recently commissioned policy advice on the consequences of food supply disruptions at the national or international level. While on the whole scenario studies of disruptions have been somewhat reassuring, international food crises or price peaks may still occur, and some countries, such as the Middle East and North African countries are quite vulnerable (Wright and Cafiero 2010). Moreover, poor coordination and effectiveness has so far prevented a focused all-out response to food crises for famine-prone areas in Africa (Burger *et al.* 2010).

Much attention in food supply chains in richer countries has gone to food quality issues and, after 9/11, food security in the sense of safeguarding the quality of the supply. Quantitative risks have been downplayed until recently. Yet, these risks, combined with those related to the changing structure of the many food supply chains warrant a renewed look at the role that governments can play.

In this paper we investigate the risks, the likely private-sector responses to these risks, and the remaining risks that call for public action. We characterize the food supply chains as complex systems, and interpret the roles played by the agents involved within this framework. To highlight these roles, we draw a parallel with the governance of water quality and quantity in transboundary water flows.

Background

Globalization has increased trade, both in absolute terms and in relation to consumption and production, or to Gross Domestic Product. Trade in agricultural products has increased too, but for large countries, such as the EU and the USA, the degree of self-sufficiency, production divided by consumption, has not diminished over time. The EU has a high degree of self-sufficiency and meets close to 100% of its consumption from domestic production.

The traditional effect of liberalized international trade - specialization of countries in production and export of those goods in which it has a comparative advantage or in which it can realize economies of scale – is not observed for agricultural commodities. This is partly due to trade restrictions that are still in place for these products. Other causes can be the lack of economies of scale in agricultural production, or the rather large transport costs that, even though these have fallen over time, still make it worthwhile to produce food close to where it is consumed.

These aggregate figures however obscure a tendency towards globalization of particular food items. The overall trend towards sales of processed food products implies that manufacturing of food products has increased relative to agricultural production. In this process ingredients are used that are sourced worldwide and, even though these ingredients do not add up to much in volume terms, they link domestic food consumption to production in many parts of the world. Similarly, trade in feed has increased relative to production of meat, and also relative to production of feed.

These developments have implications for the exposure to risks in food supply. At the country level, an increased regional specialization in agricultural production as a result of liberalized world trade would have exposed consumers to new risks, in that their food supply would depend on other countries' policies, currencies and trade-links with their own country. A harvest failure in any of the specialized producing countries would have more severe repercussions for the consumers than they were in the past. This fear is generally unwarranted, as data and simulations of global models for world trade under liberalized scenarios and even under various climate-change scenarios, do not show large regions such as the EU to become more exposed to specific producing countries for their overall food provision (Bindraban *et al.,* 2009).

The trend toward more processed food, and the use of worldwide sourced ingredients for it, however, makes certain food products more dependent on other countries than hitherto was the case. The same holds for feed: whereas the EU is more than self-sufficient in grains and meat, it imports almost all of the proteins that are fed to the animals that provide the meat.

Production of meat in the EU has become more exposed to changes in conditions elsewhere and this implies an exposure to risks that is different from the past. Within the EU, there are still large differences in this exposure: whereas meat producers in the Netherlands, Germany and Denmark import large amounts of feed, meat producers elsewhere in the EU rely more on domestically produced feed, or even self-produced feed. Hence the exposure to risks differs.

While the policy induced liberalisation of world trade has not led to major shifts in the production of food, feed and livestock products, it has enabled the food industry to source globally and thereby better serve the consumer's desire for novel and ready products.

The new risks this brings about, and how to deal with these, are the topics of this paper. Risks are seen as the probability of detrimental outcomes for the firms. The more probable and the more detrimental these outcomes, the higher the risk.

Our approach is to investigate the risks encountered in supply chains, and the private sector's responses to these risks, before elaborating on the need for government actions. If we better understand the workings of distribution strategies, better government intervention is possible (Lederman *et al.* 2009). Discussing market failures presupposes objectives against which failure is measured. Craighead (2007) finds an inconsistency between government objectives of risk management and industry capabilities; the objectives are not the same. Lean-production and niche strategies are at right angles to the need for 'slack', exemplified by redundancy, excess capacity, generalist expertise and multiple entryways (and exits) in a system leaving the possibility to 'divert your supply chain through another vein while you recover.' Also disruptions in critical nodes, such as distribution centres, have critical effects on supply, especially in retail, a high-volume, low-margin business.

The World Bank identifies three types of flows in supply chains; physical flows, information flows and financial flows. Each of these flows may encounter choke points, and have their own types of risks and ways of diverting and spreading risks. Only when information on probabilities and expected losses is available, risks are insurable – otherwise, other forms of risk absorption need to be found elsewhere in the networks that form the backbone of the system. As networks have both productive and relational ties, steering can seek to affect not only price, quality and quantity but also trust and reputation (e.g. Gereffi *et al.,* 2005).

The next section elaborates on the risks in (international) food supply chains and addresses the question of relevant distinctions of risks. We settle for a distinction into qualitative risks (including food safety issues) and quantitative risks that are linked to supply disruptions. In sections 2a and 2b we discuss these two types of risk as advocated in the literature. Under 2b, we sketch the possibilities of these

quantitative risks using the case of soybean supply to the EU. In section 2c the risks at a more aggregate level are discussed, including any externalities of firm level handling of risks.

Section 3 then dwells upon the managerial responses to these risks, *ex-ante* and *ex-post*. Responses are made by firms, governments and other stakeholders, and can work out differently at the aggregate level of the sector. This we see as an emerging risk.

In section 4 we discuss the types of governance that are conducive to dealing with risks, including those at the sector level, again distinguishing qualitative and quantitative risks.

Section 5 concludes the analysis.

2. Risks in international food and feed supply chains

Supply chain risks are manifold and impossible to pinpoint precisely because of their unpredictable nature. There are risks in customers, prices, transport, processing, administration, finance, human resources, suppliers, input prices etc. and firms must cope with them. To prepare for this coping, some classification of risks is useful. An empirically founded classification comes from Svensson (2000) who divided the risks encountered by (Swedish) manufacturers into two sources: atomistic (a single source that can be directly addressed) and holistic (possibly multiple or less easily reached sources of disturbance) and two categories: quantitative and qualitative. Almost all disturbances found in his survey were located in the quantitative category, and of these, a majority in the atomistic source.

Wagner and Bode (2008) divided supply-chain risk sources into supply and demand and three other sources: regulatory, infrastructure and catastrophic. The first two are typically within the reach of a company's staff as they interact on a daily basis with customers and suppliers. Yet, sources of disturbances can be further downstream and disturbances in their behaviour can reach the firm strongly if shocks are multiplied (bullwhip effect). Or the source can be further upstream in which case it depends on the supplier's position and behaviour whether the disturbance reaches the firm. Quality problems are typically on the supply side. The other sources of disturbance lie outside the direct supply chain and are governed by public authorities (regulation, infrastructure, and responses to catastrophes). They found empirically that performance of the firms is related to the disturbances in the first two sources, but not in the last three. Performance is measured using scores on dependability and speed of delivery, order fill capacity and customer satisfaction.

For the food sector it is natural to distinguish quality as a possible source of disturbances. A great deal of attention is directed to maintaining quality standards, especially where these mitigate potential risks of food-borne diseases. The other dimension, quantitative disturbances, is less often emphasized where studies of the food supply chain are made. We follow Dani and Deep (2011) in this distinction. They derive processes in response to a negative shock that differ for qualitative and quantitative shocks. For the latter type, it is typically private sector actions that are required, and leadership of private agents that make this work; for the qualitative shocks, regulatory and government authorities are typically of great importance too.

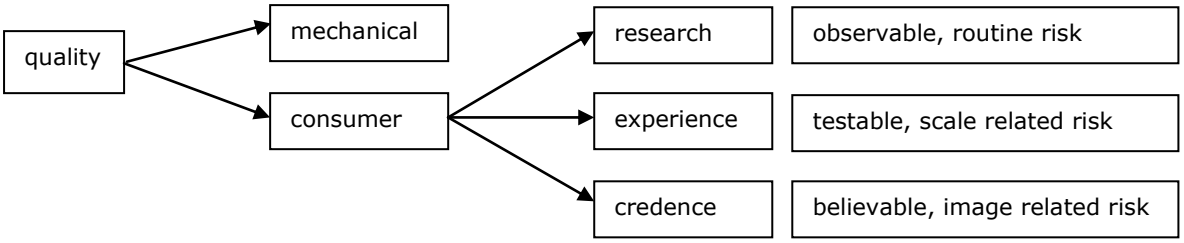
This differential governance of how to deal with quality and quantity shocks applies to rich countries. In poorer countries, the focus of governments is often on the quantitative risk, securing food supply, and they tend to devote less resources to quality issues. In this sense, the change in governance of the food supply chains from the state to the private sector, that is observed to have taken place in rich countries over the past decades (Lee and Marsden 2009) reflects not only the changes in political preference, and entrepreneurial capabilities, but also a decrease in risks related to quantitative shocks. A stronger role for the government as to quality control tilts the balance between state and private sector again towards the state. We shall elaborate on the qualitative and quantitative risks in the next sections. The focus is on the rich country case.

2.1 Qualitative disturbances

Food quality can be divided into, say, mechanical qualities and consumer qualities. Mechanical qualities are those characteristics that affect shelf life of products, including resistance to outside forces (high/low temperatures, humidity, shocks…). These qualities enhance the saleability of products, facilitate storage and make the products more attractive to the sellers. Consumer qualities make them more attractive to buyers: food safety characteristics, but also attributed qualities such as the product being special/ordinary, modern/traditional, sustainable/disposable etc. A common distinction in qualities is into *search*, *experience* and *credence* attributes, referring to directly visible, indirectly observable and not observable attributes (cf. Ponte & Gibbon, 2005). Health issues can be ranked in the second category.

These quality attributes of the final consumer goods, both mechanical and consumer quality attributes) are dependent on the qualities of the intermediate products (and processes) that lead up to these final goods. Disturbances in these qualities may occur anywhere from original producers to final retailer and this necessitates coordination of information throughout the supply chain.

The most conspicuous consumer quality attributes are related to health risks. Notable cases of BSE in England (Cleeland, 2009), EHEC in Germany (Fidler, 2011) and melamine in China (IRGC, 2010a) involved the loss of many lives. Dioxin contamination of pork occurred in Belgium in 1999 (Bernard *et al*., 1999), Ireland in 2008 (Tlustos *et al*., 2012) and Germany in 2011 (CMAJ, 2011). A common factor in these cases is that the cause was a minor ingredient in the feed or food that was consumed. These ingredients were not easily traced. The starting point for the inquiry was at the consumer end or, in most dioxin cases, at the intermediary stage where the contamination was detected. From there, it required tracing the origin along all possible supply lines, back to the farms, and their suppliers, and their suppliers. Once found, the original sources of contamination could also have affected other types of food and feed, as was the case with melamine, and these roads towards other potential dangers need to be tracked as well. The stakes involved are high, obviously for the consumers concerned, but also for the authorities and the companies that were the original source of contamination (it typically led to their bankruptcy). In the process of tracing the original source, food scares erupt, borders are closed for certain products, affecting the trade in a much wider range of allegedly suspect food or feed until and well after the original source is found. For example, Spanish growers of cucumbers suffered losses in relation to the EHEC outbreak, even though their product was not the source. (Unlike their Dutch competitors, however, they were at the end of the growing season, easing their pain.) Dutch statistics (Productschap Tuinbouw, 2011) show that German consumer purchases of cucumber did not return to normal until the end of August 2011, whereas the source was identified (as unrelated to cucumbers) some 9 weeks earlier (and 5 weeks after the start of the search). Similarly, in the case of dioxin, a much wider range of firms is affected as consumers temporarily shied away from consuming this type of meat, and many healthy animals on other farms were slaughtered as a precautionary measure. While the shock is initially a quality shock, it translates into a quantitative shock in that supplies are disrupted by interventions such as closing of borders or transport bans.



Of the three types of consumer quality (based on research, experience or credence) disturbances in the visible quality (that can be detected by research) are routinely avoided by the firms, as requirements can be included in contracts and inspections. The second type is addressed when firms have tasting/testing laboratories, and even then only the known types of hazards are detected, but not the unknown ones like the strain of bacteria that led to EHEC. The equipment for testing not directly observable qualities will only be affordable to major companies, and smaller companies are therefore exposed to more risks. The third type of quality (credence) is related to the image of the firms. It forms an important reason for firms' advertising efforts. More and more, credence is derived from (or even requires) third-party

certification against standards that companies in the supply chain themselves have helped to establish, together with civil society groups. Disturbances occur if news is made public that affects the image, either generically for the product ('production of *foie gras* harms animal welfare'), or specifically for a brand ('Wagner Pizza stops using plop-chicken'). The stronger the brand name, the more valuable the reputation, the more sensitive to negative publicity and concomitant risks. In this sense, larger firms are at a disadvantage compared with small, anonymous companies.

In most of the literature, quality management is seen as implying concern for what happens upstream only. The way crops are grown, or animals are kept, transported, processed, obviously affect the quality of the final product of the firm. Yet, especially where credence quality is concerned, firms should also care about what happens downstream. The reputation (at the consumer end) of farmers or primary processors is dependent on how downstream processors and retailers treat and market their products. Indeed, groups of producers that want to establish a high-quality name for themselves may be required to set up their own downstream channels and branding to make this effective. The more the consumers rely on credence of a product's quality, the more should participants upstream of the supply chain care about what happens downstream, and the more such risks demand attention.

Summarizing the above, disturbances in product quality are routinely handled in the upstream and downstream contacts of firms, notably where mechanical qualities and visible consumer qualities are at stake. After Svensson's distinction, these contacts are generally holistic rather than atomistic as the collaboration of the whole supply chain is likely required to deliver quality. A modern trend is towards more credence-related quality, involving reputation of both the product and firm. This puts specific requirements on the way risks are managed: downstream handling of the products is of some concern too, next to the care about upstream quality; public news messages are potential sources of disturbances as they may harm a firm's reputation and thereby the perceived quality of its products, requiring a firm to be even better informed about all that is going on in its supply chain.

2.2 Quantitative disturbances

Disruptions in the flow of goods towards, in and from the firm form a major daily concern of firms. They are related to changes in demand and supply factors, which normally demand attention of the firms. In addition, other disruptions due to strikes, natural calamities etc. affect the regular flows through the supply chain. Based on a sample taken in the 1990s, Hendricks and Singhal (2003) show that announced disruptions in the flows of products significantly affect shareholder values of the firms. Kleindorfer and Saad (2005) note increased attention paid to disruption risks, related to "longer paths and shorter clock speeds". The empirical work in the USA that they quote shows a positive correlation of incidence of disruptions with a parent company's debt/equity ratio and also a negative correlation with the host county's socio-economic status. They claim that this suggests that disruptions are a consequence of weak management or weak motivation of personnel.

Peck's (2006) study on the food sector in the UK indicates that firms are obviously concerned with contamination, but also face challenges dealing with quantitative disruptions due to strikes, fires, pandemics, traffic, and terrorist actions. She further noted that the tendency toward consolidation left little room for spare capacity, and that in general firms were not strongly investing in Business Continuity Management. In a similar survey among Dutch firms in the food sector, Meuwissen et al. (2010) report that quantitative disruptions, for example due to loss of electricity or transport, are among the most important threats to firms, and that firms did not feel very well prepared for such disruptions. Another important threat for food companies was the loss of key suppliers. Both this Dutch survey and Peck's survey in the UK point towards key infrastructure that may form a bottleneck in the supply chain, and would render food supply sensitive to sudden disruptions in these key areas.

A particular concern for supply disruptions led to a study commissioned by the Dutch 'Platform on Agriculture, Innovation & Society', on the effects of sudden disruption in the supply of soya beans (or soya meal) to the EU. While earlier studies for this Platform showed that in general the EU was close or above self-sufficiency in food, this did not hold for EU's dependence on imported proteins for the livestock industry. Some 90 percent of all soya consumed in the EU is imported, almost all from North and South America. In the light of discussions on whether or not genetically modifies soya could be

admitted into the EU, this threat of a sudden disruption in the imports was not completely illusory, and it was considered an important threat (ranked at third place) by the food companies interviewed by Meuwissen.

To see the timing and severity of such a drastic supply disruption, Jansen *et al*. (2010) simulated the repercussions of a sudden shortage in a quarterly indicative model of the EU feed and livestock sector. They included the dairy, beef, pork, poultry and egg sectors, included EU production of grains, roughage and protein crops, and allowed for stocks of feed. A special feature of their model is the distinction of cohorts for the age distribution of the animals, which enables study of effects on animal production cycles. One of their simulations is for a very extreme scenario of zero soya imports, and no substitute trade in meat products. In this case, an import stop leads to immediate drops in pork production (by 25%), poultry production (50%) and egg production (5%). Over time, higher meat prices (given the assumed autarky in the EU) compensate for the soaring prices of feed, and lead to higher levels of meat production with a delay of 3 quarters for poultry and 5 quarters for pork; the higher levels of production lead to lower prices and again lower production levels. These wave-like responses require a few years to fade out. This shows the two dimensions of such a shock: its depth, shown by the drop in production levels (with logical consequences for farmers' incomes and firms' turnover) and its length, as shown by the time it takes to come back to normal conditions.

The model was also used to simulate a drought that would affect grain and roughage production. A shortfall of roughage would typically affect the dairy and beef sector more than the pork and poultry sectors, and lead to initial culling of cows, increasing beef supply, followed by lower supply of beef, while milk production would move to lower levels from the start. It would take this sector longer to recover from such shocks than the poultry and pork sector: up to 5 years.

In reality, with reasonably open markets, the effects on consumers are very small as they have alternatives, in the form of other products and similar products from elsewhere. But while this protects the consumers, producers can be hit even harder by a shock in their input provision as their selling prices cannot accommodate for the rise in input costs.

Thus, disruptions in supply, typically caused by factors beyond control of the firms, may strike many firms that are not well prepared. Economic considerations induce them to sacrifice some resilience in favour of profits. Nodes in the supply system may prove weak points when disturbances occur. Large supply disruptions cannot be solved by the market and governmental intervention is likely to be called for.

2.3 Externalities and sector-level risks

While much of the literature is concerned with supply-chain effects and a company perspective on risks, there are some aggregate effects of the responses that need consideration.

A first aspect is the adding-up problem that arises when individual firms take measures to prevent or to cope with a risk, and the aggregate of these measures affect their effectiveness. A well-known example from developing countries is farmers keeping cattle as precaution against drought, but with low efficiency as cattle prices drop when a drought occurs. Similarly, if all firms start hoarding certain inputs in the expectation of upcoming shortages, these very shortages are affected. Under 2b we already touched at sector-level effects of major calamities: if regions are effectively autarkic, price responses at the product level may compensate for shortages (and high prices) on the input side.

Some of these aggregate effects are, therefore, virtuous, in the sense of mitigating the effects of the initial shock, but others (such as the self-fulfilling expectations) are vicious. The individual rationality of firms' responses must then be countered by sector-wide (or governmental) actions to dampen their aggregate effects.

A second adding-up problem arises when firms take individual precautionary measures, such as dual sourcing, and plans to use bypasses in case of disruptions, and these individual measures call upon the same limited resources. In this case, the capacity of these resources, while sufficient for single

companies, is not enough to serve them all. Hence, while all individual risk management plans look fine, they will be surprised to find that more companies had though of using the same road, when it comes to actually executing the plans. This scenario is only avoidable when plans would be coordinated.

A third aggregate issue arises when individual measures have aggregate external effects. An example is the use of antibiotics in livestock industry. Individually, farmers use these to counter risks of diseases. In the aggregate however, their widespread use leads to the evolution of bacteria, such as MRSA and ESBL, that are resistant to all available antibiotics, and pose a direct threat to human health.

A fourth aggregate risk stems from the spatial concentration of agricultural sectors, notably livestock industry. Upon outbreaks of animal diseases, this concentration leads to measures, that quickly affect many more farms and animals than would have been the case had farms been more widely separated. Examples of outbreaks where this typically occurs are swine fever and foot-and-mouth disease. It even extends to human health: concentration of goats or sheep close to human settlements favoured incidences of large numbers of people suffering from Q fever in Jena (Germany) and during the very large outbreak in the Netherlands in 2008 and 2009 (Evaluatiecommissie Q-koorts, 2010).

These aggregate and external effects are traditionally within the realm of the government, as market forces do not provide operational allocation mechanisms. Individual firms essentially free ride on state provisions in cases of emergency. While they make their individual contingency plans (to be discussed in the next section), the government should also prepare for contingency measures consistent with the aggregate of these plans. Lacking this, individual plans may not prove robust upon simultaneous execution.

3. Managing risks in food supply chains

Following Kleindorfer & Saad's (2005) unpacking of risk management into S for specification, A for assessment and M for mitigation, we have discussed S in section 2, which sketched the various sources of risks and along which roads these affect food supply and the supply channels. We now move on to the assessment and mitigation. This section therefore discusses the various approaches firms take to deal with the risk.

The firms follow heuristics that are spelled out in numerous ways in the relevant literature. Using principles, categories, steps, questions (such as '5 why's') managers are helped to identify possible sources of disruptions or situations where disruptions or quality defects may arise. The residual problems, i.e. residual after management mitigates the original risks, are the types of problems materially affecting firms and consumers, and are thereby of some concern for other firms in the chain and for public authorities.

In this section we highlight the typical responses that firms have vis-à-vis risks, and the residual risks that remain. We distinguish again qualitative risks and quantitative risks, and we also address adding-up and external effects of individual responses. This provides the basis for the assessment of the roles that governments can play, which is the topic of the next section.

3.1 Managing qualitative risks

The previous section distinguished *mechanical* and *consumer quality*, which relate to intrinsic characteristics of the product, where the relevant attributes can be observed from the product itself, or to extrinsic characteristics, which the consumer attributes to the product. Many intrinsic attributes can be determined and put on paper and therefore included in contractual arrangements. Many others, typically those that are related to 'experience' quality or 'credence' attributes of the product can be included in arrangements only indirectly, i.e. by stipulating that supplying firms adhere to certain protocols such as HACCP standards (such as ISO) and criteria of certification systems (cf. Ruben *et al.*, 2007). In all cases managing quality implies measuring quality, which in turn implies defining quality. Managing quality risks unavoidably includes defining also the factors that determine quality. Once these factors are known, systems can be set up to monitor and evaluate these factors so as to spot possible threats to quality. With systems running well, the next step is to convince customers of the assured quality, which requires managing the image of the product and the firm, in many cases through third-party certification. This sequence of steps is also spelled out by the IRGC (2008): pre-assessment, appraisal, characterization and evaluation, management and communication.

Food-supply chains are typical in that they deal with perishable goods and face many quality requirements related to human health that are set and enforced by the government. The latter aspect implies adherence to minimum standards. Unlike other quality attributes, these minimum standards cannot be traded-off against costs of production; the way to assure that the minimum standards are met can still differ from firm to firm, with some taking more risks than others. Costs of monitoring adherence to these minimum standards are borne by each firm, but the public authorities typically help in assuring that supplying firms provide sufficient quality.

The former typical aspect of the food supply chain, the perishability of goods, implies that time constraints are imposed on the movements from field to fork, rendering logistics crucial, and its management more important for quality compared to other industries. This leads to strict internal procedures in the larger firms in the supply chains and to strict procedures for those operations that are performed by supplying firms. The stakes for the firm are high as both quantity and quality are affected by logistic glitches upstream, and this motivates strong emphasis on regulating supply lines. Economies of scale in doing so may then lead to vertical integration of firms that– without such strict quality requirements – would be viably organized in separate entities, trading with each other through spot markets.

Assurance of quality to the customer can benefit from (and lead to) this form of vertical integration, but it can also be realized by having access a large range of suppliers, large enough to supply at least enough of the required quality. Such a range of suppliers can be viable if there are also markets with lower quality standards to which they sell this part of their produce.

As the whole length of the supply chain affects the quality of the product delivered to the final consumer, approaches to assure quality are typically holistic, rather than atomistic. All partners are involved, leading to stronger need for governance of the chain.

Repercussions of these management actions for the residual risks are a drastic reduction of the health and quality risks facing consumers in normal times. Quality aspects less easily addressed are those that require laboratory assessment, and those related to novel 'credence' attributes. When attributes are not easily observed, any economies of scale in assessing quality imply that assurance thereof is limited to large-scale companies, putting small partners in a more difficult position. The supply of credence quality aspects requires standard setting and implementation that also favour large scale companies, as these can wield more power in how the standards are set (Ponte & Gibbon, 2005). The residual risks, therefore, reflect the dominance of these large-scale companies. Any defects that may arise in such firms can have large repercussions for many customers and may linger on due to loss of reputation. Without these dominant firms and their risk management, final consumers would be faced with many, but small risks. Their frequency has been reduced by the modern organisation of the sector, leaving only a few, but potentially larger risks.

The type of risks has also expanded from a product-oriented risk to include company-oriented risk. As *credence* and *experience* quality aspects become more important and quality less directly observable, it is the food manufacturing company that is held responsible by the consumers. Likewise, they hold the company responsible for the conditions under which all components of the products are produced. In the eyes of the consumers, firms are more vertically integrated than they in reality are. The implication is that firms in the food industry, especially those at the end of the chain, have an even stronger incentive to control what happens upstream. Firms have responded to this challenge by establishing quality control systems extending to the primary producers. In summary, quality management, notably the management of credence quality, induces vertical integration of firms. In the food chain, it shifts the lead to firms further downstream. In some sectors, the industry proved capable of implementing quality control systems reaching out to primary producers.

While concern for quality and reputation promotes larger companies with some cost reduction, it also reduces opportunities for large-scale production and marketing of primary commodities (as more of these are handled within the vertical conglomerates) and it reduces the diversity of supply lines. This entails risks related to the concentration of flows via single or few companies. By analogy with the banking sector, this renders some of these companies 'too big to fail' die to their vital role in the system's survival.

3.2 Managing quantitative risks

Quantitative risks partly overlap with qualitative risks where volumes of a product are rejected for quality reasons and delivery of the intended volume is thereby jeopardized. In this sense, qualitative risk management serves both dimensions. Often, however, volume risks are handled differently from quality risks. Difference is due to the instruments that are available to regulate volumes. Volumes can be measured and monitored and therefore contracted more easily; in some cases volumes can be stored for a while, creating a buffer to cope with disruptions in the supply. The control and regulations of the conditions under which production, transport and processing must take place, which quality management brings about, are less elaborate for the volumes per se. Managing supply disruptions does require, however, a study of what can go wrong on the road from farm to the firm and, less often, from the firm to the final consumer. Some nodes in the supply networks are of critical importance and would require monitoring, and necessitate contingency plans.

In the food supply chains, Dani & Deep (2011) note that while quality-related risks, and health risks in particular, receive much attention from public authorities, quantitative disruptions 'are usually solved without government involvement' (p. 402). As Peck (2006b) elaborates, most firms in the (UK) food industry do not have complete Business Continuity Management Plans. They have prepared for eventualities such as strikes and temporary restricted access and power failures in some of their units, but not in all. Nor do they count with aggregate problems that would arise if fuel were to become scarce or transport otherwise became impossible. Firms appear to rely on *ad-hoc* inventiveness and flexibility and one concern of the firms is that – in times of trouble - regulations on working times or traceability

requirements (which would not be possible in case of IT failure) would be lifted so as to allow them the required flexibility.

Many firms in her survey concede that redundancy and spare capacity are at odds with the pressure to reduce costs. She concludes that firms act out of 'enlightened self interest' and aim at continuity of serving their customers and shareholders, rather than the public good of securing access to food to the public at large. While in normal times allocation of resources can be governed by the 'invisible hand' of the market and the self-interest would coincide with public interest, it is not likely that market forces can make the allocation of resources to risk management to align individual and public interests. Reason is that there are no direct returns to investments in such activities and no pricing mechanism that governs such allocation. Nor is the allocation in times of calamities likely to be governed by the market.

In preparing for supply disruptions firms are advised to follow heuristics, such as the ten principles of Kleindorfer & Saad (2005), which call for close interactions with suppliers and customers, including information exchange; prevention through diversification, slack capacity and modular set-up of processes; and total quality management including analysis of weakest links. While larger firms in Peck's survey typically do most of this, smaller firms rely on their major suppliers or customers to help them manage disruptions (cf. Jaffee *et al.*, 2008)

This organisational model resembles the social capital that plays a role in securing the livelihoods of farmers in risk-prone areas in developing countries. The accumulation of ties of single households with neighbours, relatives and relations near and far forms a network that can be called upon for information, help and loans. Idiosyncratic risks, that affect individual households, can be insured through such networks, just as individual firms can be helped out by their suppliers or customers, or even competitors. Covariant risks that affect all households of a network simultaneously cannot be covered mutually and require either self reliance through individually accumulated assets or outside help or solidarity in an even wider network. Similarly, supply chains partners will be able to help out in individual cases, the more so if it affects their own business too, but would not be in position to help when a calamity strikes all at the same time.

In their study of the effects of a sudden supply disruption of soya to Europe, Jansen et al. (2009) indicatively modelled the markets for soybeans, grains, animals and livestock products. Their approach assumed that it is markets that coordinate responses. A sudden stop on soya imports leads to immediate scarcity and to monopoly positions of those that happen to have some stocks of protein feed. What price mechanism governs the allocation of this scarce feed over cattle raising sectors? As modelled, it was the profitability of the sectors, the price elasticities and the considerations of feed stock owners that determine the outcome involving extremely high prices. The expected duration of the stop played a crucial role for the stock holders: only during the import stop can they benefit from their position, and whatever is not sold fetches low prices afterwards. It would seems reasonable, however, to assume that the government will not put the market mechanism to such an extreme test, and will intervene and try to distribute feed at fixed prices over the sectors, on some politically determined basis. Either way, whether allocation is by market or by the state, the outcome will be difficult to predict for individual firms, and difficult to include in contingency plans to deal with such scarcity. In these circumstances, with high uncertainty (if not ambiguity), an approach involving all stakeholders and the government (if not the civil society too) is advisable, as suggested in IRGC (2008).

The management of quantitative risks, therefore, has led to highly reliable supply chains that are robust to many types of small shocks. The resilience as to larger shocks, striking many partners at the same time is however doubtful. The firms have insufficient incentive to prepare for the worst, nor is the aggregate of these contingency plans put to the test, or has the government worked out its role consistent with these plans and informed the companies accordingly. Changes in the position of some firms (e.g. rendering them monopolists in case of calamities) are also easily overlooked.

3.3 Effects at the chain level

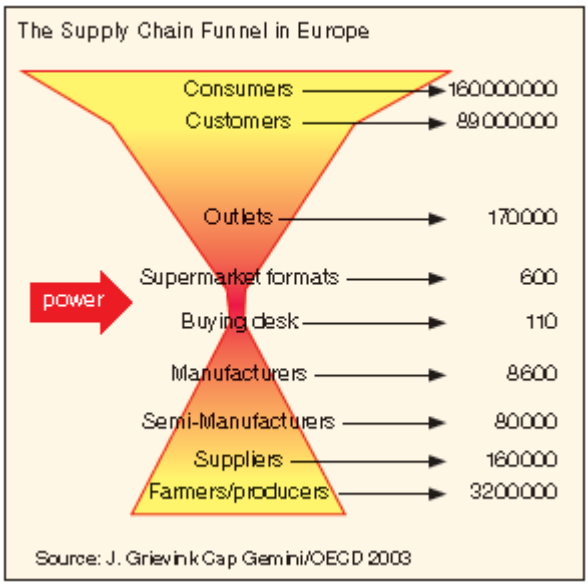
The individual actions of firms to guard themselves against quality defects and supply disruptions involve the other chain participants both ex ante and ex post. Ex ante, i.e. in preparation for a shock, the elaboration of quality standards, the framework for exchange of information and the creation of 'social capital' demands collaboration. Typically such collaboration is led by dominant actors in the chain.

Dominance is related to size, and size to economies of scale or scope, so that often the links in the chain where largest economies can be realized become dominant actors (Gereffi & Korzeniewitcz, 1994; Ponte & Gibbon, 2005). For supply-led chains it is economies of scale, and for demand-led chains it is also economies of scope, that determine leadership. In the car industry these are the car manufacturers and these chains are supplier led, but in the food chains, a mixture of large retailers, food manufacturers and large primary processors and traders dominates the chains. In the fresh products sector, the large (European) retailers set up GlobalGAP, a certification system for production and handling of these products, and thereby provided leadership in quality control throughout the chain.

In the food chain, where human health is concerned, the government is actively involved. Quality assurance systems may still be led by dominant firms but the government is setting minimum standards on the food products and it is these standards that the quality assurance systems are meant to reach (or surpass). The government acts on behalf of the multitude of consumers who by themselves cannot do this for lack of representative organisation.

Where no clear leadership in the chain prevails, organisations of chain participants have a role to play and, recognizing the importance of collaboration, firms have an incentive to form such organisations.

The organisation of the food system is such that relatively few firms intermediate between a multitude of farmers and an even larger group of consumers. The picture on the left from Rabbinge & Linnemann (2009: 128) originating from Grievink (2003), sketches this funnel model. The narrow part of the funnel houses but a few firms, and while these have individually developed contingency plans, their aggregate usefulness depends on the compatibility of these plans.



Ex-post, the way individual firms deal with risks has repercussions on the sector as a whole. Here the actions of one firm may conflict with those of another. It is easily conceivable that two firms call upon the same resource in times of trouble, each thinking that they would be the sole user of this resource. Thus, risk management plans that look fine from an individual point of view may not be effective when more firms are simultaneously affected. If such competition for the same resource suddenly erupts in times of a shock, the outcome is unclear. Indeed, many firms in Helen Peck's UK survey indicate they are concerned about how fuel would be distributed in case of shortage; or whether their staff will be eligible for scarce vaccinations in case of epidemics. And she also indicates that some nodes in the distribution network, like ports, have become so specialized that they have become efficient but vulnerable links in the supply chain (IRGC 2010b: risk factor #4: differential vulnerability to risk).

The same critical position can be taken by individual firms within the chain: they may *de facto* be indispensable for an acceptable performance of the supply chain. They tend to be large and of crucial importance in the small waist of the funnel. Failures of such firms would have strong effects throughout the chain. By analogy to the financial sector, the 'system companies' are too big to fail. By the same analogy, this provides a reason to put a closer watch on these firms, closer perhaps than hitherto is common.

The food supply chain is not solely concerned with food supply. The sector as a whole is also a major factor of landscape, nature and environment, and the aggregate effects of what the sector does, are felt in these domains too. Thus if risk mitigating measures add up, as explained in the earlier section for the use of antibiotics, and lead to externalities such as an increased exposure to diseases, it is at the aggregate level that measures must be taken. Typically such measures, such as compulsory refraining from using some of the antibiotics, are designed in close collaboration of industries concerned and the

government. This also holds for regulation limiting geographic concentration, and measures taken in case of contagious animal diseases.

Management at these aggregate levels and coordination of the firms' actions in this field has strongly grown over the past decades by better organization and representation of the private industry in global networks. Well-organized lobby groups in the USA and the EU act both as influential partners in setting government policies and as points of coordination for the industry. The food sector is notable for its high degree of organisation. Yet, (aggregate) risk management in relation to outside shocks, such as drought, flooding, disease outbreaks, does not appear high on the agendas of the organisations. Much attention is given to compensatory measures to be taken after the event, but little evidence is found of precautionary plans of the private sector at the aggregate level. Probably the tension between costs to their members and benefits for the aggregate prevent the organisations from devoting large resources to such strategies, and rely (or better: call) on the government to do this. This stands in contrast to the attention given to the major risk of farmers, price volatility (Székely & Pálinkás, 2009). Policies to secure agricultural incomes and market-based institutions to cover price risks (notably futures markets) abound in developed countries. Yield risk (the second major risk of farmers) can be covered by crop insurance schemes, but – with some exceptions – these are not popular, even when subsidized.

Above, we mentioned four sector-level risks (adding-up effects, coordination failure in risk mitigation, externalities and spatial concentration). The first risk of adding-up is partly managed by the markets in so far as low yields can be compensated by higher prices, partly by private (or public-private) institutions in the sense that information is given as soon as a risk manifests itself which may limit excessive herd-like behaviour. Food scares form an important herd-effect at the consumer level and must be taken into account in any communication strategy. Risks due to externalities, including vicinity of other farms and human settlement, are barely managed. The management thereof calls upon more than a few government services and legislation at various levels. The case of Q-fever in the Netherlands shows how easily a concern of the Ministry of Health about increasing incidence of the fever can be frustrated by the Ministry of Agriculture, not accepting *a prima facie* that these incidences were due to goat raising (Evaluatiecommissie Q-koorts, 2010).

4. Governance and government

When disruptions are relatively small, private chain members are normally well able to adjust in large disturbances however, solutions are often ill-coordinated and incite calls for state intervention as the risk absorber of last resort. Governments then emerge as 'channel leaders' or directors in supply chains, in both the harder (material) and softer (cultural, normative) sense.

States control essential infrastructure that functions as key logistical nodes in the system's commodity flow, and may prevent core companies essential to the chain's survival from collapsing. This makes states de-facto lead actors in food supply chains, a role however which only becomes apparent after the fact. Especially in liberalising economies however, this role is ill-reflected in policies and literature. Public bodies are therefore well advised to acknowledge this lead role and consider its scope for actions in future chain disturbances.

For the present purpose, we treat supply chains as 'unruly', complex, self-organising systems – risk-reducing interventions seek to reduce the unruliness by simplifying the systems. (More conceptual detail on complex systems is found in Appendix 1). Interventions or self-organised collective responses seek to make the chains more straightforward and predictable. This does not necessarily reduce price shocks. As markets are constrained, they become smaller so that shocks may actually become bigger. A modularised approach to markets however has the potential to prevent shocks spilling over into other markets, as happened in 2008.

Attempts at collective international action were tried at the Food Summit after the food price peak of 2008, but have not translated into concrete actions. Proposed reform of global governance institutions regulating food trade have also come to nothing (Burger *et al* 2010). What has so far not happened is the elevation of food to an international security issue ('securitisation', see appendix). While nationally public-private infrastructure is often subject to national preconditions with the 'shadow of hierarchy' [1], internationally there is no overall regulating body. It appears that while national networks work fine, transboundary linkage between those networks is still underdeveloped.

States thus tend to intervene unilaterally. Once food is declared a security (emergency) issue, states can push aside normal rights, rules and procedures,

In *quantitative terms*, government may respond to market failures by overruling the market - for example by nationalising one or more links in the chain, imposing temporary import or export controls on a volume basis when prices explode uncontrollably due to positive feedback (IRGC 2010b: risk factor 3) or making direct investments in production capacity as did China, India and Saudi Arabia in Africa. More structural measures would involve promoting government arrangements that increase chain flexibility and 'slack', such as increasing buffer stocks (IRGC 2010b: risk factor #2: reduced safety margins),

In qualitative terms, markets do not guarantee safe food, so that governments have a clear regulatory role in setting and enforcing standards – although relying on non-state actors.

A problem here however is that governments themselves may act unpredictably and inconsistently due to political rationality. Having adaptable contingency plans for crisis intervention policies and carrying out stress tests can promote more predictable actions.

So far state responses seem to be reactive rather than proactive. The dismantling of the welfare state has meant a reduced sense of state responsibility for collective risks and acceptance of top-down interventions Moreover emerging risks deriving from modern technologies exceed the capacities of many of established risk management practices.

As a result chain-simplifying interventions tend to be temporary and often suboptimal. Deregulation has reduced risk preparedness while strengthening ex-post repression. While in acute crises a form of command-and-control may be resorted to, mostly a mix of management, regulation, coordination and especially facilitation of self-organisation will be more adequate what roles can governments play more structurally without compromising the system's complexity too much? In complex risk-managing

[1] the option governments have at their disposal to intervene in a coercive manner if all else fails – which normally does not even need to be invoked, as non-state actors are fully aware of this option.

networks, the public sector's role is more about strengthening nodes (bottlenecks) and ties (relationships) between chain actors. Steering in such networks takes place through discussion, persuasion and 'seduction' rather than coercion. As we noted in Section 1, trust and reputation is one of the network relations that can be subject to international supply-chain governance. In risk-managing networks, the public sector's role is about strengthening nodes and ties between actors.

This pertains to the potential for achieving normative/cultural change in the chain. Hall (2000) has noted that in asymmetrical transnational chains, a channel leader with sufficient power to impose its will on other stakeholders in the supply chain, with technical competencies, and under specific pressure can change the supply chain's norms – in our case, towards a stronger risk culture. Somewhat similarly a federal public agencies like FEMA (the US disaster manager), constrained by weak regulatory powers, has resorted to public policy marketing strategies (Buurma, 2000) to promote Disaster Risk Reduction norms.

4.1 Parallel with water management

We feel it is instructive to draw a parallel between the 'flows' of food and those of water. Both types of flow have important quality and quantity attributes, and are prone to (health-related) risks. To make the comparison reflecting *chains*, with shifts in ownership, we draw on examples of transboundary water governance.

From pump to tap, unaccounted-for water (losses) but also quality losses can be enormous. As water is so crucial to health, some water supply managers aim at total quality control in the water supply chain, preventing all risks (fail-safe) rather than accepting a degree of risk (safe-fail), seeking to prevent the alignment of weak links in the chain (the 'holes' in Reason's Swiss Cheese model of safety, Reason 1990).

A difference between water quality and quantity chains is the choke point. While surface water quality erosion mostly comes from a myriad of non-point sources, quantity is regulated and centralised by a limited number of infrastructural choke (control) points – dams, weirs, locks, which help cushion shocks such as floods and low flow, and are relatively easy to govern but also highly vulnerable to disruption.

In transboundary **water quality** management, downstream governments have stepped in to force upstream concessions on behalf of their water sector, but the role of experts and public opinion has proved crucial in enforcing standards. International scientific standards are available for quality (e.g. salinity and toxics), but on international water courses these are not easily enforced. Upstream and downstream actors tend to have asymmetrical preferences (Dinar, 2006): upstream polluters harvest the benefits of economic activities and suffer only a fraction of the damage at the detriment of downstream users. Industrial and agricultural pollution upstream cause major treatment costs downstream. Stricter regulation for upstream inputs which can be harmful downstream in the chain may harm upstream profitability, as farmer protests to stricter water quality regulation in Mexico showed (Grendelman and Huibers, 2010). If the downstreamer is dominant, upstreamers are more likely to accept a deal. Non-hegemonic downstreamers thus need other sources of countervailing influence. The Netherlands' government for example took the initiative in both the Rhine treaty and OSPAR agreement on sea water quality. In the Rhine case, the Netherlands (whose West part is extremely vulnerable, located as it is below sea level) opened a diplomatic offensive after strong pressure from beleaguered drinking-water companies. Public opinion, including NGO allies, but also incentives (side payments) were used to get the upstreamers in France and Southern Germany to release less chlorides into the Rhine (Dieperink, 2011). A major driver was the Seveso dioxin spill in 1976, leading to the forced interruption of the chain, and then swift European environmental legislation on a strong public mandate. It allowed non-experts an unprecedented 'right to know' (De Marchi *et al.*, 1997). The success of the Rhine treaty was eventually built on a combination of moral appeals, diplomatic pressure and the creation of a transboundary negotiation platform (Dieperink, 2011). On the river Elbe likewise, the transboundary river commission served as platform for joint problem solving by identifying priorities for action while the commission's reporting to the public served as an enforcement mechanism (Dombrowsky, 2008). On the Tisza,

downstream Austria supported clean-up activities in a hazardous Romanian site[2], again showing downstreamers effecting a change upstream.

For **quantitative water** governance (low flow and floods), upstream power is more concentrated and controlled, providing environmental services in regulating the timing and quantity of water but also with the risk of uncoordinated or unwanted releases[3] or hoarding. 'Coordinated transboundary action is still rare, even in Europe. Flood management is a largely a public, if often decentralised affair. The EU flood directive stipulates that upstream countries cannot pass on their flood risk to downstream countries. In practice joint repression in border areas of the Meuse, for example, has worked better than early warning. While upstream controlled flood storage for downstream benefit has not seen much application, on the Rhone, shared by France and Switzerland, upstreamers voluntarily absorb flood risk, reducing their own economic and demographic growth potential in order to strengthen Lyon (F) and Geneva (CH), thus absorbing the cost of externalities from major cities (Pigeon 2012).

Power asymmetries may lead to upstream self-restraint. Turkey claims it saves Iraq from flood extremes by cushioning the peaks, and has reliably made up for dry years by passing on more water the next year – but delivering its services on its own terms without consulting chain partners. There is a *de facto* regime in terms of predictable behaviour, not in terms of formal cooperation. Self-organisation has led to pragmatic percentage-wise distribution agreements between downstreamers for times of low transboundary flow, downstream shortage on the Euphrates-Tigris, but also on the Murray-Darling (crossing intra-Australian state borders), is regulated by guaranteeing a percentage rather than minimum flow (sharing the pain) at the macro level[4].

In this domain however, there are now initiatives to retrofit the upstream part of the water chain. On the lower Rhine, upstream Nordrhein-Westfalen and the downstream Netherlands have established a working group after the 1995 flood to undo past actions for quick discharge of flood water.

In sum: transboundary water systems are complex supply chains, especially where quality is concerned. Risk offloading along the chain is still rife. Where there is coordination in quantitative transboundary risk management, network governance of supply chains prevails, replaced by temporary command-and-control interventions, quotas and priorities, only when a disruption is labelled a disaster/acute crisis.

In transboundary water quality issues, governments have tended to apply a mix of national regulation and facilitation of transboundary negotiation and coordination. The water supply industry takes an increasingly active role in preventing infections. In transboundary pollution control, expert and public opinion and information flows were important drivers in releasing funds and energies for upstream source control. In low-flow situations, such coordination is often absent and downstream quotas or prioritisation may need to be enforced.

4.2 Implications for food supply chains

The lesson to learn from this comparison with water supply, is the shift of the centre of gravity of the governance: where quality is concerned, stakeholders are more easily rounded up for discussions on measures to be taken than when quantity is in danger. Quantitative disruptions always shift the centre of gravity further upstream, where supply comes from. Deals on quantities are more often made on behavioural rules (say equal share of whatever is available) than on absolute amounts. Other stakeholders and experts, and the public opinion, are more often involved in quality agreements.

This also applies to the food supply chain. Agreements on quality tend to be holistic, those on quantities rather atomistic. Hence a greater need for governance arises when quality must be secured. Sometimes,

[2] http://www.zinke.at/Tisainc.htm
[3] In times of peak flow, upstreamers make decisions that increase downstream uncertainty or discharge. India, for example, tends to open the floodgates of the giant Farakka dam near the border with Bangladesh, worsening the flood in Bangladesh; in the Meuse river, multiple Belgian interventions (for hydropower and flow diversion) make for uncertain discharge across the Dutch border.
[4] Within the territory, downstream governments may set quota according to pre-established (or ad-hoc) priorities. In the Netherlands, for example, water allocation is guided by a prioritisation rule of thumb: 1. security/non-reversible damage. 2. Public utilities 3. Small-scale high-added value use 4. Other economic interests. Regional non-state water is governed by a similar rule.

firms in the supply chains are quite capable of arranging this themselves (as the retailers do via GlobalGAP). Private participants then act as chain leaders. The same may hold in the downstream direction for a firm that demands from its retailers utmost care in handling and selling its own high-end niche product. In many cases, the stakes of the consumers are best represented by the government, which then acts as chain leader, and which can also lawfully regulate whatever is decided by the partners. This involvement also implies a role in case of shocks: the government, which also monitors, can credibly punish firms for not adhering to standards, and impose measures to be taken to prevent harm to the consumer. Where the government is not involved, as in quality systems that are privately agreed upon, the ultimate punishment is to be ousted from the supply chain, but this may not form a credible threat to firms crucial to the provision of the product.

But the government also has a role in coordinating contingency plans and responding to these plans. As we have seen in the previous sections, companies may draw up plans, but cannot incorporate aggregate effects of these plans. The market is much more likely to fail in times of calamities. And concentration of firms in the food supply chains has increased. These three conditions justify government actions to consider a role that is consistent with the contingency plans of the firms in the supply chain.

In the previous sections we have divided risks into qualitative and quantitative risks, and the former into risks to quality aspects that relate to technical characteristics, and consumer-oriented attributes indicated by *research, experience* and *credence*. We discussed that managing these risks is relatively simple for the visible, easy-to-determine attributes. The management of quality aspects related to experience and credence requires laboratories, protocols, auditing and reputation, all of which have strong economies of scale and therefore can be more favourably managed by larger firms. Quantitative risks require Business Continuity Management strategies to prepare for disruptions caused by factors external to the chain, such as strikes, power shortages, but also congestion at nodes in the supply network. Where behavioural responses are relevant, knowledge is missing on what these will be in times of trouble, and, given this uncertainty, plans involving a wider group of stakeholders will be in order. Otherwise, all these privately managed plans suffer from adding-up problems in that their simultaneous implementation may not be feasible. This calls for governance of these plans. Where the food-supply chain community is not ready to coordinate (or even discuss) all these plans, governments have a role to play. Here, governments play their customary role of stepping in to solve a coordination problem. In some cases, firms have become so large and crucial to the supply chain, that their business continuity plan also determines the continuity of the whole chain. This too, is a reason for collective demand to be party to such plans, and the government would be in a good position to represent the collective or at least to facilitate such collective action of the stakeholders of the chain.

Where international chains are concerned, governments find themselves in a position that firms have in a national chain: how to deal with upstream suppliers and downstream customers. For appropriate risk management, governmental involvement is often unavoidable or at least desirable, but in international cases, this requires intergovernmental arrangements, that must be aligned with private sector agreements within the chain. Appropriate frameworks for these arrangements are partly provided by mechanisms of the World Trade Organisation, and – less powerfully – by forums of the UN and commodity organisations (cf. Burger *et al*. 2010).

5. Conclusions

Governance of the food supply chains is an important factor to mitigate risks. Firms have many reasons to engage in risk management and also to engage in supply chain coordinating mechanisms. But these two types of management actions are not normally combined: while the supply chain coordination deals with everyday actions, including small disturbances, risk management should (also) target major disturbances and plans to secure continuity in case of major disruptions caused by outside factors. While the immediate partners in the supply chain are necessarily involved in such plans, a holistic approach to risk management in the chain appears typically not undertaken. Nor are, to our knowledge, adding-up problems of such plans worked out.

This creates space and need for governmental involvement. There are several aspects to this involvement. One is the exchange of information by the chain partners. In all risk management guidelines, the involvement of 'nearest neighbours' in the supply chain is advised. Those further down the line or upstream are more difficult to involve. Also, it is difficult to let the neighbours into the companies own plans on what to do in case of reputation damage of other more private risks, e.g. financial, or into plans to circumvent the neighbours if so needed. Hence, information about the plans is at least partly privately held. This carries the danger that –even if these plans are fine– they may not work well because they interfere with the plans of other companies. Here lies a role for the government, not just nationally, but also in international arrangements.

This role would be the traditional role of solving a coordination problem, but should also be extended so as to bring risk management plans of the whole supply chain in one hand. The complexity of the supply chain makes this both a necessity (for efficient risk management) and a challenge.

As we have seen above, the risks that come from adding-up of individual responses is what justifies coordination, typically by the government. Especially in times of disruptions, when information is hard to come by, communication of factual information is important, not only to help form a reasoned opinion about the disruption but also to put individual firms' actions in a proper perspective. All too often these actions are seen as displaying hidden information which triggers copying. This can be prevented by information on facts *and* on the firms' actions.

We made a distinction between chain leaders that can be formed by private participants, typically the major firms in the chain, and a role of the government as *de facto* chain leader. We argued that such a role would be desirable in case consumer interests need a champion, such as when their health is at stake. It may also be desirable if the food supply chain cannot organize itself, for lack of appropriate leadership or agreement about it. It can even be desirable if the leadership is there, but the leading firm has too much power, or has become too unavoidable in the chain. A responsible government therefore should be alert always. Yet, the types of involvement will differ: consumer health interests can be represented by demanding minimum standards and leaving the implementation to the chain; malfunctioning chains can be helped towards better coordination even without actually taking chain-leadership; crucial firms can and should be inspected regularly, but it requires no governmental role in the chain.

While a strong dynamic performance of the food supply chain demands restraint on the side of the government, lest innovation would be hampered, the aggregate effects of the firms' actions, internal and external to the chain require governmental oversight. To play this role well and keep pace with globalization, intergovernmental arrangements on risk management and oversight are wanted.

Acknowledgment

We are grateful to Krijn Poppe of LEI, Wageningen University and Research Centre for his helpful comments on an earlier draft.

References

ABAG, 2010. Water System and Disasters Background Information Compiled for the 2009-2010 Update of the ABAG-Led Multi-Jurisdictional Local Hazard Mitigation Plan for the San Francisco Bay Area; http://quake.abag.ca.gov/wp-content/uploads/2010/10/Water-and-Disasters.pdf

Bakshi, N. and P. Kleindorfer (2009) Co-opetition and Investment for Supply Chain Resilience *Production and Operations Management* 18 (6): 583-603.

Beck, U. (1992) *Risk Society: towards a new modernity*. London: Sage.

Bindraban, P.S., C.P.J. Burger, P.M.F. Quist-Wessels and C.R. Werger (2009) Resilience of the European Food System to calamities. Report for the Steering Committee Technology Assessment of the Ministry for Agriculture, Nature and Food Quality, Plant Research International, Report 21, Wageningen UR.

Burger, K. (2009) Food calamities and governance – an inventory of approaches. DEC, Wageningen University and Ducth Platform for Agriculture, Innovation & Society.

Burger, K., J. Warner and E. Derix (2010) Governance of the world food system and crisis prevention. Wageningen University and Dutch Platform for Agriculture, Innovation and Society.

Buzan, B., O. Waever and J. de Wilde (1998). Security. A New Framework for Analysis. London: Lynne Reaner Publishers

Cleeland, Belinda (2009) The Bovine Spongiform Encephalopathy (BSE) Epidemic in the United Kingdom. IRGC, Geneva.

Craighead, C, J. Blackhurst, M.J. Rungtusanatham and RB. Handfield (2007), The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities." *Decision Sciences* 38(1): 131-156.

Dani, S. & A. Deep (2010): Fragile food supply chains: reacting to risks, *International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management*, 13:5, 395-410

De Man, A.-P. and N. Rooijakkers. Alliance Governance, Balancing control and trust in dealing with risk. *Long Range Planning* 42 (2009) 75-95 http://www.entrepreneurship.ethz.ch/education/lectures/Alliance_Advantage/Trust_Risk_de_Man_2009.pdf

De Marchi, B., S. Funtowicz and J. Ravetz (1997) Seveso: A paradoxical classic disaster. In J. K. Mitchell (Ed.), Long road to recovery**:** Community responses to industrial disaster. New York: United Nations University Press United Nations University. pp. 86-120.

Dieperink, C. (2011) International water negotiations under asymmetry, Lessons from the Rhine chlorides dispute settlement (1931–2004). *International Environmental Agreements*. http://igitur-archive.library.uu.nl/milieu/2011-0517-200604/Dieperink.pdf.

Dinar, S. (2006). Assessing side-payments and cost-sharing patterns in international water agreements: The geographic and economic connection. Political Geography, 4, 412–437.

Dombrowsky, I. (2008) Institutional design and regime effectiveness in transboundary river management – the Elbe water quality regime. *Hydrol. Earth Syst. Sci.*, 12, 223–238. http://www.hydrol-earth-syst-sci.net/12/223/2008/hess-12-223-2008.pdf

Donaldson Soberanis, I.E. (2010) An extended Bayesian network approach for analyzing supply chain disruptions, PhD Dissertation, University of Iowa http://ir.uiowa.edu/cgi/viewcontent.cgi?article=1674&context=etd

Evaluatiecommissie Q koorts (2010) Van verwerping tot verheffing. Q-koorts beleid in Nederland 2005-2010. Ministerie van Economische Zaken, Landbouw en Innovatie, Den Haag

Fidler, David P. (2011) International Law and the *E. coli* Outbreaks in Europe. *Insights,* Vol 15(14), June 6, 2011. American Society of International Law

Grendelman, R. and Huibers, F. (2010) Governing Peri-Urban Wastewater Used by Farmers. Implications for Design and Management. In Bas van Vliet (ed.). *Social Perspectives on the Sanitation Challenge*. Springer Science Business Media. Ch 12, 189-.

Gereffi, Gary and Miguel Korzeniewicz (eds.) (1994), Commodity Chains and Global Capitalism, Westport, CT, Praeger

Grievink, J.-W. (2003). The Changing Face of the Global Food Supply Chain. Paper to OECD Conference 6-7 February 2003, The Hague. In Changing Dimensions of the Food Economy. OECD, The Hague, The Netherlands.

Hall, J. (2000) Environmental supply chain dynamics. *Journal of Cleaner Production* 8: pp. 455-471.

Hendricks, K.B. and V.R. Singhal (2005) Association between Supply Chain Glitches and Operating Performance. *Management Science*, Vol. 51, No. 5 (May, 2005), pp. 695-711

Huibers, F. P. and J.B. van Lier (2005), Use of wastewater in agriculture: the water chain approach. *Irrigation and Drainage*, 54: S3–S9.

IRGC (International Risk Governance Council) (2008) An introduction to the IRGC Risk Governance Framework. Geneva.

IRGC (2010a) Emerging food safety risks: Melamine-tainted milk in China, October 2010, Geneva

IRGC (2010b) The Emergence of Risks: Contributing factors. Geneva. http://www.irgc.org/IMG/pdf/irgc_ER_final_07jan_web.pdf

Jaffee, S., P. Siegel and C. Andrews (2008) Rapid Agricultural Supply Chain Risk Assessment – Conceptual Framework and Guidelines for Application. Commodity Risk Management Group, ARD, World Bank, June 13, 2008

Jansen, D.M., C.P.J. Burger, P.M.F. Quist-Wessel and B. Rutgers (2010) Responses of the EU feed and livestock system to shocks in trade and production. Plant Research International, Wageningen UR and Platform Agriculture, Innovation and Society.

Kleindorfer, P.R. and G.H. Saad (2005) Managing Disruption Risks in Supply Chains. *Production and Operations Management,* 14 (1): 53-68.

Lederman, R.S. Kurnia and J. Lederman (2009). Designing Supply Chain Systems to Cope with Catastrophes. PACIS conference paper. Association for Information Systems. http://www.pacis-net.org/file/2009/[50]Designing%20Supply%20Chain%20Systems%20to%20Cope%20with%20Catastrophes.pdf

Lloyd's (2010) *Globalisation and risks for business. Implications of an increasingly interconnected world*. Lloyd's 360^0 Risk Insight.

Manuj, I. and J.T. Menzer (2008) Global Supply Chain Risk Management *Journal of Business Logistics*, Vol. 29(1), pp. 133-155

Meuwissen, M.P.M., K. Burger and A.G.J.M Oude Lansink (2010) Resilience of food companies to calamities – perceptions in the Netherlands. Wageningen University and Platform Agriculture, Innovation and Society.

OECD (2010) Risk and regulatory policy. Improving the governance of risk. Paris

Olsson, A. and C. Skjöldebrand (2008) Risk Management and Quality Assurance Through the Food Supply Chain – Case Studies in the Swedish Food Industry. *The Open Food Science Journal*, 2008(2): 49-56

Peck, H. (2006a): Reconciling supply chain vulnerability, risk and supply chain management, *International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management*, 9(2): 127-142.

Peck, H. (2006b) Resilience in the Food Chain: A Study of Business Continuity Management in the Food and Drink Industry. Report to the UK Department for Environment, Food and Rural Affairs, London.

Perrow, C. (1984) Normal Accidents: Living with high-risk technologies. Princeton University Press (1999), first published by Basic Books.

Pigeon, P. (2012) Flood-risk and watershed management conflicts in France: upper catchment management of the river Rhône. In: J. Warner, A. Van Buuren & J. Edelenbos (Eds.). Making Space for the River. IWA Press. Ch. 13.

Ponte, S. and Peter Gibbon (2005): Quality standards, conventions and the governance of global value chains, *Economy and Society*, 34:1, 1-31

Productschap Tuinbouw (2011)
http://www.tuinbouw.nl/files/page/Marktbeeld%20Saladegroenten%20in%20Duitsland.pdf

Rabbinge, R. and A. Linnemann (Eds.) (2009) European Food Systems in a Changing World. European Science Foundation.

Renn, O. (2008). Risk Governance. Coping with uncertainty in a complex world. Earthscan.

Reason, J. (1990). *Human Error*. Cambridge University Press.

Ruben, R., M. van Boekel, A. van Tilburg and J. Trienekens (Eds.) (2007) *Tropical food chains – Governance regimes for quality management*. Wageningen Academic Publishers

Svensson, G. (2000),"A conceptual framework for the analysis of vulnerability in supply chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 30 Iss: 9 pp. 731 - 750

Székely, C. and P. Pálinkás (2009) Agricultural Risk Management in the European Union and in the USA. *Studies in Agricultural Economics* 109: 55-72.

Wagner, S.M. and C. Bode (2008) An empirical examination of supply chain performance along several dimensions of risk. *Journal of Business Logistics*, 29(1): 307-325.

Wright, B. and C. Cafiero (2010) , Grain reserves and food security in MENA countries, Technical Report, World Bank

Appendix 1

Transboundary supply chains can be seen as complex adaptive systems without a central governing body. Perrow (1984) reminds us that complex, closely-coupled systems are vulnerable to malfunction – we should prepare for failure. Renn (2008) highlights the systemic risk inherent to complex, interconnected systems.

The 'normality' of incidents should cause risk managers to prepare for failure and see the supply chain as a tightly coupled, complex system. In supply chains, one event may have different degrees of severity in different parts of the supply chain, so that the effect is not linear and hard to quantify - it may propagate faster in some locations through the network faster than others (Donaldson 2010). Craighead (2007 q in Lederman *et al*. 2009) finds that the more complex, the more severe the disruption in that portion, and also the denser a portion of the supply chain, the bigger the interruption - from deviations, disruptions and temporary shutdowns (Gaonkar & Viswanadham 2004) with increasing ripple effects.

Food chains have a degree of 'slack' on both the 'upstream' and 'downstream' ends. Buffers to cushion the effects of small incidents, but when shocks are sudden and severe, these may prove insufficient – with major consequences.

Nodal governance of complex systems concentrates on the nodes (bottlenecks) and ties (relationships) within the chain. Network governance, related to nodal governance, largely is about balancing control and trust (De Man and Rooijakkers, 2009).

Complex, coupled systems present reflexive risks: by fighting risks in one place, we increase risks elsewhere (after Beck 1992). In flood management, for comparison, building dikes displaces risk over time and space: to those outside the dikes, and by turning high incidence, low consequence risks into low incidence/high consequence risks.

Finally, 'securitisation' (Buzan *et al*., 1998) is the elevation of an issue as a security issue, legitimising extraordinary measures to ensure survival. It has a 'logic of war' that leads to the simplification of command and accountability structures normally unavailable in liberal democracies, replacing modes of nodal/network governance by top-down modes.

Appendix 2. A summary view of the risks in the food supply chain.

What is the risk and how did it develop?
The risk is

- companies draw up plans to deal with the risks they envisage, but these plans are not consistent with those of other companies in that they
  - call upon resources that other companies also use
  - do not account for market failures invoking government interventions or these very interventions
  - do not account for changes in behaviour of firms, involving change in leadership roles
- contingency plans for supply disruptions designed by the companies are incomplete
- government has no quantitative risk management plans that are
  - consistent with the company plans
  - incorporating firms' behaviours
  - communicated to the firms

It develops as companies are encouraged to make these contingency plans, and as companies become gradually more critical in various stages of the food supply chains. However, companies cannot do this on an individual basis. There is little incentive to discuss the plans with chain partners or the government as the plans typically contain crucial strategic information that are internal to each company.

What are the relevant 'contributing factors' that can explain the risk's emergence, amplification or attenuation? (see in annex II the report 'The Emergence of Risks: Contributing Factors': http://www.irgc.org/IMG/pdf/irgc_ER_final_07jan_web.pdf)

Of the generic contributing factors that lead to 'fertile ground' for risks emerging, there are some that stand out for the case of food supply chains. These are

- Loss of safety margins: it is widely acknowledged that firms carry little stock, have little spare capacity and generally work on small margins, but for large volumes. Technical and logistic sophistication has reduced risks, but the sensitivity to larger, covariant risks has increased
- Positive feedback: with food being a necessity, people (and firms; and governments) quickly respond to calamities by hoarding or other measures that aggravate the problem for others
- Information asymmetries: under this heading we rank the inconsistency between company contingency plans, and those of (the more distant) chain partners, as well as the incongruence between government plans and the set of company plans. In particular, the change in leadership that is likely to occur when calamities strike: while chain leadership normally rests rather close to the consumer end, and involves the government for quality issues, a drastic supply disruption shifts *de facto* leadership upstream to positions uncommon for industry and government.

The other factors contribute in a less outspoken manner. Their influences are summarized in the table below:

#	factor	effect	Explication
1	Scientific unknowns	+	
2	Loss of safety margins	++	Small margins, large and crucial companies
3	Positive feedback	++	Price spikes, hoarding
4	Varying susceptibility to risk		
5	Conflicts about interests	+	Strategic interests of firms works against openness
6	Social dynamics	+	Globalization, generic ingredients, but single suppliers
7	Technological advances	—	
8	Temporal complications	+	Often detection at consumer end only
9	Communication	—	Existing network for quality control
10	Information asymmetries	++	Between chain partners, private sector and government
11	Perverse incentives	+	External effects neglected (e.g. use of antibiotics)
12	Malicious motives and acts	+	

Other factors are the size and criticality of some firms and nodes in the supply chains, that pose risks to the chain as a whole. A further factor, typical for the food supply chains, is the perishability of most food, requiring short delivery times or freezing capacity (and uninterrupted energy for it).

How (and how early) was the emerging risk identified?

The framework for detection of quality defects in food is long established, at least in the richer countries. Exposure to supply disruptions is a risk, acknowledged only when food prices spiked in recent years; it was, however, high on the agenda in the remote past, as it still is in many poorer countries.

How did it make it onto the political/government agenda?

It did require what we call 'securitization', that is: declaring a threat to (political) security, such as in the case of uproars and wide protests against the governments.

How was the emerging risk dealt with?

A heightened emphasis on company business continuity plans, some intergovernmental discussions, but that's it. A global authority is not there, albeit that facilitating institutions are present.

What was adequate and/or inadequate about risk management?

There is, to our knowledge, no organized approach involving government and private sector of the supply chains; this leaves the risk at the aggregate level largely unattended.

The case of risks in the food-supply chain shows how measures to mitigate quality risks have led to a functioning network of companies under guidance of governments, but also to concentration in the industry. This increases the risks of supply disturbances as it reduces the number of byways and increases exposure to single defects. Companies may (and do) design contingency plans, even for larger supply disruptions, but cannot foresee the aggregate effects, the changing leadership roles in the supply chain, or the governmental responses to these extreme conditions. This forms a lacuna in the overall risk management strategy.

What guidance can be offered as a result of this case study analysis?

Governments, given their double role as player and (crisis) manager in the food chain. should take the lead in coordinating contingency plans of firms in the food supply chain, and devise its plans to deal with these situations. These plans, at company, sector and government level should be made consistent.