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Supply chain sustainability: A risk management approach

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ABSTRACT

This paper develops an operational perspective of supply chain sustainability, by considering it as a risk management process. It explores the nature of sustainability-related supply chain risks, distinguishes them from typical supply chain risks and develops an analytical process for their management. An empirical study is conducted to generate insights about how sustainability-related risks should be managed in an integrated way. A mixed method approach is adopted for data collection and analysis. Through an extensive literature review and personal interviews, 30 risks across the three main pillars of sustainability (environmental, social and economic) are identified first. A large survey across different industrial sectors and two exploratory empirical case studies in two textile manufacturing companies are subsequently conducted to assess and analyse several dimensions of sustainability-related risk. The failure mode and effect analysis (FMEA) technique is utilised to assess the relative importance of the selected risks, to identify their potential causes and effects and test potential correlations between the identified risks. Based on the findings of the study, risk treatment strategies are proposed for all the identified sustainability-related supply chain risks. The findings show that endogenous environmental risks are perceived to be the most important across different industries and the interconnectedness between several sustainability-related risks is very high. This points to the need for integrated sustainability risk management approaches to facilitate the development of effective sustainable strategies.

1. Introduction

The management of risk in operations/supply chains has emerged as one of the principal research topics in the recent operations and supply chain management (SCM) literature (Narasimhan and Talluri, 2009; Gurnani et al., 2011; Tang et al., 2012). This interest is cultivated by the continuing uncertainty for the world economy, business trends such as increased outsourcing/offshoring and advances in information technology, which have induced the development of complex global supply chains (Trkman and McCormack, 2009). Notwithstanding their major benefits, the extended supply chains are more vulnerable, exposing organisations to higher levels of risk.

The pursuit of sustainability is increasingly recognised as an effective strategy to deal with some of the contemporary challenges facing global supply chains. It leads to enhanced competitiveness and improved financial performance (Wang and Sarkis, 2013) and generates moral capital for firms to mitigate the consequences of potential business risks (Godfrey et al., 2009). Sustainability can be considered as the degree to which present decisions of organisations impact on the future situation of the natural environment, societies and business viability (Krysiak, 2009). With this broad definition, sustainability strategies should consider the level of future *uncertainty* and therefore the *risks* that decisions may impose on the natural and social environments, in addition to the investment costs that are required to make supply chains more sustainable.

Traditionally these investment costs and associated risks were externalised to the natural environment and the society. To a great extent they were also transferred across supply chains and absorbed by a large number of suppliers. The growing consumer awareness of the importance of adopting sustainability strategies that consider the effects on the triple bottom line (planet, people, profit), as well as the development of more accurate sustainability metrics for working conditions, accidents, carbon footprint and corruption indices, have increasingly required companies to take into account these costs and associated risks. This is understandable as the largest part of a company's footprint and social responsibility falls outside of its direct control in manufacturing, packaging and transportation. Recent supply chain scandals such as the horsemeat scandal of European supermarkets, the Rana Plaza disaster in the textile industry and the poor working conditions in Apple's suppliers underscore how these sustainability-related risks affect the businesses.

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The focus of business strategies has moved from local optimisation of sustainability factors, to consideration of the interface of the operation with its suppliers (Kleindorfer et al., 2005). Supply chain sustainability is increasingly perceived as an important source of cost reduction and essential for the long-term profitability of a firm (Wang and Sarkis, 2013). Supply chain managers' responsibilities have evolved to take decisions on sustainable sourcing, local content development, relationship management and asset recovery, in order cut down costs and minimise sustainability-related risks. As a result, the identification of sustainability-related supply chain risks, the assessment of their impact and the development of risk management tools are becoming critical issues for supply chain managers (Hoffman et al., 2014).

Although there is a growing interest in the links between supply chain sustainability and risk, few studies have investigated the risks brought about by (the lack of) supply chain sustainability. Some of them focus simply on environmental risks (Cousins et al., 2004) and others are limited to specific sectors (e.g. Teuscher et al., 2006). Anderson (2005) and Anderson and Anderson (2009) generated seminal articles, advocating that any risk management strategy should incorporate sustainability-related risks. However, the conceptualisation of some of these risks is limited and his work focuses on minimisation of the negative effects of poor sustainable performance purely from a financial management point of view. Foerstl et al. (2010) advanced the study in the field by analysing how competitive advantage can be generated with the development of appropriate sustainable supplier management programmes and Hoffman et al. (2014) investigated the processes whereby supply chain issues may generate sustainability-related risks. There is lack of research that explores the nature of supply chain sustainability-related risks in an integrated manner and develops risk management strategies to treat them. This study sets out to address these issues by exploring two main research questions:

RQ1: What is the nature, the causes and effects of sustainability-related supply chain risks?
RQ2: How can sustainability-related risks be managed?

The aim of the study is to generate insights for the development of sustainable supply chains. We adopt a risk management perspective to sustainability, by taking into account the risk that is associated with the business decisions and their effect on the biophysical, social and financial ecosystems. Based on this theoretical foundation, supply chain sustainability can be conceptualised as the integrated management of a *nexus of* (those specific) *supply chain risks* that are related to the natural environment, the society and the viability of the firm. The proposition that is put forward is that by identifying and successfully managing sustainability-related supply chain risks, an effective allocation of resources across the supply chain can be achieved, thereby rendering supply chains more sustainable. Similarly, supply chain risk management (SCRM) is not conceived merely as cost saving but rather a value creation activity, given that it can lead to more sustainable supply chains.

The paper proceeds as follows. Through a synthetic literature review, the second section explores the nature of sustainability-related risks, differentiates them from typical supply chain risks, and develops the conceptual rationale for considering sustainability as a risk management process. The third section develops an analytical risk management framework that drives the study, based on existing risk management theory. The fourth section presents the methodology for an empirical research that utilises the developed framework to identify areas of concern for organisations. The analysis and discussion of the data are presented in the fifth section. Based on the findings, risk management strategies are proposed to address how sustainability-related risks can be addressed. The paper concludes with a presentation of the findings of the study, its limitations and an agenda for future research.

2. Typical vs. sustainability-related supply chain risks

The nature of risks in supply chains has been explored extensively over the past years (e.g. Hallikas et al., 2002; Zsidisin et al., 2004; Tang, 2006; Wu and Blackhurst, 2009). Typical supply chain risks involve disruptions and delays caused by *supply risks* such supply capacity constraints, quality issues, supplier liquidity problems, supplier dependency, product design changes, delivery delays (Chopra and Sodhi, 2004), *procurement* related risks such as exchange rates, inventories and stockouts (Hallikas et al., 2002), *logistics and transportation* risks (Wu and Blackhurst, 2009), supply chain *relational risks* such as hold up risks and moral hazard (Zsidisin et al., 2004), *demand risks* such as demand volatility and inaccurate forecasts, information distortion and stock accumulation due to the bullwhip effect (Sinha et al., 2004), and infrastructure and systems risks such as breakdowns, equipment malfunctions (Zsidisin et al., 2004). A representative classification of supply chain risks separates them into two major categories: *endogenous* risks that are caused by companies' activities along their supply chains and *exogenous* risks that are brought about to companies by their interaction with external environment that they operate (Faisal, 2009).

Apart from these typical risks, the growing awareness of markets and communities for sustainable business practices, has brought about additional and/or different risks for organisations (Blackburn, 2007). By taking into account the triple bottom line view of sustainability of the Brundtland definition, these risks involve environmental, social as well as financial/economic hazards. These sustainability-related risks are differentiated in many aspects from typical supply chain risks. They consider consequences on the natural ecosystem, corporate reputation, financial exposure, as well as compliance with laws, rather than disruptions in supply chain operations. Regarding the environmental dimension, the risk guiding principle is to satisfy the requirements towards the quality of a shared ecosystem. The social dimension refers to the delivery of responsibilities towards employees, customers, business partners, governments and societies (Porter and Kramer, 2006; Pullman et al., 2009). The financial dimension incorporates monetary risks brought about by the financial environment, deceitful behaviour of corporations and individuals, and an endeavour for sustained economic growth (Jeucken, 2004).

The report by United Nations Global Compact and BSR (2010) suggests that common sustainability-related risks for many industries are greenhouse gas emissions, natural disasters, accidents, energy consumption, packaging waste, environmental damages during logistics and transportation. Other "sustainability" risks may include boycotts against a company's products, litigation against companies to recoup financial damages caused by environmental accidents, non-compliance with laws, or unethical behaviour, social justice risks that arise from unfair employment and working practices, increase in commodities and energy prices as a result of fuel shortages (Anderson, 2005). The BSR report (BSR, 2007) mentions a series of business scandals that are emphasised in media. These relate to social related risk events such as child/forced labour, unethical treatment of animals, environmental malpractice, price fixing, bribery allegations, frauds and patent infringements (Hoffman et al., 2014). These risks are important and pose a threat for many companies, because they have a major

Table 1
Sustainability-related supply chain risks.

Endogenous	Exogenous
Environmental	
• Environmental accidents (e.g. fires, explosions)	• Natural disasters (e.g. hurricanes, floods, eartquakes)
• Pollution (air, water, soil)	• Water scarcity
• Non-compliance with sustainability laws[a]	• Heatwaves, droughts
• Emission of greenhouse gases, ozone depletion	
• Energy consumption (unproductive use of energy)[b]	
• Excessive or unnecessary packaging	
• Product waste	
Social	
• Excessive working time; work-life imbalance	• Pandemic
• Unfair wages	• Social instability
• Child labour/forced labour	• Demographic challenges/ageing population
• Discrimination (race, sex, religion, disability, age, political views)	
• Healthy and safe working environment	
• Exploitative hiring policies (lack of contract, insurance)	
• Unethical treatment of animals	
Financial/economic	
• Bribery	• Boycotts
• False claims/dishonesty	• Litigations
• Price fixing accusations	• Energy prices volatility
• Antitrust claims	• Financial crises
• Patent infringements	
• Tax evasion	

[a] Compliance with sustainability laws may involve issues related to all categories; for classification purposes only it has been put under the environmental dimension.
[b] Energy consumption is related both to economic/financial as well as environmental issues.

impact on organisations' reputation and can cause revenue loss. A distinctive characteristic of these types of risks is that they may have damaging effects to organisations, without causing (or being the cause of) any disruption in its operations.

Possible risks associated with these three main categories are given in Table 1, through a synthesis of different classifications found in the literature (Anderson, 2005; Spedding and Rose, 2007; Blackburn, 2007; United Nations Global Compact and BSR, 2010; Hoffman et al., 2014) and interviews with selected supply chain managers that participated in this study. Their definition and major proponents are provided in Appendix A. This is not an exhaustive list of sustainability-related risks; our objective is to point out the breadth of different sustainability-related hazards that need to be considered for the development of supply chain sustainability strategies.

2.1. Considering supply chain sustainability as a nexus of risks

The potential consequences of these risks may have damaging effects for companies. Any attempt for their management however should not simply be about eliminating the potential costs of their consequences. It should instead be a strategic decision process for the creation, or preservation, or exchange of value (MacMinn, 2002). By conceptualising supply chain sustainability as a *nexus of risks*, a firm's corporate strategic objective is to select which risks to incorporate in its governance structure and operations and which to transfer to the external environment, in a way that could enhance its value proposition to its customers. The strategic choice will then be to allocate resources and develop capabilities in order to manage effectively those risks. Incentives can be realigned across the supply chain by designing appropriate supplier contracts and providing credible assurances that appropriate actions will be taken in case any of these risks occurs. Even though supply chain sustainability has gained weight in the political arena and the marketing strategies of firms, its incorporation in operations decision making processes has not been explored accordingly (Krysiak, 2009; Hoffman et al., 2014).

3. Risk management for sustainability-related risks

SCRM tools are mechanisms to assess and separate risks in a way that they can be borne in the least expensive way (Wu and Blackhurst, 2009). Several risk management frameworks are found in the literature using different terminologies (e.g. Hallikas et al., 2004). A consensus exist however that the main stages of SCRM involve five sequential stages: risk identification, assessment, analysis, treatment and monitoring. These stages are described using examples for sustainability-related risks, to assist the development of a supply chain sustainability risk management process.

Risk identification: This is the first step where all possible supply chain sustainability-related risks are identified with tools such as risk checklists, taxonomies and risk mapping (Chapman, 2006).

Risk assessment: All the identified risks are assessed – typically in terms of their likelihood of occurrence and the impact that they may have on supply chain performance. Usual methods used are either intuitive (e.g. brainstorming), inductive (e.g. checklists, preliminary hazard analysis, event and fault tree analyses and FMEA), or deductive (e.g. accident investigation, controlled experiments) (Chapman, 2006).

Risk analysis: Following their assessment, the risks are prioritised in terms of their relative importance. Pareto analysis, or more complex techniques such as fuzzy AHP are typically used (Faisal, 2009). Their potential causes and consequences are then explored. Root cause and sensitivity analysis, cause and effect analysis, or controlled experiments can be used to identify their drivers and pathways (Hallikas et al., 2004). This is an important step in the

risk management process. Only if a company understands the root causes and potential effects of a risk, it can then decide on the most appropriate response. Risk analysis may also involve correlation analyses, controlled experiments, or simulations to identify potential correlations and causality between risks, which in turn can be useful for any risk treatment strategy as it may be formulated to tackle two, or possibly more risks.

Risk treatment: Four major responses are suggested in the literature to treat supply chain risks. These responses are linked to sustainability-related risks:

- *Avoid*: It involves the *avoidance* of an activity that may lead to exposure to a risk (Miller, 1992) – e.g. drop, or not select suppliers that use unsustainable technologies or processes.
- *Control*: It involves any attempt to *prevent* risks through reduction of the probability of a risk event occurring – e.g., establish a supplier development programme to reduce the probability of environmental accidents. It may also involve actions to *mitigate* the consequences (severity) of a sustainability-related risk, or to reduce the probability of a potential consequence to take place – e.g. respond swiftly to negative reports about unsustainable practices by a supplier.
- *Share*: It involves *cooperation* with suppliers to achieve risk pooling (Miller, 1992) – e.g. multilateral supply chain agreements about the level of carbon foot print across entire supply chain. This response involves partial transfer (avoidance) of the risk to the supply chain. This option may also include transferring the risk by using *insurance* against the likelihood that it will surface (Vose, 2008).
- *Retain*: It involves the acceptance of the potential damage that will be incurred by a sustainability-related risk event, in cases where the actual cost of the other strategies would be higher than the total cost of the potential damage (Vose, 2008).

Any of these responses should be tied to the drivers of sustainability-related risks and anchored to what is an acceptable range of solutions that match the sustainability values of a company, as well as the cost of their implementation. For example, retention of the risk for child labour on the grounds that the overall costs of risk mitigation would be smaller than avoiding the risk, may not be acceptable.

Risk monitoring: The final stage involves continuously monitoring the effects of the response strategy to a particular risk, identifying any changes due to the dynamic nature of supply chains or some changes in regulations or operating policies, and then proposing new solutions (Wu and Blackhurst, 2009).

3.1. Risk management framework for sustainability-related risks

Even though a risk management initiative for sustainability-related risks should follow the same logic, fundamental differences exist to the risk management process for typical supply chain risks. Sustainability-related risks may be relatively easy to identify, however the assessment of their impact on corporate performance is a more complex process, inasmuch as it is not easy to assign monetary value to human capital, to the long term effects on the environment and to corporate reputation (Hoffman et al., 2014). Inductive methods using experts' perceptions, or controlled experiments are more appropriate techniques than the use of operational or financial performance criteria (Rao and Goldsby, 2009). The response strategies of typical supply chain risks aim at reducing supply chain complexity and lead times, minimising costs, improving responsiveness and optimising operational efficiency. Sustainability-related risk treatment efforts on the other hand are geared towards the elimination of the negative consequence to a company's brand, image, or shareholder value (Anderson, 2005). These are by default more abstract terms that are more difficult to evaluate. Table 2 shows a comparison of the different focus between typical and sustainability-related risk management efforts (Nakano, 2013; Chopra and Sodhi, 2004; Hoffman et al., 2014).

Irrespective of the distinctive nature of sustainability-related risks, their management process should be part of the overall business risk strategy of a company, as sustainability-related risks may be precursors to typical supply chain risks (Pullman et al., 2009). For example, natural disasters, or environmental accidents cause supply and demand disruption risks. In this respect, existing, established risk management methods can be useful in the development of an instrument for the management of sustainability-related risks. Following the discussion of the process of managing sustainability-related risks, Fig. 1 presents the risk management framework that is adopted in this study.

4. Research methodology

This study is both exploratory and confirmatory. It seeks to develop novel insights about the notion of supply chain sustainability as a risk management process, through a conceptual identification of sustainability-related risks. It also applies well-established tools and techniques to come up with generalisable answers about how sustainability-related risks should be managed, albeit without the use of hypotheses testing. Due to this dual methodological orientation, the research was designed through the utilisation of three data collection methods and a combination of mixed methods for their analysis. The risk management framework provided the structure for the formulation of data collection and analysis processes of an empirical study, in order to achieve the research objectives.

4.1. Data collection

The nature of sustainability-related risks (RQ1) was explored first through an extensive literature review. An initial list was sent to supply chain managers from 30 selected companies of different industries in the UK and France. A snowballing sampling technique was used, based on initial contacts with two large manufacturing multinational corporations. Through a brief interview managers were asked to identify whether these risks are evident or not in their companies' supply chains.

A large survey was subsequently conducted using the list of potential sustainability-related risks to analyse them using the developed risk management framework (RQ2). A random sample of 600 certified senior supply chain professionals listed with the national purchasing and supply organisations in France and the UK was selected, from different industrial sectors (energy, professional services, construction and engineering, facilities, metals and mining, pharmaceutical, automotive, textile and fashion, aerospace and defence, utilities, food, chemical, electronics, machinery).

The exploration of potential causes and effects of sustainability-related risks, (RQ1) involved face-to-face semi-structured interviews with managers of two textile companies in the UK and France. The interviews lasted 1 h on average. The companies produce a variety of clothing products globally, have a central role in the configuration and resource allocation in their supply chains and have established risk management and sustainability programmes.

4.2. Data analysis

The first four sequential stages of the developed risk management framework steered the analysis process that was followed to answer the research questions. The risk monitoring and control stage is not included in the analysis, as the study was not based on a longitudinal fieldwork in a particular company. The data collection and analysis methods are shown in Table 3.

Risk Identification: A content analysis of academic papers, industry reports and white papers was conducted to produce an initial list of sustainability-related risks. The final list was then completed by incorporating the comments of the interviewed managers (Table 1).

Risk Assessment: The FMEA technique has been applied for the risk assessment and analysis steps. FMEA is an established technique that can be used to study problems that might arise in a system. It can be used to evaluate and measure risk factors in a systematic way, without the need of complex statistical methods (Stamatis, 2003). The FMEA has been applied as follows: the survey participants were asked to evaluate the level of severity (S), probability of occurrence (P) and ease of detection (D) of each risk factor (Tuncel and Alpan, 2010). Likert type scales of answers were used, using numbers from 1 to 7 (Table 4). A definition for each risk grade was also provided to facilitate the responses and avoid confusion. Respondents were also given the option to give potential causes of each risk category. 124 Usable answers were received, giving a response rate of 20.6%.

The detectability (or ease of detection) of a risk hazard is commonly used in the FMEA method (Stamatis, 2003), and it is considered a significant factor in this study. Speier et al. (2011) suggest that the ability to recognise an incident and its consequences depends on the detectability: some incidents/consequences are easy to be recognised, whereas others referring to the environmental consequences, e.g. "*contamination of food with a biological agent that goes undetected*" (p. 725), can be very difficult. In this respect, detectability is not related to the probability of the occurrence of a sustainability-related risk, but to the probability of occurrence of a consequence. It may alter the probability of a consequence of a risk occurring, with the assumption that proactive decisions will be acted upon to prevent its negative consequences (Sodhi and Tang, 2009). This can lower the overall level of importance of a particular risk. By keeping it distinct in the risk management process, it assists in the subsequent state of risk treatment: either through the reduction of the probability of the consequences of an observed sustainability-related risk, or through improving the detectability, thereby preventing the consequence (harmful effect) of occurring.

Risk Analysis: Following the assessment of risks in these three dimensions, FMEA proceeds with a calculation of a risk index score based on the three dimensions of risk. Multiplication of these components enables the prioritisation of risk factors based on risk priority numbers ($RPN_i = S_i^* P_i^* D_i$, where i = risk factor). The higher the RPN, the greater the risk of that event. After the calculation of RPNs, the major risks were calculated through a Pareto diagram. The FMEA process was complimented by a series of cause and effect analyses. Managers of the two participating companies were asked to identify potential causes and effects of all the sustainability-related risks, as well as to assign a level of probability for each of the potential causes or effects they mentioned (from 1-extremely improbable, 2-improbable, 3-neutral, 4-probable, 5-extremely probable). Only those causes and effects that were assigned a high probability score (4 or 5 were included in the analysis). 10 Semi-structured interviews were conducted (5 in each company) that involved the head of risk management and senior operations, and supply chain managers.

Once the major risk factors have been identified and assessed and potential causes and effects were identified, correlation analyses were conducted, using data from the survey, to identify potential correlations amongst the most important risk factors. The correlation coefficient varies between $[-1, +1]$, to reflect a positive $(+1)$, a negative (-1), or no correlation (0). Potential causality between the hypothesised correlations was not investigated. The correlation analyses reflect the managers' perceptions about the degree of relationship between prioritised risk factors and do not involve financial or other performance measurement data.

Risk Treatment: The final step involved analysis of the interview data of the case companies. Managers were asked about the actual or potential response of their company in light of the presence of the identified risks. The discussion was open ended to enable interviewees

Table 2
Risk management of typical vs. sustainability-related risks.

	Typical supply chain risks	Sustainability-related risks
Risk identification	Disruptions to supply chain (delays, forecast errors intellectual property, inventories, capacity, etc.)	Deterioration of ecosystems, effect on societal values and responsible management
Risk assessment	Based on operational or financial metrics/methods	Inductive studies
Risk treatment	Shared, organisation-wide understanding of supply-chain risk through stress testing and tailoring	Portfolio of strategies for managing all three dimensions of sustainability
Methods for risk treatment	Based on management and assessment of risks and proper business planning	Scenario planning and simulation, automatic fault detection, automatic recovery
Risk treatment opportunities	Opportunities for business improvement (internal) and win business from competitors	Competitive advantage and a chance for business excellence

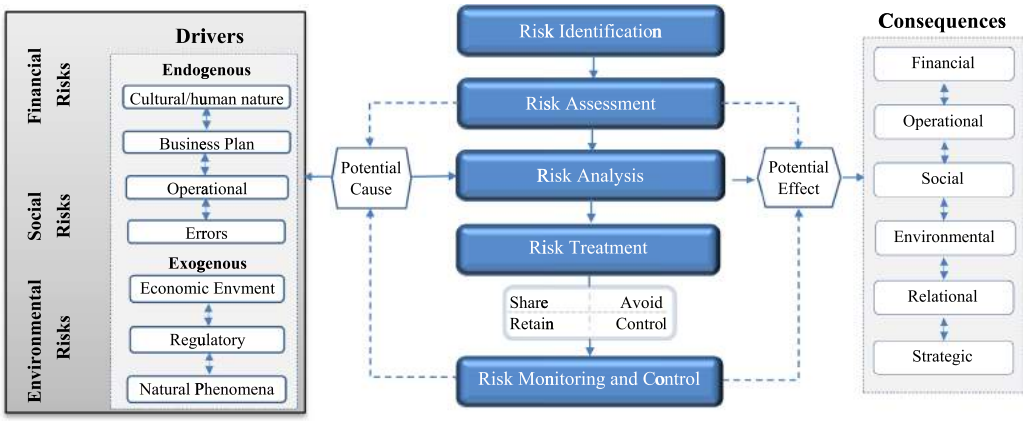

Fig. 1. A risk management framework for sustainability-related risks.

Table 3
Methodology.

	Analytical step	*Data collection*	*Analysis method*
Identify RQ1	• Identify sustainability-related supply chain risks	• Literature Review/Pilot Study	• Content Analysis
Assess RQ2	• Rate the probability of occurrence, severity and detectability for each risk	• Survey	• FMEA
Analyze RQ2	• Calculate risk priority numbers (RPN) and prioritize risks using Pareto analysis • Carry out cause and effect analysis to identify potential risks drivers and effects • Carry out correlation analysis for prioritised risks	• Survey • Interviews • Survey	• FMEA • Case Studies • Correlation
Treat RQ2	• Find strategies and actions to mitigate all possible risk events	• Interviews	• Case Studies

Table 4
Risk scales.

Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**
severity	No effect	Negligible effect	Minor effect	Moderate effect	Major effect	Critical effect	Catastrophic effect
Frequency of occurrence	Almost never	Rarely	Infrequently	Occasionally	Frequently	Usually	Almost always
Detection of hazard	Certain	Easy	Moderately easy	Moderate	Difficult	Very difficult	Impossible to detect

to respond in their own words and identify critical risk incidents with specific response strategies. The interviews were recorded and transcribed verbatim and the analysis sought the emergence of patterns in the interviewees' responses. The companies' practices for actual risks or combination of risks and recommended strategies were finally categorised using the response strategies of the risk management framework: avoidance, prevention, mitigation, cooperation, insurance, and retention.

5. Research findings

5.1. Risk assessment and analysis (RQ2)

Using the FMEA method, RPNs for each potential risk have been calculated. Each answer in the questionnaire for the severity, probability of occurrence and detectability was multiplied with the numbers of the respondents that chose it and the sum of all these figures was divided by the total number of people who participated. The RPN was then calculated as the product of severity, probability of occurrence and ease of detection of each risk factor (Table 5).

Descriptive statistics of the results show that, as a group, sustainability-related risks are perceived as having major consequences for organisations (mean=4.71); they occur occasionally (mean=3.65) and are moderately difficult to detect (mean=3.98). A comparison between the three major thematic groups indicates that, social-related risks are perceived as "slightly lesser risks" compared to economic, or environmental. Although environmental (exogenous) and social related issues have higher media exposure, the survey results show that the perceived priority numbers of economic and environmental (endogenous) risks are higher.

An interesting observation is that endogenous risks are perceived as being more "important" than exogenous. This is because endogenous risks originate primarily from the actions (or lack of action) of a company or its suppliers, which have the direct responsibility for their control/mitigation. On the contrary exogenous risks are mostly unpredictable and more difficult to manage as responsibility is difficult to assign. This finding can be interpreted as a sign of growing awareness of firms' responsibility towards a more sustainable business culture.

The most (perceived) important risk factors are identified with the use of a Pareto analysis (Fig. 2). As it can be seen, a clear Pareto rule does not apply, as 2/3 of the total identified risks add up to almost 80% of the cumulative percentage of risks. This is unsurprising, given that there is a wide variety of sustainability-related risks and companies from different industries that participated in this study, which led to a more homogenous spread of the perceived importance of the selected risks.

Concerns about environmental risks such as greenhouse gases, pollution, non-compliance with sustainability laws and natural disasters dominate the list of the most eminent perceived risks, reflecting both how environmental issues impact economic activity, as well as how little noticeable action has been taken to address them. Respondents also underscore the distressing effects of the recent financial crisis that continues to cripple the attempts for world economic recovery. Among the economic risks, bribery allegations/corruption are perceived as close to equally impactful as financial crises, reflecting both an economic as well as a social phenomenon; the rising awareness of the social responsibility of businesses in light of the increasing socio-economic equality that is experienced in developed as well as developing economies. Child labour is ranked as the most pressing *social* risk, primarily due to its severity and difficulty in detecting it, rather than its frequency of occurrence. This reflects the difficulty in managing global supply chain in a sustainable manner and indirectly points to the need for greater transparency and traceability of supply chain processes.

The top 8 sustainability-related risk factors revealed by the survey are natural disasters, greenhouse gas emissions child/forced labour, financial crisis, bribery allegations, pollution, non-compliance with sustainability laws and energy consumption. It should be noted that as the study has been conducted in northern Europe, the responses and results of the analysis reflect the climatic, socio-economic and regulatory contexts that exist in this part of the world. Hence, risk factors such as heatwaves and droughts, unfair wages, social instability, water scarcity are ranked low, since they are not perceived to be sensitive issues for the companies operating in this region.

Table 5
Priority risk numbers for risk factors.

Sustainability-related risks	Scale: Min = 1, Max = 7			**RPN** *Si*Pi*Di*
	Severity	occurrence	ease of detection	
Environmental (endogenous)				
Energy consumption	4.95	4.85	4.31	103.49
Environmental accidents	5.93	3.45	4.52	92.43
Greenhouse gases	5.94	5.60	4.27	142.17
Non-compliance with sustainability laws	5.32	4.94	3.98	104.42
Pollution (air, water, soil)	5.61	4.86	3.86	105.32
Product waste	3.94	3.56	3.58	50.33
Unnecessary packaging	3.89	4.74	2.95	54.34
Mean	**5.08**	**4.57**	**3.92**	**93.21**
St deviation	0.869	0.781	0.532	
Environmental (exogenous)				
Natural disasters (flood, earthquakes)	6.16	3.72	5.73	131.37
Heatwaves, droughts	4.09	1.62	3.27	21.70
Water scarcity	4.81	2.79	3.26	43.67
Mean	**5.02**	**2.71**	**4.08**	**65.58**
St deviation	1.050	1.052	1.423	
Social (endogenous)				
Child/forced labour	6.13	3.65	5.70	127.40
Discrimination (race, sex, religion, age, politics)	4.10	3.65	4.87	72.64
Unhealthy/dangerous working environment	5.11	3.22	2.90	47.67
Inhumane treatment/harassment	4.81	3.62	3.91	68.10
Unfair wages	3.08	2.21	4.12	28.06
Unethical treatment of animals	4.81	3.41	4.17	68.38
Excessive working time/work-life imbalance	3.13	5.17	4.39	70.94
Mean	**4.45**	**3.56**	**4.29**	**69.03**
St deviation	1.099	0.873	0.861	
Social (exogenous)				
Demographic challenges/ageing population	2.60	4.42	2.22	25.49
Pandemic	4.51	2.42	3.52	38.44
Social Instability/unrest	4.81	2.29	3.21	35.37
Mean	**3.97**	**3.04**	**2.98**	**33.10**
St deviation	1.198	1.194	0.678	
Financial/economic (endogenous)				
Antitrust claims	4.25	2.65	3.70	41.61
Bribery allegations/corruption	4.86	4.62	5.17	116.08
False claims/dishonesty	3.92	4.47	4.04	70.79
Patent infringements	5.02	3.28	3.06	50.42
Price fixing accusations	4.73	2.93	4.11	56.79
Tax avoidance/evasion	3.21	4.51	4.16	60.28
Mean	**4.33**	**3.74**	**4.04**	**65.99**
St deviation	0.685	0.889	0.688	
Financial/economic (exogenous)				
Boycotts	5.74	3.14	3.27	58.84
Energy prices volatility	4.88	3.45	3.57	60.07
Financial crisis	6.11	4.26	4.87	126.81
Litigation claims	4.87	2.11	4.65	47.59
Mean	**5.40**	**3.24**	**4/09**	**73.33**
St deviation	0.624	0.889	0.788	
Mean overall	**4.71**	**3.65**	**3.98**	
St deviation	0.956	1.019	0.812	

5.2. Potential causation and effects of sustainability-related risks

Potential causes of each sustainability-related risk were explored with data collected from the selected case studies. Cause and effect analysis were conducted, to understand the root causes of each prioritised sustainability-related risk. A qualitative assessment based on perceived levels of probability of the occurrence of a causal event and its ease of detection has been used (Hallikas et al., 2002). The interviewed managers were asked to provide a list of potential causes as well as effects of each sustainability-related risk. A taxonomy that classifies the effects of a sustainability-related risk event descriptively into financial, operational, environmental, social, relational and strategic consequences was also used to track risk events. The results of the cause and effect analyses are provided in Appendix B.

5.3. Correlation between sustainability-related risks

The risk assessment analysis proceeded with bivariate correlation analyses to investigate potential relationships between the most important factors (those with an RPN of more than 100). The correlation analysis is essential for the risk treatment stage. If there is a positive correlation between two risk factors, treatment of both risks can be achieved at the same time, whereas if there is a negative correlation, treatment of one risk may have the opposite effects of the other risk. Potential causal relationships between the analysed risks are not investigated in this study. This would have required controlled empirical comparative studies of particular cases to study the effect of one risk on another, which is beyond the scope of this paper. Table 6 shows the results of the

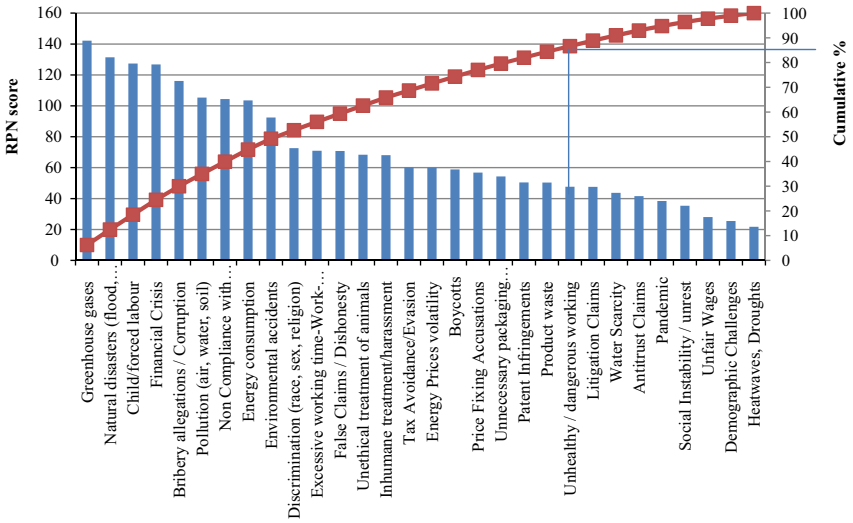

Fig. 2. Pareto Diagram for RPN of sustainability-related risks.

analysis. The analysis could be extended to include more factors; for the scope of this study however, which is to generate insights about how an integrated risk management approach could lead to more sustainable supply chains, conclusions can be drawn by focusing the analysis on the most important factors. The following convention has been applied: 0: *no correlation*; ± 0.1 to ± 0.4: *weak*; ± 0.4 to ± 0.7: *medium*; ± 0.7 to ± 1.0: *strong correlation.*

The findings support some of our expectations regarding the correlation between sustainability-related risks factors. The analysis (predictably) shows strong correlations between factors belonging to the same category (e.g. greenhouse gas emissions with energy consumption and pollution, and the economic risks of bribery with financial crises). Similarly, the regulatory risk of non-compliance with sustainability laws (which was classified under environmental factor in this study) shows statistically strong correlation with the majority of the selected risk factors. This epitomises the importance of the imposition of legal frameworks for safeguarding sustainability objectives.

It is worthwhile to make a note of a few additional observations for the resulted correlations. Firstly, the findings show that there are statistically strong correlations between environmental and economic related factors, as well as social and economic related factors. For example, child labour is highly correlated with bribery (0.572; $p < 0.05$) and financial crises (0.713; $p < 0.05$). However, a significant correlation between social and environmental related factors is not observed.

An interesting finding is the negative correlation between financial crises and energy consumption (0.123; $p < 0.05$) and pollution (0.323; $p < 0.05$). This points out to the temporal, positive effects of economic downturns, since the reduction of economic activity leads to less energy consumption and air pollution. Nevertheless, there still a positive correlation between financial crisis and greenhouse emissions (albeit not significant), which demonstrates that there is no impact to carbon emissions, despite the reduction in economic activity.

5.4. Risk treatment

The last stage in the risk management process has been to propose strategies in order to reduce or eliminate the risk factors. For this step, qualitative data from the interviews with the managers of the two companies was used. The managers were asked to discuss decisions and actions that they would take to deal with the risks and make suggestions for risks that they have less control. Their responses were codified in terms of the 6 risk management strategies (avoid, mitigate, prevent, cooperate, insure, retain). The findings from the cases are presented in Appendix A.

The results show that risk *prevention* and *mitigation* control strategies are the most likely to be used for sustainability-related risks (they appear in 23 and 19 risks categories respectively). Holding safety stock, having quality management systems, due diligence, responsible contracting, purchasing and verification processes, are some common control responses. Risk *reduction* strategies are also commonly used (in 13 risk categories) to reduce the likelihood and/or severity of risk event. Complying with regulations and standards, having contingency plans and training programs for employees are some common reduction strategies for both companies. Interestingly, *cooperation* is not likely to be used (each is considered only in 8 risk categories). This raises some important insights about the lack of supply collaboration and the difficulty to insure against sustainability-related risks. Reflecting the growing importance of sustainability-related risks, a strategy to absorb and *retain* the risk is rare (only suggested in 2 risk categories).

6. Discussion

Based on the conceptual grounding of this study, the results of the empirical findings and discussions with companies' representatives and academics, several implications are drawn for theory and practice.

6.1. Implications for theory and literature

The core theoretical proposition of this study is that supply chain sustainability can be seen as a nexus of risks that need to be managed. Drawing on sustainable supply chain literature and on risk management theory that views risk as an opportunity (Jensen and Meckling, 1976), the study argues that with the development and application of appropriate risk treatment strategies, supply chain sustainability can be improved and the negative consequences of these risks could be restrained. This novel proposition is gaining momentum in the field of supply chain management (Krysiak, 2009; Hoffman et al., 2014) as it provides an operational notion of supply chain sustainability (rather than an abstract objective) and sets the theoretical foundations for the development and implementation of effective sustainable operations and supply chain strategies. This proposition also extends the literature

Table 6
Correlations between most significant risks (RPN > 100).

	GHG emissions	Bribery	Child labour	Energy consumption	Financial crises	Pollution	Non-compliance with laws	Natural disasters
GHG emissions								
Pearson corr.	1	0.373	0.342	**0.882****	0.375	**0.727***	**0.739****	**0.704****
Sig. (2-tailed)		0.118	0.771	0.004	0.121	0.041	0.003	0.038
Bribery								
Pearson corr.		1	**0.572***	0.426	**0.713***	0.412	**0.794***	0.220
Sig. (2-tailed)			0.034	0.412	0.041	0.502	0.029	0.134
Child labour								
Pearson corr.			1	0.250	**0.603***	0.264	**0.680***	0.206
Sig. (2-tailed)				0.684	0.012	0.457	0.038	0.514
Energy consumption								
Pearson corr.				1	−**0.123***	**0.759****	0.329	0.621
Sig. (2-tailed)					0.034	0.005	0.240	0.208
Financial crises								
Pearson corr.					1	−**0.323***	**0.750***	0.250
Sig. (2-tailed)						0.043	0.042	0.432
Pollution								
Pearson corr.						1	**0.346***	**0.616***
Sig. (2-tailed)							0.031	0.028
Noncompliance with laws								
Pearson corr.							1	0.312
Sig. (2-tailed)								0.534
Natural disasters								
Pearson corr.								1
Sig. (2-tailed)								

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

on supply chain risk mitigation strategies (e.g. Kleindorfer and Saad, 2005; Heckmann et al., 2015; Wiengartena et al., in press) by highlighting the different nature of sustainability-related risk and the need for an integrated treatment to deal with the negative consequences.

The distinction of sustainability-related from typical supply chain risks generates useful insights regarding their causes and effects, as well as the nature of appropriate risk responses (see both Appendices A and B). Although the actual causes of typical supply chain risks can be normally attributed to poor or misinformed managerial decisions that result to supply chain disruptions, sustainability-related risks may arise from what appears to be a rigorous business decision without resulting in operational disruptions. The decision for global sourcing may be a wise decision insofar as it may lead to competitive advantage. However poor employment conditions in an offshore location (a social risk that may be out of the control of the purchasing company), may trigger intense stakeholder reactions that may have negative consequences for the firm, without causing supply disruptions. The treatment of sustainability-related risks therefore aim at dealing with the negative effects that these risks have to the companies' stakeholders (shareholders, customers, governments and society), rather than rather than minimising cost of supply chain disruptions.

The empirical findings of the study indicate different interrelationships between sustainability-related risks. Previous research has proved that there is a direct and significant link between environmental and financial performance (Pullman et al., 2009; Wand and Sarkis, 2014), something that can also be extrapolated from this study. A direct correlation between environmental and social risks does not seem to exist. This corroborates findings from other studies which also point out that social sustainability performance does not have an effect on environmental performance and vice versa, yet both dimensions are correlated with economic/financial performance.

6.2. Managerial implications

By considering the risks associated with sustainability, the findings of the empirical study have strong implications for the development of integrated sustainable supply chain strategies. The empirical research shows that the majority of the most eminent sustainability-related risks emanate from the company's activities or goods that it creates (or its supply chain processes). In their attempt to deal with sustainability-related risks, the priority of supply chain managers would be to identify these "endogenous" issues and, through risk management strategies, treat them appropriately. Based on the findings from the case studies, a company's strategic direction to "endogenous" environmental and social risks should be to internalise them and to attempt to find strategies to *mitigate* them through reduction, control and sharing processes, rather than to avoid, or transfer them to the extended environment. The chief operating officer of the UK-based textile company explained during his interview:

> *"Our priority is to increase as much as possible the transparency across our supply chains, to be able to identify and eliminate any potentially damaging practices of ourselves or our suppliers to the environment. If we end up paying for the damage we create, this would eradicate our profit"*

Conversely, risks that originate outside an organisation are more difficult to identify and control with mitigation strategies. Sinha et al. (2004) argue that there is no clear benefit for an

organisation to attempt to deal with exogenous before mitigating endogenous risks, because these risks are largely outside the enterprise's control. Exogenous sustainability-related risks should also need to be managed, albeit with different risk treatment strategies. The cause and effect analyses of the case studies further revealed that unsuitable investment environments and disruptions in production may occur. Although these types of risks are difficult to control, they can be managed through efficient contingency planning (Wu and Blackhurst, 2009). Natural hazards can be mitigated with control responses and sometimes with sharing and flexibility responses. Although exogenous environmental and financial risk factors are common for the companies in this study, prioritised risk events can change according to company's operations and its supply chain. When responses for sustainability-related and typical supply chain risks are compared, it is seen that although control and reduction responses are used by both risk events, flexibility, sharing and risk insurance responses are usually preferred for typical risks. The CEO of the French textile company described: *"…we have to be ready, many things can happen that could disrupt our business. We have contingency plans for our projects (especially in vulnerable regions), we have a supplier auditing programme, but increasingly we have also started insuring against extreme climatic events".*

The proposed sustainability risk management framework can be applied on different supply chain levels: (i) to a firm that is interested in incorporating sustainability-related risks to its operations strategic decisions, (ii) to the dyadic relationship with certain suppliers as part of the supplier selection and assessment processes, and (iii) the overall supply chain strategy where sustainability-related risks relate to decisions about regional of international investment, and the relationship of a firm with its extended network of stakeholders (customers, governments, shareholders).

7. Conclusion

Although a growing body of research has examined the nature of supply chain risks and generated useful insights, there has been little research to expand risk considerations that involve the notion of sustainability across the supply chain. The objective of this study has been to identify specific sustainability-related risks and through the development of a risk management framework and a systematic empirical research to propose strategies for their treatment. Its overall aim has been to develop a process for enhancing the supply chain sustainability. A list of thirty (30) sustainability-related risks has been produced and classified into six thematic clusters through a comprehensive literature review. A detailed risk management process has been developed and specific recommendations have been made for supply chain managers. The findings of the empirical study show that the majority of the most significant sustainability-related risks relate to endogenous risks that result from companies' operations. These risks are generally controllable, or partially controllable if appropriate strategies are put in place. Major exogenous sustainability-related risks were also found to be correlated to endogenous risks, which leads to the conclusion that through a holistic and systematic risk management process sustainability-related risks could be contained. Furthermore, several detailed risk management strategies for each of the identified types of risks are also proposed, categorised into eight responses, each containing different strategies based on high vs. low-risk areas.

The study contributes to the sustainable SCM literature, by considering supply chain sustainability as a risk management process. With this perspective, sustainable supply chain strategies should be established by identifying and assessing pertinent sustainability-related risks and then analysing their estimated financial, environment and societal effects. This approach serves as a springboard to propose an alternative theorising of the organisation of economic activity that can facilitate the effective allocation of resources across the supply chain, through the effective appreciation and treatment of several types of risks that govern economic uncertainty. It also contributes to the SCRM literature, through the development of a wide-ranging list of sustainability-related risk factors and the design of an analytical framework for risk management that combines well-known techniques (FMEA, causal models, and correlation analyses). The framework provides a structured and systematic method for supply chain practitioners for the containment of sustainability-related risks.

There are a few limitations that can be overcome with future studies. Firstly, the list of sustainability-related risks should not be considered as an exhaustive list. Its purpose is to illustrate the wide variety of different risks related to sustainability. Secondly, the survey collected and analysed data from companies in different economic sectors in two countries. For that reason, the resulting prioritisation of the risk factors and proposed risk management strategies should not be viewed as generalisable findings, as the level of severity, frequency of occurrence and level of detectability of risks are likely to be unique for a single organisation. Finally, causal relationships between risk factors (or between the different risk categories) are not investigated in a systematic way. The occurrence of a sustainability-related risk event may not necessarily yield a specific undesirable consequence, or it may yield not one, but several consequences. Similarly, the occurrence of a risk event may be attributed to a number of potential causes. In order to determine actual causes and effects of specific sustainability-related risks, controlled (experimental) case studies would have to be conducted to ensure the internal validity and reliability of the study. An event study could be applied to establish specific causes and effects of sustainability-related risks during the period that risk events take place (Surroca et al., 2010).

Future research can advance the current study in several ways. First, studies can be conducted to explore varying risk attitudes and behaviour among different managers. Risk averse and risk seeking managers have an influence on decision making, which can change the choice of risk response. The results can be then linked to the correlation analysis that has been conducted in this research, which will give a comprehensive understanding of the choice of risk mitigation strategies. A second area of future research could utilise "hard" measures such as financial and operations' performance data, to determine the consequences of sustainability-related risks on companies and based on this, risks could be prioritised. As in all empirical studies, the study could benefit from a larger sample size. For example comparative studies could be conducted in different economic/climatic regions to investigate the perceptions and effects of sustainability-related risks.

The pursuit for supply chain sustainability poses both significant opportunities and major risks for organisations. The theoretical potential and empirical evidence about the importance of sustainability-related risks that this study has provided generates exciting research challenges to be tackled in the future. Supply chain management and production economics research would considerably benefit from studies that investigate sustainability-related risk management topics.

Appendix A

Definitions and treatment of sustainability-related risks

Sustainability risk	Definition	Source	Risk response	Practices
Environmental (endogenous)				
Energy consumption	Inefficient energy use for the production and delivery of goods and services	Diesendorf (2007)	– Mitigate – Prevent	– Invest in renewable energy sources – Utilise energy efficient technology
Environmental accidents	Accidents that affect the environment; caused by a firm's operations, machines or staff	Blackburn (2007)	– Prevent – Mitigate – Reduce – Cooperate – Insure	– Locate facility away from urban areas – Emergency plans for potential accidents – Respond fast to media/ government reports – Work with suppliers to identify risk source – Insure against potential catastrophes
Greenhouse gases	Emission of atmospheric gases that contribute to the greenhouse effect	Anderson and Anderson (2009)	– Avoid – Prevent/share	– Use clean energy, avoid polluting suppliers – Monitor CO_2 footprint across the supply chain – Engage suppliers in GHG emission reduction programmes
Non-compliance with sustainability laws	Failure to comply with environmental, employment and financial regulations such as the EU directives, UK Anti Bribery Act, labour legislations/Equality Act	www.Europa.eu, www.Defra.gov.uk	– Prevent – Control – Share	– Collect and disseminate regulatory information to ensure compliance – Acquire ISO14001 certificate – Conduct sustainability audit with key suppliers
Pollution	Air, water or soil contamination due to facility operations or products	Blackburn (2007)	– Avoid – Prevent – Reduce	– Locate facility away from urban areas – Design contracts to prevent pollution – Sustainable waste management/disposal
Excessive product waste	Unusable or unwanted substance or material produced during, or as a result of a process, such as manufacturing or transportation	The Free Dictionary, www.thefreedictionary.com	– Mitigate – Prevent	– Recycle – Sustainable waste management/disposal – Apply lean management practices
Packaging	Failure to comply with packaging standards or excessive packaging	Blackburn (2007)	– Prevent – Cooperate	– Use sustainable packaging – Design products requiring less packaging
Environmental (exogenous)				
Natural disasters	Disruptions caused by natural disasters (hurricanes, flood, storms, earthquakes)	Waters (2011)	– Mitigate – Cooperate/ Reduce – Insure	– Contingency plan for SC resilience – Work with suppliers to receiver fast from potential consequences – Insure against disaster

Heatwaves, droughts	Vulnerability caused by increase in temperature due to climatic change	Halldórsson et al. (2009)	– Mitigate – Cooperate/ Reduce – Insure	– Contingency plan for SC resilience – Build flexible supply chain – Insure against phenomenon
Water scarcity	Risk caused by the lack of sufficient available water resources to meet the demands of water usage (for energy creation, manufacturing, transportation)	UNDESA (2014)	– Prevent – Mitigate – Cooperate	– Clean energy for less water consumption – Water Recycling – Continuously assess the water footprint
Social (endogenous)				
Child/forced labour	Work that deprives children of their childhood, and is harmful to physical and mental development	ILO (2014)	– Avoid – Prevent – Share – Mitigate	– Avoid investment in regions with poor record for child labour – Develop and apply responsible sourcing policy – Work closely with suppliers to limit the child labour – Respond swiftly to negative reports
Discrimination	Prejudicial treatment of an individual based on their membership in a group or category, in a way that is worse than the way people are usually treated	Cambridge Dictionary	– Prevent – Mitigate – Transfer	– Generate practices for equal opportunities – Formalise complaint handling system to act swiftly to allegations – Employ legal services to deal with equal opportunities
Unhealthy/dangerous working environment	Working conditions under unhealthy operations in untrusting workplace/use of hazardous materials that threaten employees' health and safety	Halldórsson et al. (2009)	– Prevent – Mitigate – Reduce – Insure	– Training programs for employees. – Locate facility away from urban areas – Safety instructions and contingency plans – Full medical Insurance for employees
Inhumane treatment/ harassment	Behaviour which has the purpose of violating an individual's dignity or creating a degrading, hostile offensive or humiliating environment for an employee	Clift (2003)	– Prevent – Mitigate	– Generate practices for equal opportunities – Have a formal complaint handling system to act swiftly to allegations; – Have remedial/ disciplinary action
Unfair wages	Unfair payment to employees	Blackburn (2007)	– Prevent – Cooperate	– Apply laws for minimum or fair wage – Engage with suppliers, industry bodies, NGOs to monitor wages
Unethical treatment of animals	Treat animals cruelly and cause unnecessary suffering or pain to them for business purposes	PETA (2014)	– Mitigate – Prevent – Reduce	– Disclose info. about animal treatment – Apply EU Animal Welfare Strategy – Define crisis team to deal with attacks
Excessive working time	Heavy workloads and job demands beyond legal requirements	The Free Dictionary, www.europa.eu	– Reduce – Mitigate – Prevent	– Reduction of flexible hours – Establish incentives for balanced life

			– Insure	– Monitor productivity levels continuously – Use health insurance for all employees
Social (exogenous)				
Demographic challenges	Employment issues related to mass immigration, ageing population, population growth	UK Bribery Act		
Pandemic	An epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people	Last (2001)	– Retain – Reduce	– Adopt to new reality – Train employees/adopt new technology
Social Instability/unrest	Disorderliness and disruption due to strikes, work stoppages, street protests, demonstrations	ILO (2014)	– Mitigate – Reduce – Insure	– Have health procedures to protect staff – Contingency plans for remote work to ensure resilience in operation – Insure staff against pandemic
Economic (endogenous)				
Antitrust claims	Claims arising against a company that violates competition laws (cartels, price gouging, refusal to deal, tying, predatory pricing)	Taylor (2009)	– Avoid – Reduce – Mitigate	– Avoid investment in unstable regions – Build relationship with local communities, – Monitor flow of resources from unstable areas – Build extra capacity
Bribery/corruption	Offer (or accept) money or gifts to a potential client (from a supplier) in exchange for business	Black's Law Dictionary (2009)	– Prevent – Cooperate	– Adopt antitrust principles to recognise when an problem is possible – Work with potential suppliers to interpret law
False claims/dishonesty	A deception deliberately practiced by an individual or a corporation in order to secure unfair or unlawful gain	False Claims Act	– Avoid – Prevent – Mitigate	– Avoid countries with poor transparency record – Apply UK Bribery Act: Inform and train staff – Implement compliance programme to detect corruption, introduce whistleblowing systems, use IPOs – Monitor conduct of third parties/agents
Patent infringements	Sale, or commercial use of a patented invention without the permission of the patent holder	The Free Dictionary, www.thefreedictionary.com	– Prevent – Mitigate	– Certify Employees – Use whistleblowing systems, enforce false claims Act
Price fixing	Conspiracy between sellers or buyers to coordinate pricing for mutual benefit of the traders	Black's Law Dictionary (2009)	– Prevent – Mitigate – Insure	– Licence product – Insure against infringements from customers/suppliers
Tax avoidance/evasion	Tax liability minimisation that occurs from a sound financial plan/ illegal attempt to reduce the tax amount payable by fraudulent means	Black's Law Dictionary (2009)	– Prevent – Reduce	– Develop and implement compliance procedures with EU laws – Establish reputation Management programme

Economic (exogenous)				
Boycotts	Abstaining from using, buying, or dealing with an organisation, as an expression of protest, usually for social, moral, or *political* reasons	Wikipedia (Wikipedia.org)	– Reduce – Prevent – Retain	– Collaborate with tax collection authorities – Conduct independent audit to ensure compliance – Accept risk if penalties are low
Energy prices volatility	Unpredictable and continuous energy and fuel price variation		– Mitigate – Cooperate – Transfer	– Improve Environmental Audits – Close industry collaboration – Hedge against volatility
Financial crisis	Sudden loss of large part of nominal value of financial assets (bubbles, banking panics, stock market crashes, currency crises, sovereign default)	Wikipedia (Wikipedia.org)	– Mitigate – Transfer	– Ensure liquidity through insurance-like securities or securitisation – Engage governments, financial institutions to jointly support liquidity
Litigations	Probability of lawsuits against a company for sustainability related issues	Investopedia	– Prevent, Avoid – Insure	– Develop a review system that tracks and evaluates litigation exposure – Develop an internal information system that informs managers in a timely manner existing or pending litigations

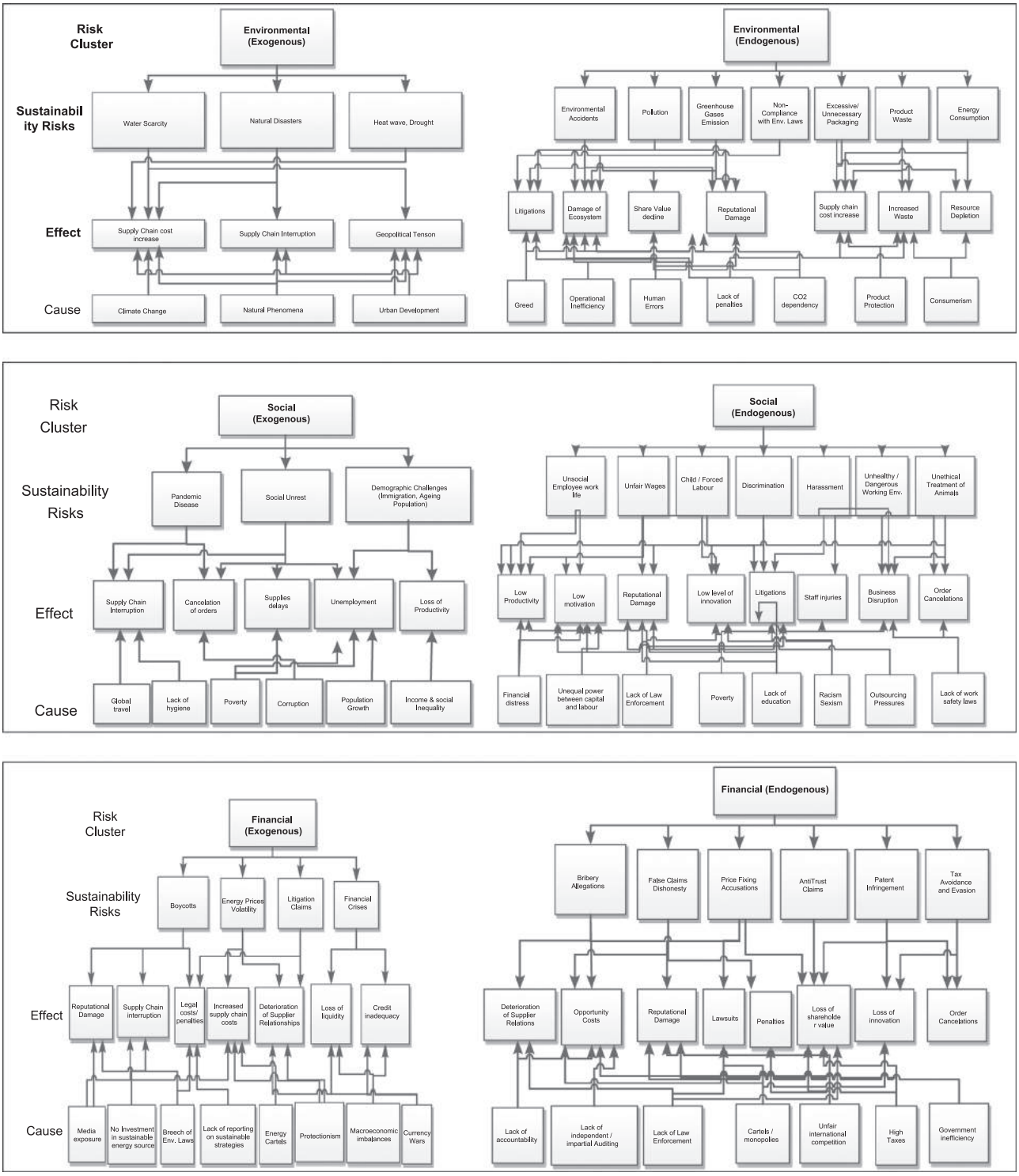

Fig. B1. Hierarchical risk causes and effects.

Appendix B

See Fig. B1.

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