Strengthening Resilience of Supply with Essential Goods through Public-Private Emergency Collaborations: Challenges and Incentives

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Abstract

Private actors ensure the supply of essential goods such as food, drinking water, and medicine to the population. However, crises such as natural disasters, human-caused conflicts, or pandemics can cause disruptions of private supply chains and, subsequently, supply shortages in the market. In this case, public actors need to become active and responsible for supplying the population with essential goods. Nevertheless, the ability of public actors to provide essential goods in a crisis is constrained due to limited resources and a lack of knowledge about the relevant commercial supply chains. Therefore, companies that produce, distribute, or sell essential goods can be valuable partners but must be adequately motivated to participate in crisis management. A promising form of collaboration to strengthen resilience lies in the concept of public-private emergency collaborations (PPECs), elaborated in different studies within the dissertation. The necessity of PPECs and their public acceptance depends on the attitude and preparation of the population, which is why the empirical investigation of these accompanying questions is another central part of the dissertation.

Five studies published as companion articles address necessary prerequisites and approaches to the design of collaborations in crises: Study A examines the PPEC concept and puts it into a more specific framework, considering logistical requirements in a game-theoretic model. The model addresses private actors' incentives to collaborate, such as a positive reputation or learning effects for internal processes. Both can provide a substantial —- not least financial —- advantage for the company in the long run. Study B investigates crises and PPECs from a company perspective by evaluating an empirical study with 398 responses from essential goods and logistics companies. The results show companies' high interest in participating in PPECs. Nevertheless, the data reveals that certain conditions, such as adequate compensation or consideration of companies' operational procedures, must be fulfilled for collaboration with public actors. Study C addresses the attitude of the population in a survey of 402 randomly selected participants and finds that the population highly values companies' involvement in PPECs. The companies' communication strategy and the population's risk perception affect the attitude. Study D analyzes the stockpiling behavior of the population in two door-to-door surveys, the first with 330 participants and the second with 402. The timing of the before-and-after survey provides a special value: The study considers possible changes due to the COVID-19 pandemic. The results show low stockpiling levels and that stockpiling has only marginally increased during the COVID-19 pandemic. Study E examines an economic experiment with 262 participants in 13 sessions to clarify the importance of safety-stock levels for companies' reputation in a failure-prone supply chain. The design made it possible to disentangle indirect losses due to customer churn and direct losses due to disruptions, thus quantifying firm reliability and customer loyalty.

Four general recommendations for the stakeholders in crisis management, public actors, private actors, and the population, are derived: First, all stakeholders must adapt their behavior and improve current protection measures and strategies against global crises and supply chain disruptions. Second, humanitarian crisis management is a team effort involving many actors. Therefore, understanding synergies, mutual attitudes, and the incentive constellation of the actors involved is a crucial prerequisite for success. Third, crisis management also includes the right communication strategy. It is not only important to contribute but also to communicate it in a successful and convincing way. Fourth, collaborative approaches, as in PPECs, where each stakeholder brings his or her strengths into the collaboration, are beneficial for all parties involved, and increase society's overall resilience.

Consequently, this dissertation provides valuable insights into the status of humanitarian crisis management from the perspective of different stakeholders. It offers the potential to improve this field of research through collaborative approaches, as in PPECs, addressing the strengths and incentives of stakeholders accordingly.

Contents

Abbreviations

BCM	Business Continuity Management
CSR	Corporate Social Responsibility
EFA	Exploratory Factor Analysis
FEMA	Federal Emergency Management Agency
FMCG	Fast Moving Consumer Goods
GDP	Gross Domestic Product
HL	Humanitarian Logistics
HO	Humanitarian Organization
KPI	Key Performance Indicator
LR	Long Run
LSP	Logistics Service Provider
NGO	Non-Governmental Organization
PPEC	Public-Private Emergency Collaboration
PPP	Public-Private Partnership
RQ	Research Question
SC	Supply Chain
SD	Standard Deviation
SR	Short Run
THW	Technisches Hilfswerk
UN	United Nations
WTP	Willingness To Pay

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Part I

Framework, Foundations and Implications

1 Introduction and Motivation

When the Coronavirus Disease 2019 (COVID-19) pandemic started to spread across the globe, it caused strain, delays, and outages in global supply chains (SC) (WEF, 2022). The fragility of nowadays interconnected and globalized SCs came to surface (HBR, 2020). Inter alia, this pandemic came with severe consequences for many sectors of humanity (Soga et al., 2021). Public crisis management departments became active in order to cushion the most severe distortions, e.g., by disposal of protective measures of the population (DLF, 2022), or financial support of stumbling enterprises (tagesschau, 2021). However, particularly during the first wave of the COVID-19 pandemic, there are many examples of companies that adapted their production chains and started to produce, for example, medical equipment such as respirators (3M, 2022) or disinfectants (FOCUS Online, 2020). Other companies were among the first to offer COVID-19 testing centers to the population (Müller, 2021). These examples illustrate the important contribution that companies are able to provide in times of crisis.

The context of this dissertation is the analysis of crisis-related supply shortages, with a focus on preparedness and management. That is, the forward-looking planning and provisioning of the population during and after a crisis event, such as those necessitated by natural disasters, accidents, or human intervention. The management of crises in developed countries like the US or Germany that affect the population lies within the responsibility of public actors (FEMA, 2022; BBK, 2022). In severe crises, public actors have to take responsibility for the population's supply of *essential goods*, such as water, food, and medicine (Fang and Norman, 2014). In the example of Germany, central players in humanitarian logistics (HL) have state functions, especially civil protection authorities and the Federal Agency for Technical Relief (THW) (THW, 2022). Nevertheless, experience from past crises in industrialized countries shows that the organized involvement of private-sector actors, such as food manufacturers, retailers or freight forwarders, can contribute to a faster and higher level of supply for the population in crisis management (N. Busch and Givens, 2013). Companies can be valuable and supporting partners in these efforts.

Collaboration between public actors and private actors in the form of public-private partnerships (PPPs) is well known in the infrastructure sector, as well as in education, including construction, management, or maintenance of infrastructure, and provision of education services (Patrinos et al., 2009). In the crisis context, PPPs promise potential for crisis management in terms of possible efficiency and time gains — factors of particular importance in crisis management. The basic assumption here is that private actors have a high potential for resources that can support the state in crisis management. These cooperation potentials raise questions regarding the particular design of emergency logistics and problems of incentives in the collaboration (relationship) and contract design. On the one hand, private actors can support state actors in crisis management through their

existing resources, on the other hand, companies may pursue their own goals that do not directly coincide with humanitarian crisis management.

This dissertation was written while participating in the NOLAN project (2018–2022). This research project aimed at analyzing a special form of PPPs, called public-private emergency collaboration (PPEC), particularly designed to improve crisis management. The research focus laid on the identification of collaboration in the emergency context in urban areas in Germany. To this end, numerous discussions with experts from public authorities and companies shed light on the necessities and challenges of a collaborative approach. In addition, four workshops were organized, each with around 40 participants. Representatives from public authorities included, among others, emergency agencies and civil protection authorities at various levels. On the business side, representatives who are active in the essential goods sector, as well as in the related logistics, were present. This dissertation benefited considerably from the numerous feedback and valuable advice provided by the participants.

The main goal of this dissertation is to analyze PPECs (cf. Subsection 2.3.2) from an empirical and incentive-oriented perspective. Thereby, a central aspect is the empirical validation of the concept and its implications through surveys and a laboratory experiment. These empirical analyses examine the experiences, motives, incentives, and behaviors from the respective stakeholder perspective, and are complemented by game-theoretical modeling. Theoretical and empirical findings are used to identify strategic measures that enable cooperation between public and private actors for optimized crisis prevention. The game-theoretic model includes a plausible objective function of the involved actors to identify and analyze the resulting Nash equilibria. In total, five objectives are addressed in this dissertation, which are presented in Chapter 3.

The dissertation at hand aspires to provide decision-makers in authorities and companies with a set of methods to elaborate the circumstances under which companies would participate in PPECs. In addition, the crisis preparation of the population on the basis of stockpiling of essential goods is investigated, as it is a deliberate action on the part of those affected to conduct crisis prevention. Consequently, the dissertation also provides critical insights for researchers and practitioners. It can, thereby, improve the identification of the roles and responsibilities of stakeholders affected by humanitarian crises and the opportunities that arise from collaborations between public and private actors in crisis management to strengthen the resilience of the society as a whole.

The dissertation is structured as follows. Chapter 2 includes an overview of relevant terms, literature, and research gaps. Afterwards, Chapter 3 highlights the selected methodology. The main results of the respective studies A–E are reviewed in Chapter 4 before the managerial implications of the studies are highlighted in Chapter 5. Lastly, the dissertation is summed up and critically evaluated in Chapter 6. The companion articles A–E are attached at the end of the dissertation.

2 Theoretical Foundations

This chapter analyzes the current state of research and practice of the topics most relevant to the dissertation. To this end, Section 2.1 deals with crises, followed by Section 2.2, which considers the three relevant actors in this dissertation: public actors, private actors, and the population. It also explicitly addresses other possible actors in the context of crises and explains why they were not considered in this dissertation. Section 2.3.1 starts with presenting cooperative approaches in non-crisis management and then moves on to collaborations in the context of crises and reviews the existing literature on PPECs. Finally, in Section 2.4 the state of the art of incentive analysis and empirical research is presented, bringing into focus the use of these methods concerning crisis management and the analysis of collaborations.

2.1 A Categorization of Different Types of Crises

The term *crisis* originates from the greek word $kr\ìsis$, meaning *turning point* or *decisive turn* (Merriam-Webster, 2022). Different groups of crises, such as human-made crises, natural disasters, organizational crises or technological crises have been defined to categorize the causes (Bundy et al., 2017; MSG, 2022). According to Munich RE (2022), global economic losses caused by natural disasters alone have amounted to US$ 280 billion in 2021 (risen from 210 US$ billion in 2020), which equals about the GDP of Finland (Statista, 2022).

Bundy et al. (2017) elaborate on two perspectives on crises: the analysis of crises' internal dynamics and the managing of external stakeholders. The focus of this work is on the second part, as it aims to enhance managing of the incentives and behaviors of different stakeholders involved in crisis management. The crisis itself is considered a shock-like event, which leads to supply shortages in the market. The collaborative approaches considered in the dissertation are intended to strengthen resilience of the society. The United Nations define resilience in the context of crises as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, [...]" (UNDRR, 2022).

Of particular interest within this dissertation is the impact analysis of crises on the population leading to a lack of essential goods. These supply crises, comprising shortages of essential goods such as water, food and medicine, caused by disruptions, typically need to be managed by the public authorities of the affected areas and the locally operating companies. An example might be a spatially and temporally limited drinking water shortage due to drought or contamination. There was, for instance, a short-term blue discoloration of tap water in Heidelberg in 2019, which

triggered a run on packaged drinking water in supermarkets (Heidelberg24, 2019). Even though public authorities gave the all-clear after only a few hours, the empty supermarket shelves, which were the result of panic buying by the local population, illustrated the dynamics of such an incident. Another example is fuel shortage, as it has already occurred in the past due to low water on the Rhine and thereby blocked supply routes, or due to political decisions regarding the war in Ukraine (Euronews, 2022; Reuters, 2022).

Long-lasting crises, such as those caused by years of famine in Yemen or Sudan, must be clearly distinguished from the aforementioned crises. These types of crises differ, because the local authorities and companies are not in a position to cope with the crisis on their own. International aid measures are needed, such as those provided by the United Nations (UN), Unicef, or many non-governmental organizations (NGOs) in the regions concerned (WFP, 2022). As important as it is to manage such crises and to explore them at a scientific level, the requirements and incentives, as well as the working conditions that are to be expected by the stakeholders involved, are fundamentally different.

To summarize, this dissertation focuses on crises that can be mitigated and overcome by the respective affected parties, including public actors, private actors and the population, most effectively in collaboration. The analysis and evaluation of the consequences for the population caused by a crisis are of particular interest, mainly focusing on the (non-)availability of essential goods such as food and drinking water.

2.2 Stakeholders in Crises

After specifying the type of crises considered in this dissertation, this section analyzes how the consequences of crises can be overcome through the actions of various stakeholders by addressing them in more detail.

2.2.1 Public Actors

In the context of crises, public actors refer to all public institutions involved in crisis management. These comprise authorities explicitly dealing with crisis management, such as the Federal Emergency Management Agency (FEMA) in the US or the Federal Office for Civil Protection and Disaster Assistance (BBK) in Germany (FEMA, 2022; BBK, 2022). It also includes the Ministry of the Interior and the relevant parts of the legislation. In addition, actors dealing with the execution of relief measures are considered. In the example of Germany, the key players are civil protection organizations such as the THW (THW, 2022) and the BBK. Furthermore, civil protection parts of an army or the police are included. Public actors are financed through tax money (Henry, 2015). In the case of the THW, they are also heavily supported through volunteers (THW, 2022).

The main objective of public actors within crisis management is to minimize the suffering of the population (Holguín-Veras et al., 2013). From a strategic perspective, this is mainly achieved

through crisis resilient legislation, data collection, and information exchange with other public and private actors before any crisis event (cf. Figure 4.4). In the event of a crisis, collecting up-to-date information, coordinating support, and supplying the population with essential goods on a timely basis is crucial. Furthermore, the prioritization of support also means that differentiating people according to their vulnerability may become necessary. This includes a plan that establishes a reasoned sequence for prioritizing population based on vulnerability, given limited supplies (Stallkamp et al., 2020), preferably before the crisis. Ultimately, public actors have the power to seize goods and resources if necessary (Sattler, 2008). Due to today's highly complex processes and digitalization in companies, this seemingly quick-to-perform option, to seize resources without coordination with companies, does not lead to the desired goal as becomes clear by reference to a high rack warehouse by a logistics expert: The withdrawal-processes of these warehouses are fully automated and so complex that they can only be managed with the right qualification.

The strength of public actors in humanitarian crisis management lies within the clear objective of minimizing the population's suffering. However, the scope for public actions is limited, because they only have a restricted supply specifically designed for crisis situations. Due to the high preparedness costs of most crisis scenarios (measures are usually difficult to be planned in detail in advance), the equipment of public actors remains relatively small and is not designed to serve thousands or even hundreds of thousands of people at short notice. In addition, public actors often need time to activate the appropriate structures until aid can reach the population to ultimately help in the event of a crisis. This downside is emphasized through a lack of capacities, resources, and personnel (Lemonakis and Zairis, 2020). Private actors on the contrary, mostly have existing, well-implemented infrastructures and resources.

2.2.2 Private Actors

The term private actors refers to any company working in a free market environment — from the one-person kiosk at the street corner up to a multinational software company or car manufacturer. Logistics, water, food, and medicine companies are especially interesting candidates for crisis management collaboration (Fang and Norman, 2014). These companies are assigned to the essential goods sector in the context of this work. This restriction emphasizes the clear focus on goods that are of particular need to the population in the event of a crisis. Moreover, with respect to transportation and stockpiling, logistic companies are of extraordinary importance.

The objective of private actors is to gain profits to succeed in the market in the long term (Holguín-Veras et al., 2012), which is achieved by selling products or services. According to the authors, engagement of private actors in crisis management is considered a non-profitable extra activity. However, there are many potentials within a crisis context, which may incentivize companies to engage in crisis management.

If private actors are affected by disruptions in their own SC, stockpiling products can be an option to overcome supply failures and to prevent customer churn. According to the Ponemon Institute (2011), "the cost associated with business disruption, which includes reputation damages and

customer churn, represents the most expensive cost category." Hence, reputation is related to the company's credibility, even in times of crisis, to have products on hand for the customers. Customer churn, in turn, indicates the share of customers who were once customers but who no longer opt for the product or brand due to dissatisfaction (Ponemon Institute, 2011).

Companies can gain a positive reputation from engaging in humanitarian crisis management since such an engagement is closely related to corporate social responsibility (CSR) actions (Izumi and Shaw, 2015). According to the authors, CSR related actions can positively influence a brand's long-term success and reputation by raising customer awareness. In particular, the voluntary work of companies in education, care for the elderly, or poverty reduction is linked to an increase in positive perceptions by customers (Hamann and Strittmatter, 2014; Swanson and Smith, 2013). Another opportunity for companies lies within the learning outcomes from any crisis engagement that could be used for internal crisis management improvements as part of business continuity management (BCM) (Schätter et al., 2019).

The strength of private actors in humanitarian crisis management lies in the fact that many of the tasks involved, such as the production and provision of essential goods and the associated logistics tasks, are part of the private actors' everyday business and thus they are specialists in their particular field. The involvement of private actors in humanitarian crisis management certainly requires adjustments to their operational processes, but companies can often build on a wide range of experience in this area (Rodríguez-Espíndola et al., 2018; Bealt et al., 2016). Furthermore, due to globalized SCs, in particular large companies are flexible in adapting delivery quantities and target locations as needed. During the COVID-19 pandemic, for example, many industrial companies were able to adapt their plants and equipment to produce medically necessary goods such as respirators, disinfectants, or masks (3M, 2022; FOCUS Online, 2020).

2.2.3 Population

In fighting crises and strengthening resilience, the role of the ones particularly affected, the population, is often underestimated. All the options and actions from the public and private actors mentioned above have the disadvantage that, in the event of a crisis, they need time to be implemented, respectively switched to crisis mode, which can take a couple of hours or even days. Sometimes, some services might not be available in a specific region. In such a situation, the population's crisis resilience is critical to overcoming the crisis (Thomas and Mora, 2014).

For this dissertation, the population's behavior in terms of resilience and preparation in a pre-crisis time is of particular interest. Different research streams deal with population behavior before, during, and after crises. Literature examines stockpiling behavior of the population, and personality traits and influence of external effects on the stockpiling behavior (Gerhold et al., 2019; Ben Hassen et al., 2021; Dammeyer, 2020). Regarding external effects, the COVID-19 pandemic can be emphasized as a major cause of analysis in current research on population behavior in crises. There is, for instance, research on the change of stockpiling behavior (Gerhold, 2020; G. Busch et al., 2020), and research on cultural influences and the importance of media coverage on stockpiling

during the pandemic (Ahmadi et al., 2021). Several scientific articles have analyzed the importance of perceived threat which finally may lead to irrational behavior (Song et al., 2021; Hall et al., 2021; Sheng et al., 2021).

Other researchers have focused on the risk perception of the population towards crises. The concept of risk perception goes back to the risk paradigm of Slovic (1987), which understands "the perception of risk as a multidimensional construct, based on the combination of several subjective, qualitative perceived characteristics of a hazard (Slovic, 1987)." Using this approach, the individual risk perception of various hazards can be detected by statistically evaluating the riskiness individuals assign to a threat (Slovic, 1987). Different researchers found correlations between socio-demographic factors and risk perception in the context of crises (DeYoung et al., 2020; Doocy et al., 2013; Hoffmann and Muttarak, 2017).

In addition, risk perception and the occurrence of crisis events such as wildfires, floodings, pandemics, or global warming was investigated (van Loenhout et al., 2021; Sullivan-Wiley and Short Gianotti, 2017; Yeo et al., 2014). All these crises influence the population's willingness to increase precautionary measures. Gerhold et al. (2019) summarized the role of the population in potential crises as follows. Parts of the population overestimate the crisis management possibilities of public actors in the event of a crisis. The proactive stockpiling of goods already supports an increased resilience to a supply crisis but is currently practiced more for convenience reasons than as a precautionary measure. Socio-demographic factors such as salary (negative correlation) and household size (negative correlation) impact stockpiling quantities. For the proper handling of a crisis, Akesson et al. (2022) added that public authorities need to properly balance to convey the seriousness of the situation but not trigger a fatalism effect. Overall, the population plays an important role in successful crisis management and needs further investigation.

2.2.4 Other Actors

Besides the three aforementioned stakeholders, several other actors are involved in crisis management. These are, for example, NGOs, particularly humanitarian organizations (HO), which support governmental actors in various crises. These organizations are mainly privately funded and follow different purposes compared to public or private actors (Qing et al., 2012). Typically, these NGOs have a specific mandate, e.g., supplying the suffering population with food, health-related measures, or water (van Wassenhove, 2006). The need for NGOs in the aftermath of crises mainly depends on the resilience of the respective region. Countries such as Haiti had to rely on a large amount of aid outside their own country, including the participation of numerous NGOs, after the severe earthquake of 2010 with more than 300,000 people injured (UN News, 2022). The same was true for many countries affected by the 2004 earthquake in the Indian Ocean and the following tsunami (Williams, 2006). Due to the specific circumstances in which NGOs are mainly active, they will be considered only peripherally in this dissertation.

2.3 Partnerships

This section elaborates on collaboration between public and private actors. To start, the terms collaboration, coordination, and cooperation are delimited firstly and different forms of exchange between stakeholders are discussed.

Wankmüller and Reiner (2020) define coordination as the "process of organizing, aligning and differentiating of participating partners' actions based on regional knowledge, know-how, specialization and resource availability." Moreover, cooperation describes the process of operating alongside towards a common mission, sharing information and adjusting tasks in line with specifications of the current setting. Collaboration thereby is delimited as "establishing a close and intensive relationship [...] for jointly solving problems, where [...] internal standards, guidelines and rules are harmonized in accordance with others and trust is pervasive (Wankmüller and Reiner, 2020)." Based on these definitions, it becomes obvious that collaboration is the most intense form of working together.

2.3.1 Cooperative Approaches in Non-Crisis managment

In the following, the various forms of exchange between different actors are analyzed in more detail. Independent from crisis events, exchange between different actors is common in the business world. The first two forms, vertical and horizontal cooperation, are taken from classic supply chain management (SCM) and are related to cooperation between different private actors but also used in the crisis management context. A third form of cooperation between NGOs with a second actor is discussed afterwards. In the end, a collaborative approach to overcome the impact of crises is presented.

According to Hernández and Pedroza-Gutiérrez (2019), vertical cooperation refers to different actors along the SC, such as, to give an example, in the garment industry, the cotton producer and the jeans manufacturer. In no-crisis times, cooperation can be established in joint research or sustainability projects to increase possibilities and flexibility. It also helps to reduce costs (e.g. use of standardized contracts, trust in professional interactions) and increase profit margins. The joint added value can be used as a premium to the final sales price. In the event of a crisis, these arguments in favor of collaboration still remain while the focus of collaboration is changing: Cooperation between the actors can be used to respond quickly to possible new requirements.

Li et al. (2008) set out that this form of vertical cooperation can positively influence agility, meaning alertness to changes (improved possibilities to cope with threats and opportunities), and response capability (after having identified changes, to have increased resources to respond to them). The overall goal of vertical cooperation is to set up cooperation that benefits both partners and reduces costs (Martin et al., 2018).

Hernández and Pedroza-Gutiérrez (2019) define horizontal cooperation, e.g., if two logistics service providers (LSP) cooperate among entities in the same tier. The authors elaborate that this form of cooperation is mainly seen as a measure to strengthen SC resilience to help each other out

in case of need or crisis. Martin et al. (2018) add that such a form is implemented to improve the productivity of core activities, reach efficiency gains in supporting activity costs, and achieve production increases based on economies of scale. In the specific case of LSPs, joint route planning or sharing warehouse capacities leads to economies of scale and increased shipment frequencies. Hence, products can get to the customer cheaper and faster (Verdonck, 2017).

There are also some limitations, relating to these forms of cooperation. Within both of the mentioned settings, cartel regulations must be obeyed by the actors involved, as typically competition policies implemented by lawmakers shall ensure a free and fair competition. These regulations aim to lower prices and improve the quality of products, which shall protect all other businesses from unfair competition and consumers from welfare losses.

In case of horizontal cooperation, the problem of two or more companies coordinating their behavior or entering into agreements with one another for the disadvantage of competitors or customers could arise. Such cooperation, if directed to the disadvantage of the customer, could be subject to the ban on cartels (Bundeskartellamt, 2022). However, in a collective announcement by the European competition authorities on the COVID-19 pandemic, it was also emphasized that temporary measures in the area of entrepreneurial cooperation are necessary and appropriate (European Commission, 2020; OECD, 2020). These measures apply to ensure the supply of the population and the fair distribution of scarce products, which are limited in time and content and do not in principle constitute a violation of the ban on cartels.

Specifically for crisis management, a third form of cooperation is established: Public actors cooperating with NGOs or private actors cooperating with NGOs. Once again, the idea is that both partners have specific knowledge and resources, which, if combined, better serve their own objectives and minimize the suffering of the population (Kovács and Spens, 2007). For the specific case of collaborations between LSPs and HOs, Bealt et al. (2016) highlight that they help to better serve the suffering population after a crisis. This is achieved through increased efficiency and effectiveness on the part of the HO, as well as improved transparency in the handling of funds. LSPs, in turn, benefit directly and indirectly from cooperation as reputational gain in public perception can be achieved, possibly resulting in positive economic effects.

2.3.2 Public-Private Emergency Collaborations

One of the first explicit mentions of PPPs in the crisis context was when FEMA organized a conference entitled "Building Resilience through Public Private Partnerships" in 2011 (N. Busch and Givens, 2013). This was done to account for the importance of private actors engaging after crisis events in the US and to present them as valuable partners on the same level. FEMA generally referred to crises caused by natural disasters, like the Tornado in Joplin in 2011, which hit American soil with high regularity or terrorist attacks. Companies such as Home Depot and Walmart provided financial support, but volunteers were also flown to the crisis area in partnership with Delta Airlines. Before that, private engagement in humanitarian crisis management had not been considered a sustainable framework over a long-term period.

An emerging form of cooperation in a crisis context is defined by Wiens et al. (2018) as PPEC. The authors define a PPEC as "a special form of public-private partnership (PPP) deliberately designed for improved crisis management by joint coordination and cooperation between private and public representatives." The background to this is the consideration that public actors quickly reach their limits in crises and that private actors have many resources and much know-how to support public authorities in PPECs if the right incentives are applied.

Within PPECs, both partners can learn from each other in a crisis context. For public actors, huge efficiency gains are possible by improving digitized and standardized processes within their operations, as is already standard for many companies today. Private actors can benefit from a positive reputation through collaboration, as well as from the opportunity to learn lessons for internal crisis management through new areas of business.

The concept of a PPEC starts in a non-crisis situation, in which public and private actors already exchange information with each other or run trainings together in the framework of regular SCs. They can include mechanisms for emergency measures as well as essential goods and services in the event of a crisis. This could lead to coordination difficulties between the actors. While public actors in the context of crisis management have the task of and, in principle, have a primary interest in minimizing the population's suffering, private actors also should have a heightened self-interest in helping because a suffering population potentially means a lack of customers and employees in the affected region.

Following Bealt et al. (2016), there are three fundamental drivers for companies to engage in crisis management: internal ethical drivers, external stakeholder drivers, and internal corporate drivers. Since both employees and customers are affected by a crisis (both as those needing help and as those helping), a company has a great incentive to contribute to a quick resolution of the crisis. A company that switches to "normal market supply" in a crisis region too early also runs the risk of possible accusations of enriching itself at the expense of the affected population. Occupational safety and health measures inappropriate to the crisis can also lead to a public pillorying effect, as shown by the example of the company Tönnies during the early times of the COVID-19 pandemic (tagesschau, 2020). In this case, an uncontrolled infection outbreak had occurred in the workplace, resulting in environmental and animal welfare organizations calling for protests, and the German Armed Forces had to assist with corona testing on the plant premises.

An additional problem to be overcome is the issue of uncertainty. Hardly any predictions regarding the specific extent and spatial appearance of a crisis can be made in advance. In addition, there is a discrepancy between the objective functions of public and private actors as already discussed.

Moreover, Gabler et al. (2017) describe the issue of unidirectional communication as a further risk, which could occur when one of the partners prevails over the other. In such a scenario, no communication at the same level takes place and the bypassed partner has an increased interest not to act cooperatively. The extensive dimension of public-private cooperation envisioned in a PPEC should be emphasized, which can take place in various areas (e.g., communication, planning, goods, storage, transport or personnel).

As part of a validation conducted with experts of the NOLAN project, considering a scenario in which public actors request emergency goods from private actors via shared logistics sites was discussed, and special requirements for this to happen were made by both sides. Public authority representatives rely on cooperative companies but ask for the following requirements for a successful collaboration. The market power of ample food retail chains must not be allowed to concentrate further; in particular, potential antitrust and public procurement law problems in connection with PPECs must be clarified in advance. In addition, public actors must have a monitoring option that allows access to emergency stocks at any time, and the costs for the state must not be too high.

Private actors are willing to help with storage capacity and resources, provided that public actors take responsibility and make clear commitments regarding the selection and quantity of goods. Also, the payment must be adequate, and the processes must be able to be integrated into everyday business. Finally, governmental monitoring access must be limited exclusively to the contractually defined emergency stocks.

Further fields of application of a PPEC are conceivable in the cyber-security and communications sector and in healthcare. Regarding cyber-security collaborations, Hare (2009) emphasizes that companies are taking part in cyber-security exercises primarily due to a sense of civic-mindedness. Furthermore, the learning perspective, to gain insights from the collaboration with public partners, which can be useful for their own operations, is of high interest to the companies. As a frequently stated requirement, the costs of any participation have to be reasonable to the companies, so clear communication of benefits from the side of the public actors and the creation of mutual trust is necessary.

2.4 Incentive Analysis and Empirical Research in the Context of Crisis Management

The topics discussed in the previous sections on crisis (prevention), stakeholders, and cooperation potentials raise questions about the actors' experiences, motives, incentives, and behaviors. For this purpose, analyzing PPECs from a strategic, incentive-theoretical perspective is highly promising. One method used for this purpose in this dissertation is game-theoretic modeling. In the following, different game-theoretic terms, which are used in the context of this dissertation, are presented.

2.4.1 Role of Game-Theory

Game theoretic modeling includes identifying and analyzing Nash equilibria (NE) and determining plausible objective functions of the involved players. According to Nash (1951), in a game-theoretic setting N players interact with each other. Different strategies lead to different utility-levels for the respective player. According to the player's preference, he can rank different strategies and every player chooses a strategy from his strategy set to maximize his objective (Bartholomae and Wiens, 2016). The objective of a player may depend on both the player's and the rival players' strategies.

Bartholomae and Wiens (2016) further elaborate that in such a situation, a NE can be defined as a stationary vector of strategies for all players where none can improve their outcome by solely changing their own strategy.

The players' preferences and hence their utility functions can take diverse forms, depending on their objectives (Shapley and Rigby, 1959). In the context of this dissertation, for example, it might be purely about profit maximization or minimizing the population's suffering. It can also be about reputation gains or learning effects in executing one's activities, which are beneficial for a player. Also, a mixture of different criteria is conceivable (mutli-objective approach) and describes in sum the overall objective function of an individual actor (Sasaki, 2019).

For this dissertation, mechanism design also plays an important role. It is defined as a system to make an individual reveal his private information (Russo et al., 2018) and how the individuals can be incentivized to behave in a way so that the overall outcome of all parties is improved (Jackson, 2014). The basic assumption for the dissertation context is that private actors have a high potential for resources to support public actors in crisis management. These aid measures must be brought into play through appropriate mechanisms, such as contracts and relational contracts, on the part of public actors. Relational contracts are self-enforcing, as no external authority (such as a court) is required to enforce contractual interests. However, the contract is fulfilled by mutual agreement and in the best self-interest (Gintis, 2000).

2.4.2 Role of Empirical Analysis

Another central element of this dissertation is the empirical analysis of relevant stakeholders' behavior, motives, and objectives. Based on surveys and laboratory experiments, the experiences and assessments of the stakeholders are directly queried. Strategic measures are identified, enabling the cooperation of public and private actors for optimized crisis prevention. The population is considered an active part of successful crisis prevention. Furthermore, empirical research complements economic modeling.

In the following, terms used in the context of this dissertation are reviewed. Especially quantitative survey methods play an important role. For example, respondents can use Likert scales to indicate their agreement with a set of propositions about beliefs or actions (Bradburn et al., 2004). Answers to quantitative questions can be evaluated statistically. Mean comparisons, for example, help to compare different answers. Correlation analyses can reveal relationships between different answers and the so-called items, or regression analyses can be used to determine causalities between different items (Backhaus et al., 2016).

Exploratory factor analysis is used in some of the studies. This includes checking the extent to which different items measure the same scale based on the responses (Kartal et al., 2022). A measure of scale coherence is called Cronbach's alpha. Cluster analysis, in turn, is used to determine "partitioning similar objects into meaningful classes when both the number of classes and their composition are to be determined" (Fonseca, 2013).

3   Research Objectives

Up to this point, the actors relevant in crisis management, and different forms of interaction between the actors were presented. The already existing approaches of the PPEC concept were also emphasized.

This chapter highlights the objectives of this dissertation's five studies, which deal with different topics in the area of crisis management and public-private collaborations in crises. All studies have in common that they examine ways to overcome potential undersupply of the population in times of crises. The importance to establish supply in crises is addressed in different ways in these studies. By highlighting and analyzing problems while also providing methodologically grounded solution approaches, this dissertation aims to support an societal resilience to situations of undersupply by making crisis management more effective and agile. In this regard, the five studies show the importance and prerequisites of beneficial cooperation for all stakeholders and communication at the same level. In the next sections, various objectives of this dissertation, addressed by the different studies, are elaborated.

3.1   Strengthening Resilience through Public and Private Emergency Collaboration

3.1.1 Understanding the Central Dynamics and Incentives of PPECs

The collaboration of public actors with private actors in crisis management is relatively new and scarce in the field and in research (Wiens et al., 2018; Gabler et al., 2017), especially in comparison to research on interactions of HOs and private actors (Nurmala et al., 2018; Fikar et al., 2016). In addition, even if the collaborative action of several actors is considered to have great potential in science, analyses still predominantly evaluate the behavior of individual actors instead of a combined approach (Behl and Dutta, 2018).

Nowadays, there is still a need for more scientific research for PPECs that includes both the logistical requirements of such a partnership and the incentives and strategies of both partners. Dealing with logistical problem settings helps to understand the requirements, characteristics, and challenges in the operational implementation of a PPEC. Game-theoretic modeling elaborates conditions in the collaboration of both actors that are necessary for ensuring stable and efficient relationships. Combining both methods helps to quantitatively model the conditions and effects of PPECs, taking

into account the different objectives of the parties. Thus, on the one hand, operations research methods, conditions, and implementation possibilities of a PPEC can be considered. On the other hand, strategic equilibrium situations can be thoroughly analyzed through game-theoretic modeling. From a methodological point of view, there are only two works of Nagurney et al. (2016, 2019), combining game-theoretic analyses and logistics approaches in a crisis context. However, they do not focus on the collaboration of public and private actors.

The requirements for cooperation and stable equilibrium situations, in which all partners have a strategic self-interest in maintaining the previously established agreement between the partners, can be defined with the help of relational contract theory (Rodríguez-Pereira et al., 2021). This helps to quantify the requirements for such a partnership and considers the different objective functions of public and private actors. In turn, both stakeholders can understand more precisely how to better align their goals and what the basic requirements for successful collaboration between public and private actors in crisis management are. Study A addresses these objectives.

3.1.2 Identifying Companies' Incentives to Improve Crisis Management

In humanitarian crisis management, the adequate amount of support with the right timing is key to success. Public actors alone are often not able to reach these goals. If they can convince private actors to participate collaboratively in humanitarian crisis management, the suffering of the population can be minimized significantly (Wiens et al., 2018; Holguín-Veras et al., 2013). One approach is to align the multitude of strengths with the main objective of the companies mentioned in Section 2.2.2. Under the economic and game-theoretic assumption that companies act in a profit-maximizing manner (at least in the long run), the incentives for companies to participate in humanitarian crisis management need to be elaborated.

Humanitarian engagement is one practiced approach of private actors to carry out CSR (Johnson et al., 2011; Dahlsrud, 2008). Porter and Kramer (2011) were among the first to bring up the value of CSR for companies when they partner with public actors. Companies could not only maximize profits with the right CSR strategy, but also create a sustainable motivational factor within its value chain (Madsen and Rodgers, 2015; Dahlsrud, 2008).

As elaborated on in Subsection 2.3.2, the main drivers of private actors to engage in crisis management are internal ethical drivers, external stakeholder drivers, and internal corporate drivers (Bealt et al., 2016). However, even in the case of altruistic behavior in crisis relief, if companies are considered to protect their employees and customers, it can be seen as a way to keep the business running. Furthermore, any such engagement could be considered a new business opportunity.

From the findings of Subsection 2.3.2, it becomes clear that any possible engagement of private actors in crisis management must be addressed in a comprehensible way. Any involvement on the companies' part, for whatever motivation, could portray them as crisis profiteers to the public. For private actors, this raises the question of how crisis participation, especially in collaboration with public actors, should be portrayed to the outside world. Furthermore, it is often unclear which tasks

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could be performed by the private actor in a PPEC. Sodhi and Knuckles (2021) and Wiens et al. (2018) show that private actors themselves know best what they can contribute to a collaboration. The objective of Study B is, therefore, to provide a comprehensive empirical investigation and elaboration of tasks that arise in crises, as well as to contribute to an appropriate distribution of tasks, particularly from the perspective of private actors in the essential goods sector.

3.1.3 Investigating Population's Attitude and Collecting Information on Public Acceptance of Firm Engagement

After analyzing private actors' incentives and possibilities to engage in a PPEC, Study C takes the population into focus. From Subsections 3.1.2 and 2.2.3 the question arises how current and potential customers assess corporate involvement in PPECs. After all, the best-intended actions will ultimately be ineffective if the wider public and — in particular — the firms' customers do not appreciate the effort. This requires a change of perspective in the analysis of the stakeholders.

As already mentioned in Subsection 2.2.2, Izumi and Shaw (2015) argue that good corporate citizenship is one way to build a reputation of being a responsible player in the market, which is also perceived by the customers in that way. The economic importance of customer perception of corporate behavior has been considered in detail by Maignan (2001), which has also been confirmed by Madsen and Rodgers (2015) and Cho et al. (2019).

However, all these studies are only built on a conceptual basis to evaluate the measurement of attitude or consider other areas than crisis engagement. Moreover, none apply their concepts to a real-life customer survey. Therefore, Study C empirically analyzes how the population perceives the participation of companies in PPECs and whether this also has consequences on the purchase intention of the respondents.

3.2 Stakeholder Analysis with Focus on Risk Perception, Incentives and Objectives

To determine the need for and the conditions of PPECs, it is essential to analyze the behavior of the population and private actors in detail. The general role of both actors in crises has already been pointed out in Subsections 2.2.2 and 2.2.3. The following sections shed light on both actors' individual preparation for crises and the implications for the other actors to succeed collaboratively in crises.

3.2.1 Including Risk Perception and Stockpiling Behavior of the Population

Two key characteristics that influence the behavior and participation of the population stakeholder group in crisis management are the individual's risk perception and the stockpiling behavior. Both factors can be examined before a crisis event to provide a valuable assessment on how resilient the population is on its own. This information is highly relevant for public and private actors, particularly during a crisis. The more accurate public actors' data on the behavior and stockpiling of the population is, the better they know how precautionary the population is, and the better they can provide help to the ones that need it the most.

Akerlof et al. (2013) and Champ et al. (2011) indicate that people who experience natural hazards tend to be more willing to invest in risk reduction measurements. Gerhold et al. (2019) find no macrosocial but only personal reasons for people to perceive higher risk when it came to food shortages within the COVID-19 pandemic. So far, no research has investigated the influence of risk perception of the population on the behavior for individual crisis management as well as on the attitude towards PPECs. As this is highly relevant for a successful collaboration of public and private actors, one objective of Study C is to examine the aforementioned relationship.

The second important factor for public and private actors within a PPEC to be aware of is the stockpiling behavior of the population before crises. In Section 2.2.3, personality traits, external effects, and sociodemographic factors have already been examined as influencing factors and catalysts for the individual stockpiling behavior of the population (Ahmadi et al., 2021; Ben Hassen et al., 2021; Gerhold, 2020; G. Busch et al., 2020; Dammeyer, 2020; Gerhold et al., 2019).

The main reasons indicating the importance of knowing the stockpiling behavior of the population for a successful collaboration of public and private actors, are summarized in the following: First, the quantification of essential goods stockpiled at the households indicates the individuals' awareness of possible threats and crises. Second, it gives public actors an overview of one measure to improve crisis resilience and shows the need for fast interventions if free market supply would collapse in the course of a crisis event. Third, having socio-demographic data linked to the stockpiling behavior helps PPEC members to prioritize the help to the ones that need it the most. Fourth, long-lasting crises such as the COVID-19 pandemic may have changed the stockpiling behavior of the population sustainably, which changes the premises for a PPEC. Within related research studies, answers from the participants in the questionnaire about a particular behavior, differ from what can be observed in reality. This might be due to social desirability or other biases arising in questionnaires. Analyzing both, the intention and the actual behavior in reality, helps to gain a holistic picture. Study D combines these objectives to provide comprehensive insights into this research area.

3.2.2 Analyzing Behavior of Companies in Disruptions

Turning the perspective, stockpiling is also a meaningful strategy for private actors. As any merchant of a physical good, stockpiling may help to battle supply difficulties from upstream SC members or demand surges from their customers. These supply difficulties may have various reasons, for example, local instabilities or short-term supply difficulties due to a supplier change.

One particular interest within this dissertation is the analysis of supply failures due to disruptions in the SC. In the case of supply failure, if the merchant does not hold stockpiles, he will not be able to sell goods to the customers, which is a direct loss. This may cause customers to regard the merchant as an unreliable seller and cause them to stop buying at the merchant in the future (cf. *customer churn* discussed in Subsection 2.2.2).

Customer churn leads to direct losses, as a product cannot be sold. These losses can be measured by comparing sales data from non-crisis times with data from crisis times, but also by a second component, which is reputation related. It is the accumulation of no-shows of customers dissatisfied with the merchant's service because the product is unavailable in the store. Therefore, they will not buy the product in the future at this merchant.

According to the literature, one established variant of a reputation experiment is the product quality game, where participants, when playing over a more extended period (> 10 rounds) with each other, are willing to pay a premium for quality (Gans, 2019). While the general structure is similar to the structure in Study E, no experiment so far has considered supply disruptions, availability reputation, and customer churn rate, in combination. Study E's objective is to contribute to these various streams of research.

3.3 Interplay of the Developed Studies

Table 3.1 provides an overview of the involvement of stakeholders within the studies to outline the individual studies' relation to each other. A cross in the corresponding place can mean one of the two things: on the one hand, the respective stakeholder is directly assessed as part of a model or in the context of an empirical investigation, in the form of an experiment or a survey (M-column). On the other hand, the respective analyses have direct implications and recommendations for action for the counterpart and were therefore selected in the table in the R-column. Furthermore, in the last column, a connection to collaboration is denoted for the five studies. Studies A–C have a clear collaborative approach to crisis management. All three studies specify the PPEC concept from different stakeholder perspectives. Studies D and E analyze the behavior of individual stakeholders in a crisis context without collaboration. Both studies examine conditions that show the impact of crises on the respective stakeholders and outline the need for PPECs accordingly. Bringing these studies together, this dissertation yields a holistic contribution to enhanced crisis management by applying methodological analysis and presenting clear strategies to be used in practice.

Publication	Public Actor		Private Actor		Population		Collaboration
	M	R	M	R	M	R	
Study A: Concept & Collaboration	X	X	X	X	X	X	X
Study B: Company Engagement		X	X	X			X
Study C: Risk Perception & Attitude				X	X	X	X
Study D: Population Stockpiling		X			X	X	
Study E: Disruptions & Reputation			X	X	X		

$M = Modeling$

$R = Recommendation$

Table 3.1: Stakeholder-related context of studies and the role of collaboration

As this chapter illustrates, the present dissertation contributes to the stream of research focusing on societies' resilience and public-private collaboration in crises. The mentioned objectives were considered in the five studies. The research objectives will be answered within the presentation of the individual Studies A–E in the next chapter. The cross-study implications for the different stakeholders of a PPEC in terms of improvement of knowledge, requirements, and tasks, are discussed in Chapter 5.

4   Summary of Studies and Results

This chapter gives an overview of the study contexts and contributions, as well as on the results of the five studies that are part of this dissertation. Study A looks at the concept of a PPEC and defines the depth of cooperation between public and private actors. Study B investigates the willingness of companies to participate in PPECs. Studies C and D both deal with the risk perception of the population. In addition, Study C gains insights into how the population values company participation in PPECs, Study D assesses the population's stockpiling behavior, and examines to what extent there is a need for improvement. Study E quantifies the economic value of availability reputation in a disruption prone SC.

4.1   Study A

This section refers to the article "Public-Private Collaborations in Emergency Logistics: A Framework Based on Logistical and Game-Theoretical Concepts". This article was written in collaboration with Florian Diehlmann, Lotte Verdonck, Marcus Wiens, Alexander Zienau, and Frank Schultmann. It is published in the journal Safety Science as Diehlmann, Lüttenberg, et al. (2021).

4.1.1 Study Context and Contributions

The study's objective is to examine the concept of a PPEC in detail, taking into account logistical framework conditions and restrictions to supply the affected population. A game-theoretic model enabled the analysis of conditions and incentives for private actors to participate in a PPEC. To address the previously mentioned objective, equilibrium situations (see Subsection 2.4) are modeled in which the actors involved are willing to cooperate strategically.

First, the study analyzes the impact and development of crises in a dynamic context, which is followed by the examination of crisis management and the extent to which crisis management plays an essential role for public and private actors. Furthermore, the study contains an examination of PPPs, which are known from infrastructure or education projects, for example. This PPP concept is modified and transferred to possible cooperation in humanitarian crisis management.

Figure 4.1 depicts the basic setting of a PPEC as described in Subsection 2.3.2. Both, public actors and private actors, follow different objectives with different strategies. The interdependent decisions and collaborative approaches including the exchange of resources aim to improve logistical capacities to better serve the population in crisis events.
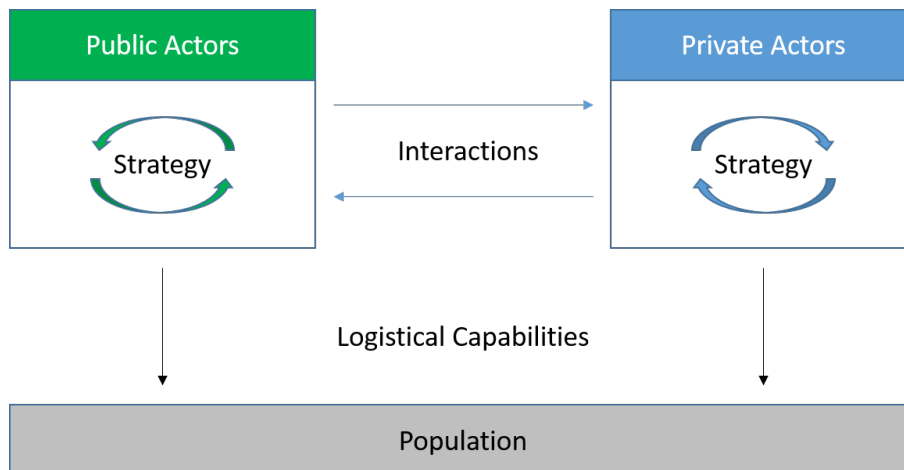
Figure 4.1: Basic setting of a PPEC (see also Figure A.3)

The study contributes to the body of literature in several ways. First of all, an overview of general forms of public and private collaborations is given. Moreover, the logistical challenges of PPECs are examined starting from typical problems of PPPs. Further logistical challenges in establishing a PPEC are identified as different power positions, problems in trust and data protection, and the distribution of costs. This raises questions about capacity planning and the precise use of resources. The game-theoretic model builds on these considerations, uses contract design and non-cooperative modeling and is based on the logistical requirements, standards, and challenges that evolve from the operations research perspective. The assumption is made that the firm cooperates mainly for two reasons: Reducing crisis-related costs and gaining a positive reputation.

4.1.2 Results and Discussion

Study A quantitatively models PPEC operations while considering the problem-specific challenge of the actors' different objectives, which were outlined in Subsection 2.3.2.

In the study, the different logistical characteristics of public and private actors in disaster are taken as the basis for the game-theoretic model. This can be, for example, the extent of damage D ($D > 0$), which in the model is defined as the degree of undersupply, a resource-based emergency reserve x^n, or budget parameters (B) of the state. Within the game-theoretic PPEC model, the study provides insight into the motivation and incentives of the partners, their strategies, and the way they interact with each other. Therefore, the model focuses on the partners' participation constraints, which define the extent of cooperation, the impact on the outcome, the conditions under which the partners' contributions become strategic substitutes, and reputation effects.

Figure 4.2 illustrates the results of the game-theoretical model by illustrating the willingness of government (x-axis) and firm (y-axis) to cooperate in a normalized scale between 0 (no cooperation) and 1 (full cooperation). In order to determine the NE (the equilibrium point at which stable cooperation between state actor and firm is possible), both actors pick their optimal strategy, given their co-player's strategy. This is reached where the best response functions of both actors intersect. The black curve represents the response function of the state. The lower blue curve shows the

response function of the firm, varied by reputational influence (upper blue curve) or prohibitively high cooperation costs from the firm (dashed line). The negative slope and convexity of the curves illustrate the submodular nature. The greater the willingness of one partner to cooperate, the lower the incentive for the other partner to cooperate. The submodular character within games evolves, where players' strategies are *substitutes* and not *complements*.
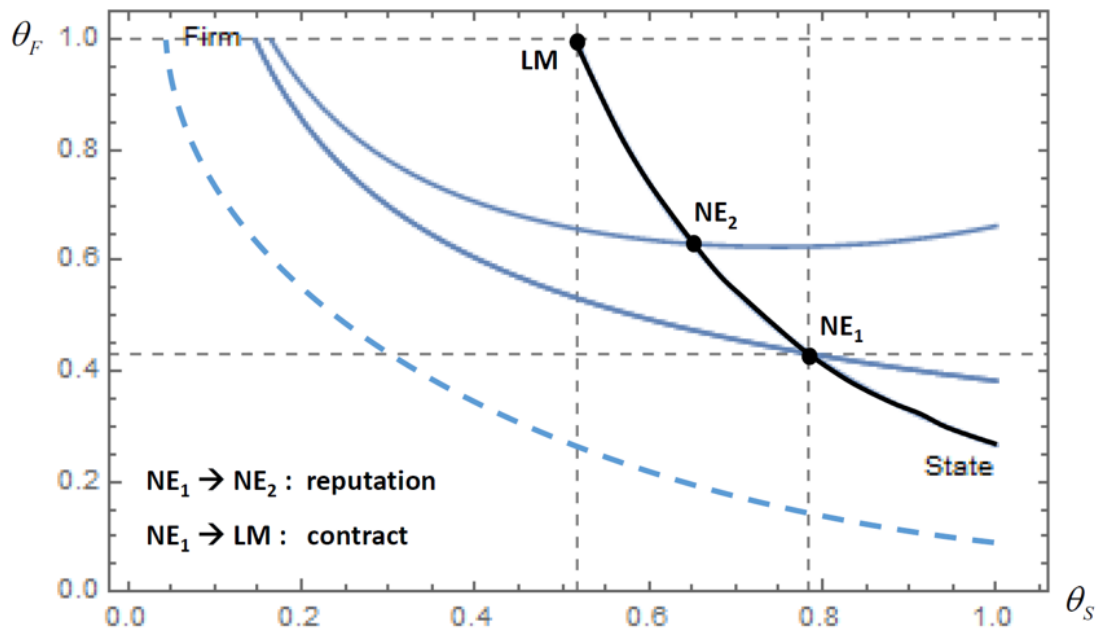
Figure 4.2: Best-response functions of public and private partners (see also Figure A.4)

Finally, the study illustrates how the state can use a mechanism design approach to incentivize firms to help with their resources to achieve a better supply of the population. Therefore, the state has to transfer a minimum transfer payment to the firm in order for the firm to be better off than without cooperation. However, from the government's perspective, the amount of this transfer payment must be below the firm's crisis-free budget.

This study offers a variety of starting points for future research. Especially the use of real-time data can help improve the processes within the PPEC concept and ensure that the population is better served in a crisis. At the same time, it is necessary to take a closer look at the motivations and incentives of the various stakeholders. This is done in this dissertation in Study B, which deals with companies' experiences, ideas, scope for support and willingness to support in the crisis context.

4.2 Study B

This section refers to the article "How to Enhance Company Engagement in Public-Private Emergency Collaborations in the Supply of Essential Goods". This article was written in collaboration with Alexander Zienau, Marcus Wiens, Ole Hansen, Florian Diehlmann and Frank Schultmann. It is submitted to a scientific journal as Lüttenberg, Zienau, et al. (2022).

4.2.1 Study Context and Contributions

The study's objective is to determine to what extent and under which conditions companies are willing and able to collaborate with the state by, for example, providing assistance in the form of the relocation of their resources towards a suffering population in a crisis situation, such as in a natural disaster or a severe pandemic.

There are many examples of the general engagement of companies in crisis management in collaboration with NGOs, resulting in reputational gains for companies (see Subsection 3.2.2). Bealt et al. (2016) particularly describe the motives of logistics service providers to cooperate with NGOs, and Madsen and Rodgers (2015) point out that cooperation with NGOs implies that crisis-related CSR engagement attracts more attention from the stakeholder groups relevant to the company.

However, cooperation with public authorities as opposed to NGOs differs primarily in terms of the far-reaching measures that state actors can take in the event of a crisis. These include, for example, a crisis-specific adaptation of existing (market) regulations through extreme measures, such as seizing company resources. In contrast, companies can be valuable and supportive partners by providing know-how, personnel, resources, or logistics capacities. This raises the question of which benefits and risks companies see in a PPEC and how they can be motivated to consider collaboration as a strategic option.

In this context, Study B empirically investigates German companies' experience and motivation regarding emergency collaborations with authorities. For this purpose, a survey with a total of 25 closed questions was prepared. Companies from the food, healthcare, and logistics sectors were randomly selected and contacted online. These sectors were chosen because they are responsible for producing and supplying essential goods. 398 valid responses were received.

Figure 4.3 shows the three research questions (RQ) and the corresponding hypotheses, which were derived from literature. In particular, the prioritization of different measures from the companies' point of view, especially with the distinction between resource-related and coordinative services, is investigated. The questionnaire also elaborates on the role of reputation and in which ways companies believe they can provide particularly good assistance.

RQ1: What are incentives and barriers for companies to collaborate with public actors?

H1: During crises, companies consider contractual business relationships as more important than mitigating suffering of population.

H2: Companies see reputation from a PPEC engagement as a benefit rather than a risk.

RQ2: What can be done to enable and promote more PPECs?

H3: Companies prefer the permission to advertise with their PPEC-role to reimbursements of costs from public actors.

H4: Companies expect to better support governments in crisis response than in crisis preparedness or crisis recovery.

RQ3: Which are efficient contributions of companies in PPECs?

H5a: Companies prefer provision of resources to coordinating assistance.

H5b: Companies expect public actors to need resources from companies rather than coordinating assistance.

Figure 4.3: Research questions and hypotheses (see also Figure B.1)

4.2.2 Results and Discussion

The results of the study clearly show that many companies have been involved in crisis contexts in the past. In general, there is a high level of willingness on the part of companies to provide assistance in the form of PPECs. However, a fundamental condition for the companies to collaborate is a fair financial compensation for their services within a PPEC. This financial aspect is of high importance to the companies and must, therefore, be accounted for by the state by a transparent communication and realistic budgeting.

One central insight from the survey is that 91% of the respondents would share information with government agencies (the same amount as those who would share information with companies in their own supply chain). Thus, companies would be significantly more willing to share information with government agencies than competing companies outside their SC, which is indicated by only 77%. Consequently, authorities should build upon this potential and show ways and initiatives to get access to this data.

Table 4.1 shows a selection of different types of assistance (column "Type") that companies assume government agencies require. The five items mentioned were assigned to the two categories *Resources* and *Coordination* using factor analysis. On a binominal scale with the answer possibilities $yes = 1$ and $no = 0$, companies responded with a Mean = 0.639 and a SD = 0.373 (n = 398) in favor of the *Resources*, which is significantly higher (one-sided t-test with p = 0.000) than *Coordination* (Mean = 0.451, SD = 0.436; n = 398). This means that companies see a higher need for resources on the government side. Somewhat contradictory to the previous statement by the companies, they prefer to support with *Coordination* rather than with *Resources*.

Type	Where do public actors need support from private companies in crisis situations?	Mean	SD	Factor 1	Factor 2
Resources	Providing goods	0.69	0.465	0.487	
Resources	Providing transportation capacity	0.69	0.464	0.797	
Resources	Providing storage	0.54	0.499	0.675	
Coordinating	Tactical planning	0.40	0.490		0.775
Coordinating	Strategic planning	0.50	0.501		0.698

$n = 398$, $0 = $*No support needed*, $1 = $*support necessary*

Table 4.1: Factor analysis for *Resources Index* and *Coordinating Assistance Index* (see also Table B.7)

Another statistically significant finding of this study is that some insights on PPECs match with the findings from the cooperative field between companies and NGOs (see Subsection 2.3.1). This relates, for example, to the right mechanism of division of tasks between the actors. From the companies' point of view, the public actor should not decide on the distribution of tasks alone. Instead, each partner can best assess the type of assistance it can provide for a particular context. Furthermore, companies see the potential to promote their PPEC engagement. Other (non-financial) benefits need to be emphasized more by public actors.

The study's findings suggest that companies are generally willing to engage in humanitarian actions. Under specific conditions, they also consider collaborations with public actors as beneficial for them. The willingness to contribute to such a collaboration depends on the type of company, appropriate compensation for the assistance provided, and the consideration of companies' operational processes in crises as the main requirements. Authorities need to keep this in mind when getting into contact with companies.

In future studies, the sample size can be increased further or the focus from Germany can be expanded to Europe or other industrialized nations to achieve better comparability of the results. More distance to the COVID-19 pandemic, or the consideration of current developments, such as the war in the Ukraine, possible changes in companies' behavior and willingness to cooperate could be investigated. In addition, accompanying qualitative surveys of individual companies could provide more in-depth information to the quantitative data of the survey. From a scientific point of view, a comprehensive quantification of the substantial assistance provided by companies would also help counter typical survey problems, such as those caused by the social desirability bias.

4.3 Study C

This section refers to the article "The Attitude of the Population towards Company Engagement in Public-Private Emergency Collaborations and its Risk Perception — A Survey". This article was written in collaboration with Amelie Schwärzel, Miriam Klein, Florian Diehlmann, Marcus Wiens, and Frank Schultmann, and is published in the International Journal of Disaster Risk Reduction as Lüttenberg, Schwärzel, et al. (2022).

4.3.1 Study Context and Contributions

Study C has two main objectives. On the one hand, the focus lies on the analysis of the attitude of the population toward corporate participation in PPECs. On the other hand, the risk perception of the population concerning crises and their handling of crises is evaluated by taking the example of the COVID-19 pandemic. Combining both objectives, this study investigates a possible connection between attitude regarding company support and risk perception.

The impact of large-scale crises such as the COVID-19 pandemic is far-reaching, affecting lives and livelihoods and seriously affecting businesses, economies, and, thus, the global economy. National and international actors engaged in post-disaster relief efforts face unique challenges in providing for and protecting populations. Governmental disaster preparedness and crisis risk management agencies reach their material and human resource limits when dealing with large-scale crises. Private sector measures, such as flexible production conversion for the manufacture of medical protective equipment, represent often untapped potential in disaster relief. To build resilient supply structures, long-term partnerships between the public and private sectors can be a crucial factor in crisis management. Collaboration between the state and the private sector in the form of a PPP in

Figure 4.4: Four phases of disaster management cycle (see also Figure C.1)

a crisis context requires a detailed analysis of the partners' reasons and incentives to participate (Wiens et al. 2018).

Figure 4.4 depicts the four phases addressed in disaster management, which build the so-called *disaster management cycle*: mitigation, preparedness, response, and recovery (see Coppola (2011)). The PPEC concept spans all four phases. The mitigation and preparedness phase are about preparing for an emergency in the form of coordination and training. The collaborative fight against crises and their long-term impact takes place in the response and recovery phase.

In contrast to the two previous studies presented, Study C focuses on the perspective of the population. Customer perception is a critical component that should be considered in corporate action (Sheffrin and Zhao, 2021). It can be managed as part of a CSR strategy, such as active participation in government-responsible crisis management. The approach of Study C is inspired by the work of Madsen and Rodgers (2015), who used the concept of stakeholder theory to link CSR and CFP. Moreover, it is inspired by Maignan (2001), who examined consumers' perceptions to link CSR with the related economic success of the company (see also Young and Makhija (2014)).

It is argued in the present study that the possible crisis management relief of companies is closely related to the concept of CSR. In addition, an adapted concept of risk perception is added from Slovic (1987) to the survey design to account for the specifics of a crisis, like the COVID-19 pandemic for the consumers. The paper investigates possible correlations between risk perception and the attitude of the population to determine the extent to which the persons' characteristics, in particular risk perception, are linked to their positive attitude.

From the perspective of companies, the lack of predictability of crisis interventions can lead to costs that are difficult to calculate while they, at the same time, can also lead to new impacts on corporate reputation. To this end, this study analyzes public perceptions toward the private sector's readiness to intervene in crisis contexts and the extent to which potential involvement influences customer perceptions.

The quantitative data collection is based on an online population survey of 402 individuals conducted between November 29, 2020 and January 9, 2021. The target population constitutes a representative sample of the overall population of Germany. Therefore, individuals aged 16 or older with web access were recruited as a sample.

With the help of selected hypotheses based on concepts of risk perception (see also Slovic's risk paradigm presented in Study C), attitude measurement, and the results of previous studies (Gerhold, 2020; Gerhold et al., 2019), the population's viewpoints regarding private-sector involvement in a PPP in a crisis context are examined.

4.3.2 Results and Discussion

Since the attitude of the population towards corporate participation in PPECs cannot be queried directly, a set of ten different questions was posed to the participants. The participants were then able to express their agreement on a 5-point Likert scale. An exploratory factor analysis (EFA) was conducted on the basis of the responses (see Table 4.2). As a result, seven items, with factor loadings from 0.476 to 0.698 were assigned to the *positive attitude index*. A subsequent Cronbach's alpha calculation to test the reliability of the created positive attitude index resulted in a satisfactory value of 0.778.

Based on the evaluation of the positive attitude index, it is found that the population supports and appreciates corporate involvement: Most respondents find the involvement praiseworthy, evaluating it as selfless and altruistic. Therefrom, it follows that the engagement of companies in crises can undoubtedly meet with a positive public response, especially if the crisis contribution is made cooperatively alongside official disaster control. This fundamentally positive public perception of a company in a partnership is also expressed in the willingness to buy the company's products in question.

Further results of the survey illustrate the existence of a low risk perception such as imminent dangers and a lack of knowledge about already existing partnerships between the state and the private sector for crisis intervention. Here, a need for an increased supply of information, also on the part of public authorities, is uncovered. The study results detect a positive correlation between the positive attitude and the risk perception of those involved, but not between the positive attitude and sociodemographic factors such as age or gender.

The study offers various starting points for further research in this area. In general, such studies can encounter the problem of social desirability, i.e., respondents overestimate CSR-related attributes in surveys, and thus distort the results (Auger and Devinney, 2007). This creates a gap between

Item	Agreement Rate[1] (%)	Mean	SD	Factor Loadings Factor 1	Factor 2
The state crisis management can better fulfill its tasks through the supportive participation of private companies.	76.22	4.03	0.901	0.698	0.193
Then crisis management can succeed more efficiently.	85.96	4.26	0.771	0.644	0.087
I see such actions as a sign of social responsibility on the part of this company.	76.79	4.07	0.976	0.607	−0.001
Companies can provide useful support for state crisis management.	86.53	4.26	0.837	0.540	0.144
Is this an opportunity for the company to take social responsibility.	85.67	4.26	0.819	0.517	0.088
My perception of this company is improving.	79.66	4.06	0.911	0.508	0.182
I am interested in whether companies engage in collaboration with state authorities.	66.19	3.81	1.000	0.476	0.133
I fear that this company only wants to enrich itself at the expense of the suffering population.	34.96[2]	3.70[3]	1.149	0.178	0.786
I see it as a tactical calculation to strengthen the image.	14.33[2]	2.97[3]	1.190	0.000	0.642
For me, this is a form of "privatisation" of emergency care, which I fundamentally reject.	10.89[2]	3.90[3]	1.091	0.305	0.439

[1] The values 4 and 5 on the 5-point Likert scale count as 'Agreement'

[2] The values 1 and 2 on the 5-point Likert scale count as 'Agreement'

[3] Item values recoded for factor analysis

$n = 349$

Table 4.2: Results of factor analysis for *Positive Attitude Index* (see also Table C.2)

attitudes and actual behavior (Kuokkanen and Sun, 2016). For purchase intention questions, it can be questioned if stated intentions are consistent with actual behavior. Purchase intention responses in empirical studies have not necessarily shown actual purchase behavior in hindsight (Carrington et al., 2010). Accordingly, a review of payment intentions and actual purchase decisions may investigate this further. Moreover, an assessment of the transferability of our results to other cultural circles, particularly focusing on internationally operating companies, could provide meaningful insights.

4.4 Study D

This section refers to the article "An Empirical Survey on the Effects of a Global Pandemic regarding the Population's Stockpiling Behavior". This article was written in collaboration with Miriam Klein, Florian Diehlmann, Marcus Wiens, and Frank Schultmann. It is submitted to a scientific journal as Lüttenberg, Klein, et al. (2022).

4.4.1 Study Context and Contributions

This study contributes to current research by providing a better understanding of the amount of stored essential goods, using the rural communities in Baden-Württemberg, Germany, as an example region. The central RQ is:

How intense is the stockpiling behavior of the population in terms of crisis prevention, and is there a measurable effect of this behavior in terms of severe disruptions as in the COVID-19 pandemic?

To answer this RQ, the study tests four hypotheses regarding stockpiling quantity, possible observed changes in stockpiling behavior in the wake of the COVID-19 pandemic, reasons for the possible change in stockpiling behavior, and demographic factors affecting stockpiling behavior.

Regarding the resilience of successful crisis management, authorities such as the FEMA or BBK recommend the population to stockpile food, drinking water, and medicines to be prepared for a supply failure (see Table 4.3 for different categories and recommended amount per capita and day). A permanent stockpiling quantity for ten days is specified for these so-called essential goods. Particularly given the ongoing COVID-19 pandemic and the intensification of crisis events triggered by climate change (for example droughts, leading to transportation disruptions and supply shortages), the stockpiling of certain goods is of growing importance. To initiate and control appropriate measures, authorities first need valid data on the status quo of stockpiling. Nevertheless, neither the public nor the private sector collects data on stockpiling levels in the population.

Stockpile category	Recommended amount per capita and day
Beverages	2 liters
Grain products[1]	350 grams
Vegetables and pulse	400 grams
Fruits and nuts	250 grams
Milk and milk products	260 grams
Meat, fish, egg[2]	150 grams
Fats and oils	36 grams
Other[3]	not defined

[1] including bread, potatoes, noodles and rice

[2] including egg replacement products

[3] including sweets, salt, prepared dishes

Table 4.3: Necessary stockpiles per capita and day according to BBK (see also Table D.2)

However, a scientifically sound database is essential for weighing further steps. This is why the stockpiling levels are one main objective to be quantified as part of the survey. A door-to-door survey (S1) in early 2020 with 330 participants is presented within the study. Figure 4.5 shows the location of the different municipalities in Baden-Württemberg where the survey was carried out. As the COVID-19 pandemic spread immediately after completing the first round of surveys, the chance to further investigate the changes in stockpiling behavior through the impact of a global pandemic opened up. Therefore, we conducted a second door-to-door survey (S2) in the summer of 2021 with 402 participants using the same streets as in the first survey.

This study's main contribution is the quantification of participants' stock levels in relation to the eight categories (see Table 4.3) that the BBK identifies as essential assets for disaster preparedness.
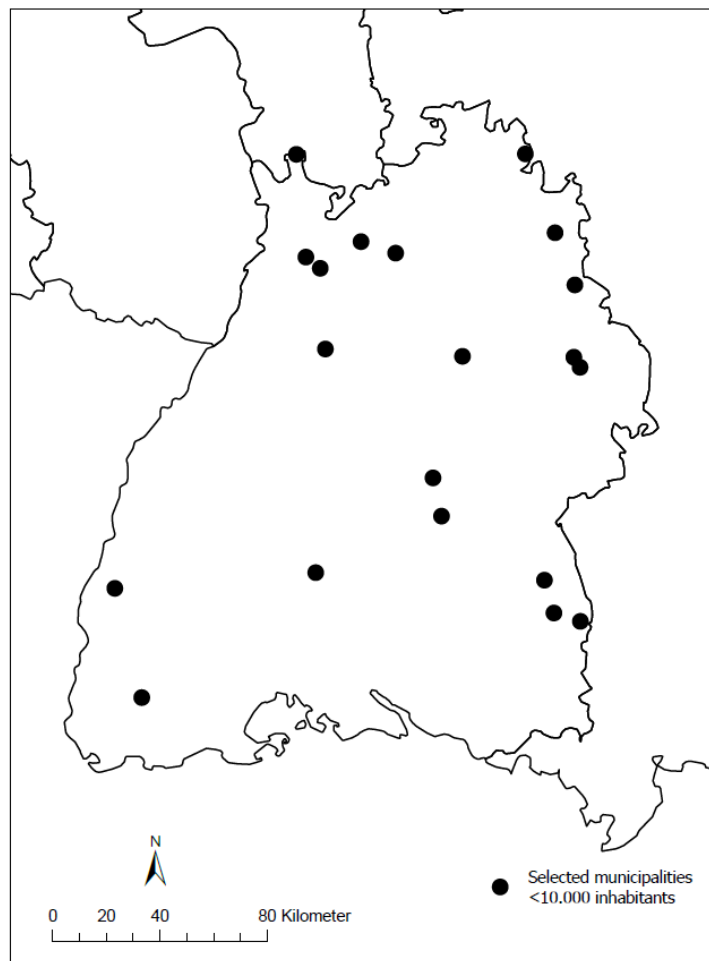
Figure 4.5: Map of selected municipalities in the federal state of Baden-Württemberg with its location in Germany (see also Figure D.1)

In addition, different sociodemographic groups of individuals with varying stockpiling behavior were identified.

4.4.2 Results and Discussion

The results of Study D support the assertion that there is a shortage in the stockpiling behavior of the population. Based on the responses regarding the suggested stockpiling amounts in the different categories issued by the BBK, an exploratory factor analysis (EFA) was performed to provide statistical evidence of a coherent food category system. The results from this calculation were incorporated into a stockpiling index (SI) developed as part of the study. In the EFA, it is possible to create a monoscale factor based on the responses that included all food categories except fats and oils. This category had no significant loading on the SI, which were confirmed by a subsequent Cronbachs' alpha test. The fats and oils category was removed accordingly. Subsequently, the SI is calculated as an equally weighted average of the data on the remaining food categories.
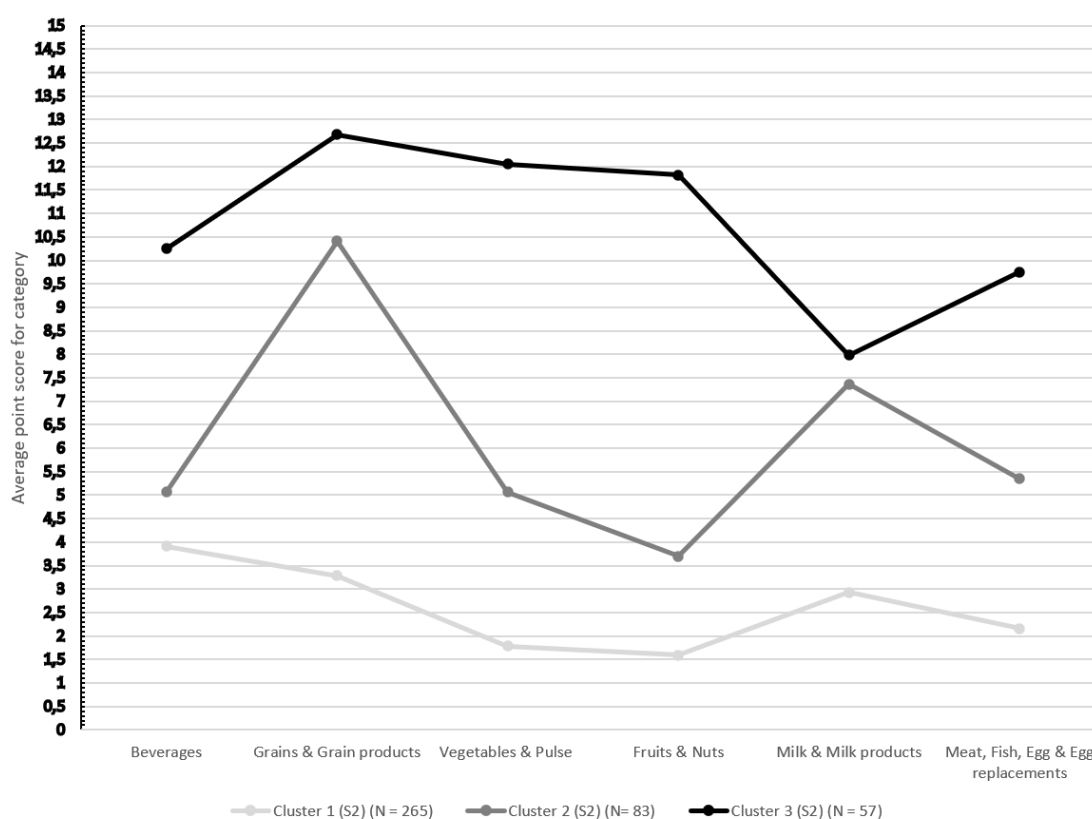
Figure 4.6: Cluster analysis of stockpiling behavior (see also Figure D.4)

Just a few (i.e., 8.86%) of the respondents could demonstrate a ten day supply of essential items as recommended. Conversely, the results suggest that COVID-19 showed short-term effects on stockpiling behavior yet stockpiling returned to similar levels in the long term. The second round of surveys did not uncover an increased fear of food shortages due to the COVID-19 pandemic. Unaffected by this are the short-term retail shortages as they occured globally, and in Germany, for example, specifically related to toilet paper and pasta (Bulka, 2020).

Another important finding is the importance of information management on the part of public authorities. The reasoning of Jones (2020) is that constant media coverage increases subjectively perceived risk and the argument of Donthu and Gustafsson (2020) is that the continued dissemination of certain "fake news" by some parts of the pouplation does little to calm people's concerns and fears. Taking these arguments as a basis, the study examines the importance of reliable, rational, and transparent communication on the part of public agencies. This is important to avoid hysteria and hoarding when a crisis occurs.

In the context of cluster analysis (Figure 4.6), the study shows differences in the stockpiling behavior of people belonging to different sociodemographic groups. For example, age correlates positively with the stockpiling quantity of the respondents. Moreover, a slightly negative but significant correlation of SI with food shopping frequency is observed, meaning that people in S2 who bought groceries less frequently tended to have higher SI values. In opposition, net income correlates negatively with stockpiling quantity.

Public authorities should prioritize support within a crisis according to vulnerability and need for essential goods. The study identifies three clusters of stockpiling types. Cluster 1 is designated as *Actual Hoarders* and includes individuals who are older on average than respondents in the other clusters. In this cluster, compared to the others, crisis prevention is given as a reason for stockpiling more often (though again, only about 30% of people gave this as a reason). They more often agreed with the fear of COVID-19 infection, while they less strictly agreed with the statement that they had stockpiled during the initial lockdown to overcome food shortages at local supermarkets. At the same time, their monthly net disposable income is lower compared with the other two clusters, and they go grocery shopping less often on average.

Cluster 2 is identified by the survey as *Convenience Hoarders* who had food stocks that were sufficient for about a week. Respondents from this cluster particularly stock foods that are easy to store (e.g., cereal products such as pasta or granola, or UHT milk). The final Cluster 3 is identified as *Contemporary Non-Stockpilers* who do not stockpile enough in any of the food categories. Particularly Clusters 2 and 3 do not stockpile enough: Public actors need to particularly address and motivate these groups of persons to specifically increase stockpiles.

In future studies, a larger number of respondents could be surveyed, for example, specifically from urban areas, across Germany, or even internationally, to obtain a larger sample size and draw further conclusions. A more in-depth analysis of the reasons and causes for stockpiling behavior and changes, especially with a focus on risk perception, can provide further information on this topic.

4.5 Study E

This section refers to the article "Supply Chain Disruptions, Firm Reputation and Customer Loyalty — An Experimental Study". This article was written in collaboration with Marcus Wiens, Milad Baghersad, Christopher Zobel, and Frank Schultmann. It is submitted to a scientific journal as Wiens, Lüttenberg, et al. (2022).

4.5.1 Study Context and Contributions

The objective of Study E is to measure the economic value of the availability of goods for a firm. To this end, an economic experiment with over 250 participants was conducted to investigate the research question of how reputation, induced by a repeated game structure, in a disruptive SC interacts with a firm's stockpiling behavior and the customer's loyalty to the firm. Moreover, the question arises whether the company has any incentive at all to build a reputation for availability of goods.

Figure 4.7 presents the repeated-game setting over five blocks, each consisting of ten periods, simulating a simple two-player market interaction between a customer (C-player) and a firm (F-player). There are two different treatments of the game played. In the first treatment, the short

run (SR) treatment, C-player and F-player are matched as a new pair every block. In the second treatment, the long run (LR) treatment, the same C-player and F-player are matched for all five blocks. With help of random procedure, the experiment simulates supply disruptions that a player in the firm role can prepare for by choosing a costly safety-stock (SS) or not (cf. Figure 4.7). In the figure, an exemplary distribution of disruptions is listed. Gray boxes represent disruptions. These disruptions can last one to three periods based on the experiment design. Except during disrupted periods, the F-player can invest in SS of one, two, or three items.

In this study, critical properties of relational contracts are experimentally measured, such as reputation building, reciprocity, and loyalty in a risk context. Players in the company role can protect themselves against supply failures by building up a SS. In contrast, players in the customer role can switch for free to a dummy player as a "competitor" of the company. The dummy player is always able to supply but with a lower utility to the C-player. Switching costs incurred if C-players want to return to their F-player.

It is experimentally tested whether and to what extent the loyalty or churn rate of customers is influenced by the reputation of the company. In addition, the company's reputation plays an important role in long-term customer-company relationships (interactions). A company can build a positive reputation in phases of frequent disruptions by reliably delivering products.

Safety-stock level S	No. unaffected rounds H ($h\%$)
0	26 (52%)
1	38 (76%)
2	46 (92%)
3	50 (100%)
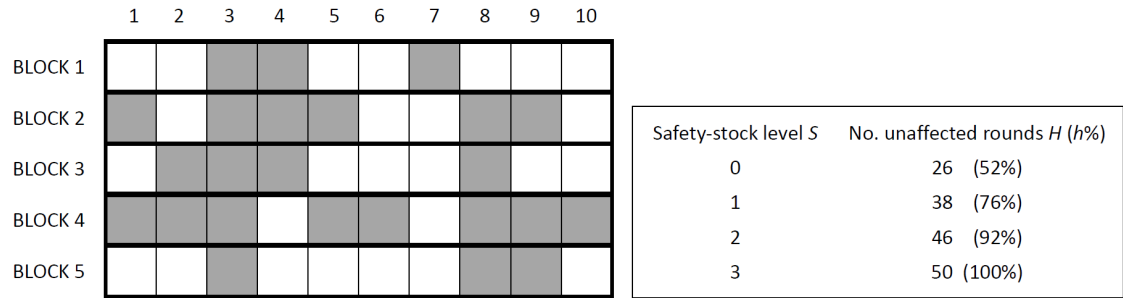
Figure 4.7: Schematic distribution of disruptions (gray boxes) and effects of different safety stock levels on the availability of goods. (see also Figure E.1 and Table E.1)

If building corporate reputation works, measuring higher loyalty levels in blocks three to five as a result should be possible, as consumers should be more willing to stay at the player-company, independent of disruptions and short-term non-availability of products.

In the context of reputation for delivery capability, customer loyalty can be measured by whether the customer still buys or buys again from the player-company (and not from the risk-free dummy firm) after a disruption in blocks three to five. This gives a loyalty index $L \in [0, 13]$ (cf. Figure 4.8 and Figure 4.10).

X = disruption;   ● = critical round, when a loyal customer should buy from the F-player again
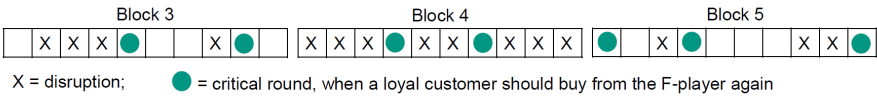
Figure 4.8: Loyalty-critical rounds over the blocks 3 – 5 (see also Figure E.2)

4.5.2 Results and Discussion

Three different hypotheses are tested with the data gathered from the experiment. The first one is that in both treatments, SR and LR, the SS-level is significantly different from zero, and customers predominantly choose the F-player instead of the bot. Given that only in 24.5% of all periods, F-players had a SS-level of 0 and the data from Table 4.4, which presents the choice of the customer (for overall results and separated for SR- and LR-treatment), the first hypothesis cannot be rejected.

Current status	Overall % $(n = 6550)$		SR % $(n = 3200)$		LR % $(n = 3350)$	
F-player	74.0	(4844)	73.0	(2336)	74.9	(2508)
Bot	26.0	(1706)	27.00	(864)	25.1	(842)

Table 4.4: Customers' overall choice of firm or bot (see also Table E.4)

The second hypothesis is twofold. On the one hand, it is tested whether the SS-level of firms in the LR-treatment is systematically higher than in the SR-treatment. The descriptive data from Figure 4.9 already shows that this is the case. The statistical test also confirms the finding. A Mann-Whitney-U-test reveals a highly significant effect ($U = 411.00$; p < 0.001***) and also a high effect size (Cohen's $d = 0.977$).

In the second part of the hypothesis, the general adherence of customers is tested, especially whether the loyalty level is higher after a disruption period in the LR-treatment compared to the SR-treatment. No significant differences were found for general adherence (LR = 21.47 periods with F-player, SD = 6.058, in comparison to SR = 20.46 periods with F-player, SD = 5.668). Concerning customer loyalty after a disrupted period, the loyalty index in Figure 4.10 shows this separately for LR- and SR-treatment. The differences are again statistically significant (Mann-Whitney-U: U = 2622.00; p = 0.013*) with a Cohen's d of 0.382, indicating an effect size low to medium.

The last hypothesis deals with the question of whether firms that choose a higher average SS-level over the initial two blocks achieve higher sales in unaffected periods and affected periods in the LR-treatment. The idea here is to measure reputation building and reciprocity. As formulated in hypothesis H3, the expected interaction corresponds to the classic reciprocal pattern of relational contracts. In the SR-treatment, the duration of the interaction between the customer and F-player is too short to build a reputation. The first 20 periods (two blocks) for building SS are considered since the firms can use these initial periods to form a reputation and build a relationship with their customers. A correlation analysis is conducted. The strong and highly significant correlation in the LR-treatment provides evidence for a reputation effect. It confirms that an indirect effect also stabilizes sales based on a relational contract between seller and buyer. The hypothesis cannot be rejected.

This study is the first to show that relational contracts can also unfold in a risk context. Measuring reputation effects and the properties of relational contracts in the context of frequency-based risk is more difficult compared to, for example, product quality issues in a stable and deterministic

market environment (Gans, 2019). As a discussion and starting point for further studies, the block length of ten rounds for the SR-treatment could be considered in more detail. This seems too long, as ten rounds can already be enough to establish a bond between the company and the customer. Moreover, the interruptions considered in the experiment are exogenous disturbances of the transaction ("noise"), which make it difficult for the customer to distinguish between the exceptionally reliable and particularly unreliable behavior of the company. In light of these challenges, the study can be seen as an important first step into the relevant research field of risk-based relational contracting.
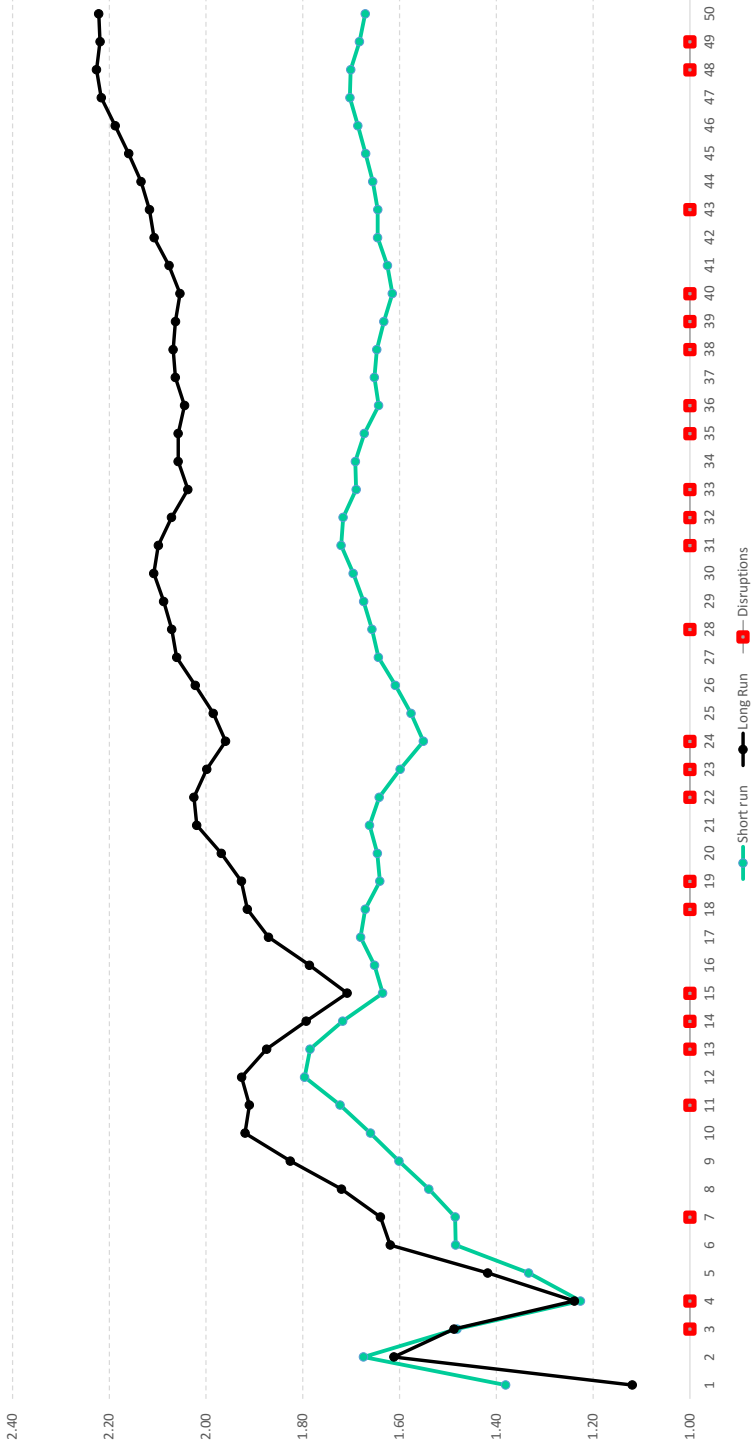
Figure 4.9: Moving average of safety stock (see also Figure E.3)
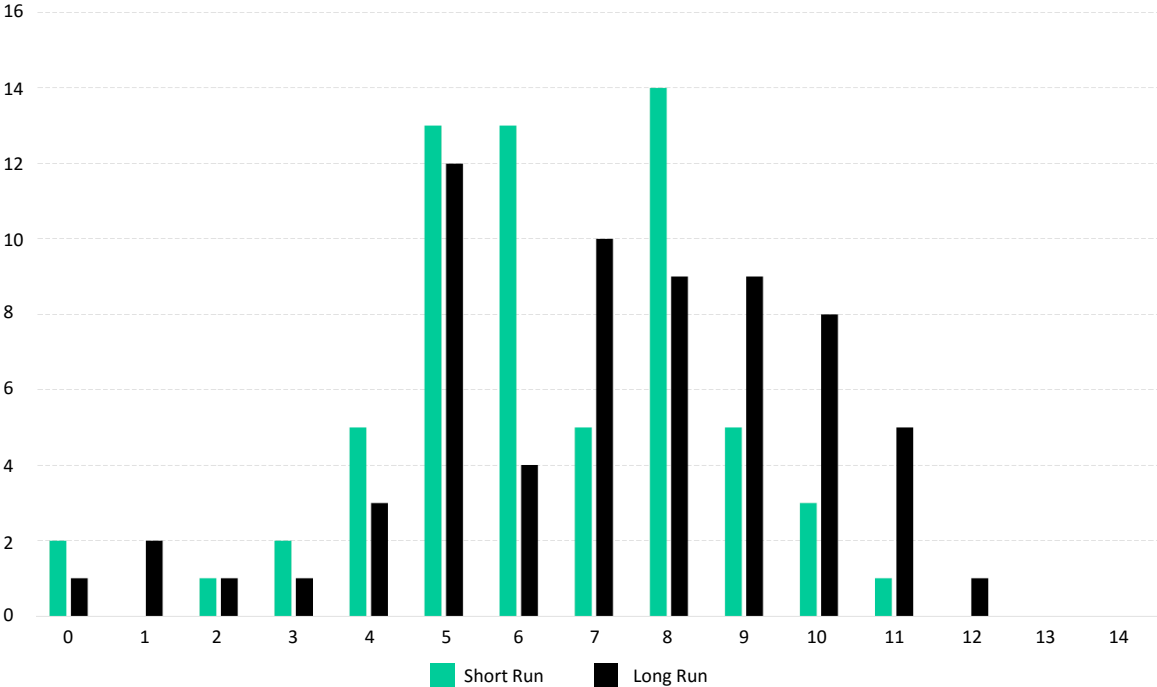
Figure 4.10: Loyalty index (see also Figure E.4)

5   Managerial Implications

After presenting the main contributions and results of Studies A–E, the managerial implications are discussed in the following. As mentioned in Section 3.3, different stakeholders involved in a PPEC are part of the cross-study analysis. These are public actors, private actors, and the population. This chapter starts with general implications applicable to all stakeholders and moves on to the separate implications and recommendations for each stakeholder based on the different study results. Table 5.1 summarizes the implications for the different stakeholders in the end.

5.1   General Implications

Global crises and supply chain disruptions are present threats and will increase in the future. All stakeholders have to adapt and improve current protection measures and strategies. In the recent past, the COVID-19 pandemic and very slow-building crises such as climate change clearly show that no single stakeholder can manage to overcome the respective crisis alone. Collaborative approaches, as conceptualized in the framework of a PPEC, are a helpful step in this direction. Collaborations between different stakeholders, where each stakeholder brings his or her strengths into the collaboration, benefit all parties involved. Furthermore, humanitarian crisis management also includes the right communication strategy, especially from the side of the companies. It is not only important to contribute but also to communicate it convincingly through channels that are seen as trustworthy by the population.

5.2   Implications for Public Actors

Public actors are central to humanitarian crisis management as demonstrated in Section 2.2.1. Based on the results of Studies A, B, and D, the following implications for public actors in terms of an improvement of humanitarian crisis management can be drawn:

In a game-theoretic modeling approach of Study A, the participation constraints of public and private partners to collaborate in a PPEC were formulated. Based on standard game-theory arguments (e.g., Bartholomae and Wiens (2016)), a player ("the company") should always choose the option which provides him with a better utility, when stuck between two options. In the PPEC example, the public actor needs to increase the private actor's benefit compared to non-collaborative case, which could be reached through direct payments or a decrease in transaction costs for the

company. These transaction costs occur through high contract costs and can be minimized through more standardized agreements between public and private actors.

In addition, Study A integrates the aspect of reputation as an addition to the standard cooperation model. The idea here is that participation in a PPEC, similar to CSR commitment, can be received positively by potential customers, thereby increasing the willingness to pay (Besiou and van Wassenhove, 2015). This has two main implications for the public actor. On the one hand, in this case, since collaboration rates are (imperfect) substitutes, it can reduce their contribution to collaboration and put correspondingly higher amounts into crisis provision. On the other hand, the public actor should ensure that the hoped-for positive image of private actors' participation reaches the population in this form. This is discussed in more detail in Studies B and C.

Study B shows that companies are valuable partners regarding resources, infrastructure, and know-how to public partners. Probably the most important key message derived from the study's results for public actors is that companies are generally willing to participate in PPECs. For this to happen, public actors must make the benefits much more straightforward. Public actors should pay particular attention to the following aspects when approaching private actors to engage in PPECs. As one main factor, public actors need to consider transferring fair cost-based payments to the companies. Another factor relates to the two sides of how companies evaluate the reputation gained through a PPEC. Reputation is seen as both an advantage and a disadvantage by companies. In order to counteract doubts about the benefits or to send a clear signal to the population about the positive aspects of the commitment, target-oriented communication by public actors would be an excellent way to proceed.

The results in Study B indicate that public actors should take advantage of the fact that the more non-financial benefits private actors can derive from a PPEC, the fewer transfer payments they expect for their PPEC engagement. On the one hand, cost reimbursements for costly aid activities by private actors should be faster and with less bureaucracy. On the other hand, these non-financial incentives must be advertised and promoted more prominently.

Among the non-financial incentives that public actors should consider, the most important conditions are first that companies want to protect their business processes before they help others. Second, they want to avoid delivery or service failures to business partners due to the PPEC engagement. Third, unused resources of public actors (such as trucks or personnel) should be made available to support the relief efforts of private actors. Fourth, public actors also have opportunities to accommodate private actors in legislation and labor law. This is what happened, for example, when the ban on trucks being operated on sunday's was lifted in Germany at the beginning of the COVID-19 pandemic (Verband Verkehrswirtschaft und Logistik, 2020). Mitigating private sector risks, such as through Hermes guarantees (BMWK, 2020), can also be another incentive for private actors. In this case, commercial activities would be covered by the government against economic or political risks.

The survey data reveals that 91% of companies are willing to share company data with public authorities. This offer should be taken advantage of, for example, by enhancing IT interfaces. This should make it possible for companies to provide their data for public emergency preparedness

in an unbureaucratic way, and, if possible, anonymously. One way to do this would be to use blockchain technology. The data, in turn, may be used by public actors to fill their demand model calculations with more accurate data. Overall, authorities need to develop a better communication strategy and networks to promote the benefits of collaborative crisis management to companies and the population in a more detailed and convincing way.

Study D looks at the stockpiling behavior of the population in the area of essential goods and whether there have been changes due to the experience with the COVID-19 pandemic. For this purpose, two representative survey rounds were conducted in rural areas of Baden-Württemberg. The main findings are that the stockpiling quantities do not correspond to the advice of the BBK and that the COVID-19 pandemic has only led to short-term increases. In the long term, there has not been a significant change in the stockpiling behavior of the population. Increased stockpiling could be achieved through a more targeted communication strategy by public actors. There were contradictory recommendations in the course of the pandemic, e.g., on the topic of correct stockpiling. Hoarding purchases could have been prevented, in which an unnecessarily large number of goods that were only available in limited quantities in the short term were procured by a few individuals. The study also gives insight on the handling of fake news (see Jones (2020)). A key finding of the COVID-19 pandemic is that, while there were short-term shortages in supermarkets, overall, the supply situation is stabilized by private actors at all times. Sensitization measures, such as information campaigns on the part of public actors, should point out that the supply could be significantly more limited in other crises to create a broader awareness of this. In addition, a cluster analysis, in which different types of stockpiling strategies were identified based on different sociodemographic factors shows significant differences in the stockpiling behavior of the population. Accordingly, public agencies should target groups of people who are lagging in terms of stockpiling behavior.

5.3 Implications for Private Actors

Some of the implications for private actors of Study A have already been touched upon in the section before. In a nutshell, besides monetary compensation for a private actor's engagement in a PPEC, they also perceive an increase in reputation as an opportunity from a PPEC. An important point here is the credibility of the action. Even though corporate engagement in PPECs is highly valued, it depends significantly on the quality and quantity of corporate outreach. The population wants the private actors to engage convincingly. The results of Study A further suggest that companies achieve a learning effect for their corporate BCM through participation in a PPEC. Within crises where the private actors are affected, business continuity is the highest priority in the eyes of the companies. In the long term, this learning can lead to cost reductions in the event of disruptions in the supply chain.

For Study B, responses from 398 companies involved in the manufacturing and distribution of essential goods and associated logistics companies were analyzed. One of the impacts noted is

the many industries and sales size-specific findings (see Study B). For example, the medical goods sector is rating reputation losses worse than LSP or food.

In the area of possible ways to assist (here divided into the two superordinate categories of coordination and provision of resources), companies, on the one hand, see a higher need for public actors in the provision of resources. On the other hand, when asked about their aid preferences, they tend to provide coordination aid more. This contradictory presumptuous statement could be clarified by a more precise idea of the respective tasks and associated financial and non-financial incentives. The study showed that companies see the most significant advantages in a PPEC as being able to quickly return to normal operations, gain early insight into the crisis, and establish contacts with authorities and other companies. Companies see the most significant disadvantages in legal risks.

The issue of liability, to name an example, is unclear to many companies. This is followed by possible obligations through contracts with authorities, leading to (negative) consequences that are difficult to assess. Furthermore, disclosure of internal data, loss of personnel, and loss of profits are possible disadvantages. The issue of contracts is viewed less critically by companies that have already had contact with public authorities in the event of a crisis compared with companies overall (46% cite this as a disadvantage compared with 51% overall). The loss of personnel due to double burdening is cited significantly more frequently by companies that have already had contact with public actors in a crisis (54% compared with 49% overall). The last two aspects illustrate that companies' expectations can change considerably as a result of contact with public actors.

Overall, it can be seen that there are slight, however significant, correlations in that the smaller the willingness to participate in a PPEC, the more frequently disadvantages are mentioned, and the higher the willingness to participate in a PPEC, the more frequently advantages are mentioned.

Study C examines the public's attitude toward corporate participation in PPECs. The results of this study initially confirm the hypotheses from Studies A and B that the population generally favors the participation of companies in PPECs. More than 85% of respondents (n=349) agree with the statement that participation in a PPEC represents an opportunity for the company to take social responsibility. In addition, a similar agreement rate confirms that crisis management can succeed more efficiently. Concerning the credibility of information, it is shown that the highest level of agreement (on a 5-point Likert scale) is with the company's own experience (Mean = 4.32, SD = 1.029). Educational brochures from government agencies and their websites (Mean = 3.97, SD = 1.028) reach the second highest level of agreement and are thus rated as more credible than companies' annual reports (Mean = 3.15, SD = 1.289), and significantly more credible than what companies present in advertising (Mean = 2.01, SD = 1.009). These results clearly show that companies should only cautiously communicate their participation in a PPEC to the outside world on their own but should, in particular, use the available communication channels of the public actors for this purpose.

The respondents have a clear prioritization regarding the credibility and motivation of companies' actions in the area of relief measures. Multiple aids were cited as the most credible (4.34 on a 5-point Likert scale), showing long-term involvement from the corporate side over the one-time aid action. This is followed by using various resources (4.11), which is said to be preferable to the

classic "donation of money" by companies. Low advertising measures on the part of the companies for their actions were also explicitly named as a factor of credibility (3.68). This factor goes hand in hand with the lack of credibility of company announcements on their website (2.34). The latter two results again illustrate the problem faced by many companies. If they want to get involved in a PPEC, this long-term participation, generally viewed as positive by potential customers, must be communicated via the proper communication channels. Otherwise, the damage is greater than the hoped-for benefit. According to the study results, specialized journals and educational brochures published by government agencies are perceived as particularly credible, while advertising is perceived as particularly untrustworthy. It is also found that a positive attitude of respondents towards a PPEC engagement is associated with an increased willingness to purchase from private actors. Companies should take advantage of this fact in their business strategy.

In addition to the positive aspects of CSR, however, in line with Madsen and Rodgers (2015), companies should consider that financial benefits will not materialize in the short term. Instead, a longer-term perspective over several years must be taken.

Study E is an experimental study analyzing the threat of customer churn as an incentive for a firm to take precautions against supply disruptions and establish a reputation for product availability. It compares the effects of two different settings for reputation building on customer response and firm performance. The results show that it is worthwhile for companies to invest in costly safety stocks, not just for self-protection motives.

While precautionary stockpiling on the part of companies is costly, it has one key advantage: customer loyalty immediately after supply disruptions is significantly higher in the LR-treatment than in the SR-treatment and also has a noticeably positive effect on companies' sales. In addition, it can be deduced from the study results that only those LR firms that use the first 20 rounds to build a reputation as a reliable supplier can effectively address customer responsiveness to be more loyal. In this case, the reciprocal pattern of efficient cooperation typical of relational contracts can be generated. However, this correlation also implies the downside of relational contracts: LR firms that miss this opportunity experience a more severe decline in their revenues. This is most likely due to their inability to meet the higher expectations of LR customers.

The following message can be drawn for firms as the primary business implication of applying relational contracts in a risk context: SS are worthwhile not only for self-protection but also as a precautionary risk management strategy that leads to fewer supply bottlenecks on the one hand and more stable and crisis-tested customer relationships on the other. In highly uncertain and crisis-ridden times due to pandemics, wars, climate change, and cyberattacks, a loyal customer base serves as insurance to succeed in the market.

5.4   Implications for the Population

As the target group of the two actors mentioned above, the population's role is unique. On the one hand, they are the ones who suffer in crises and need to be helped. On the other hand, their behavior before and during crises can also significantly contribute to the success of crisis management. The results of Studies C and D elaborate on the measures and recommendations for the population. Study C analyzes the responses to the risk perception and attitude domain about corporate participation in PPECs of 402 respondents. The results revealed a highly positive correlation between the two constructs. The study's key finding is that the population does not only value corporate engagement in PPECs positively, but it is also highly correlated with their perception of risk. Various findings on the credibility of corporate actions and how this commitment should be communicated to the public by companies to gain trust and, thus, positively influence the population's perception, is already elaborated in the previous subsection on corporate implications. Furthermore, the lack of knowledge about CSR measures of companies (see Van et al. (2020); Lee et al. (2019)) and cooperation between public and private actors in the crisis context in particular, is also relevant for understanding the population.

The study results show that just over half of the respondents (54.5%) were aware of collaborations in this area, but only 11.9% could name the actors of a specific collaboration. Here, in addition to the communication and information strategies already discussed for public and private actors, heightened awareness and increased need for information on the part of the population are necessary. PPECs are a useful crisis management tool. If they are ignored or not taken into account to the extent they should be, problems in the individual's crisis resilience can occur. For example, the individual's approach to crisis prevention is defered or is considered irrelevant to the individual because the public and private actors are relied on ultimately.

Another phenomenon identified in Study C, which is also a well-known phenomenon of detectable asymmetry in other areas of consumer behavior, is the difference between statements and actions (Carrington et al., 2010): What the population states ("we value engagement"), which is about an intention, and where they finally buy products (actions), diverges. This may have several reasons, one of them being the social desirability bias: one person assumes what the correct action for moral or ethical reasons may be. However, for convenience, financial reasons, or for selfish motives (e.g., vacation trips to distant countries by plane), the person does not act according to the previously described value compass (Kuokkanen and Sun, 2016).

The other central aspect covered in Study C addresses respondents' perceptions of risk. By forming a risk perception index aligned with the risk paradigm of Slovic (1987), it is shown that a more risk-averse respondent is more positive toward corporate involvement in PPECs. This means that PPECs appear to the respondents as a sensible measure for minimizing risk. The COVID-19 pandemic shows that personal knowledge of a COVID-19 infection from one's own social network results in significantly increased risk perception. This highlights once again that one's direct experience significantly influences behavior and perception, which may not necessarily be advantageous in terms of comprehensive crisis management, or may lead to incorrect conclusions.

The results of Study D show that the population does not stockpile enough essential goods. Here, sufficient is equated with the ten-day quantity recommended by the BBK. As a conclusion from the study it can be stated that the population needs to enhance stockpiling to fulfill the quantity recommendations. In none of the categories listed by the BBK, even an average stockpiling quantity of seven days is achieved. Understandably, it is difficult to stock fresh vegetables (2.84 days of stored product on average), fruit (2.93), or meat, fish, and eggs (3.97) for ten days, but there are also dried or frozen long-lasting alternatives. Especially for products that can be stored well, such as beverages (3.95) or cereal products (4.3), there is a need to catch up on stockpiling. The awareness of possible crisis scenarios for which it may be worth to stockpile is an important aspect that, therefore, needs to be emphasized. However, even during the COVID-19 pandemic, there is only a slight increase in crisis awareness, indicating a slightly increased perception that crisis scenarios are a good reason for more stockpiling (from 8.2% before pandemic to 9.6% during pandemic). The study also shows that a lack of stockpiling is not caused by a lack of space for storage facilities, as only 15.1% of respondents would stockpile more if they had more space. Moreover, 35.5% of the respondents justify the possible perishability of goods for not stocking more.

Overall, the results of Study D clearly imply that the population can make a decisive contribution to preventive crisis management through their stockpiling behavior. In addition, the population should also be involved in PPEC considerations so that crisis management can be more holistically considered and organized in the future.

Table 5.1 summarizes the implications for the different stakeholders.

Implications for stakeholders		
General stakeholder implications		
- Global crises and supply chain disruptions are a present threat and will be increasing in future, everyone has to adapt and improve current protection measures and strategies. - Collaborations between different stakeholders, where each stakeholder brings his or her strengths to the collaboration is beneficial for all parties involved. - Crisis management also includes the right communication strategy. It is not only important to contribute but also to communicate it in a successful and convincing way.		
Public Actors	**Private Actors**	**Population**
Public actor needs to increase the private actor's benefit compared to non-collaborative case, which could be reached through direct payments or a decrease in transaction costs for the company.	Within crises, business continuity is of highest priority in the eyes of the companies.	Lack of knowledge about CSR measures of companies as well as crisis management and crisis collaborations leads to misknowledge and misunderstandings.
Companies are open to engage in PPECs, but public actors need to consider transferring fair cost-based payments to the companies.	Besides monetary compensation, companies also perceive an increase in reputation as an opportunity from a PPEC.	Population not only rates company engagements in PPECs generally positively, but also that it is highly correlated to their risk perception.
More communication of benefits to companies, including non-financial benefits at first sight as reputation gains or learning effects, and to population is necessary.	Corporate engagement in PPECs is generally highly valued by population but it depends significantly on the quality and quantity of corporate outreach, private actors have to engage convincingly.	COVID-19 pandemic data showed that personal knowledge of COVID-19 infection sig. increased risk perception, (experience sig. influencing behavior and perception).
Further non-financial incentives: companies' protection of business processes has to be prioritized. Unused resources of public actors (such as trucks or personnel) should be made available to relief efforts of private actors.	PPEC engagement leads to learning effects in corporate BCM. In the long term, this learning can lead to cost reductions in the event of disruptions in the supply chain.	Detectable asymmetry of consumer behavior in statements and actions: What population states ("we value engagement," which is about an intention & where they finally buy products (actions), diverges.
Public actors have opportunities to accommodate private actors in legislation and labor law.	Companies see the most significant advantages in a PPEC as being able to quickly return to normal operations, gain early insight into the crisis, and establish contacts with authorities and other companies.	Stockpiling behavior of essential goods by the population is not done well enough: Population needs to stockpile better.
Public actors need to create secure and confidential digital infrastructures for private actors to share valuable business data.	Companies see the most significant disadvantages in legal risks.	Studies clearly show that population can make a decisive contribution to preventive crisis management through stockpiling.
To increase population's stockpiling, more targeted communication strategy focusing on sociodemographic clusters with least stockpiling amount. Proper handling of fake news.	Safety stocks are worthwhile not only for self-protection but also as a precautionary risk management strategy leading to fewer supply bottlenecks and more stable and crisis-tested customer relationships.	Population should be involved in PPEC considerations for a more holistical crisis management approach in the future.

Table 5.1: Implications of cross-study analysis for stakeholders

6 Conclusion

6.1 Summary

Major humanitarian crises, such as the globally recognizable climate change or the COVID-19 pandemic, are becoming more frequent and intense in recent years (OCHA, 2022). In this regard, preparatory actions by various actors play an important role. These can increase the resilience of the respective stakeholders and support successful crisis management during the course of the crisis.

The analysis and prognosis of crisis occurrence, course, and extent, and especially crisis management are critical and highly interdisciplinary topics of increasing importance. Geographical, natural scientific, sociological, economic, and political components play a role, to name only a few of the fields of work-areas involved. The present dissertation contributes to advancing the state of interdisciplinary crisis research particularly in the areas of society, economy, and politics.

In developed countries, public actors are in charge of managing crises that affect their population. However, other studies have already shown that public actors need cooperation partners for particular areas. No public actor alone can successfully manage crises.

In order to take a closer look at the topic of crisis management and to examine its potential, five studies were developed as part of this dissertation. Particular attention was paid to the views of the various stakeholders. The studies shed light on the current state of crisis management and how it could be improved, specifically in terms of collaborations between public and private actors. Thereby, the studies evaluate different collaboration designs and identify potentials for improvement in preventive measures from the point of view of various stakeholders.

PPECs as a concept for improving crisis management were examined in more detail, revealing various other potential improvements. The approach of the dissertation is to improve PPECs by considering the specifics of the different stakeholders and their incentives and objectives. Empirical studies, economic experiments, and game theoretic evaluations were used as methodologies in this context.

The main contributions can be summarized as follows. The studies provide a better understanding of the status quo of collaborations between public actors and private actors. The objectives and incentives of different stakeholders involved in crisis management are uncovered. The concept of PPECs to improve crisis management is further enhanced. Stockpiling behavior of the population is measured to determine population's current preventive measures in terms of essential goods.

Reputation mechanisms of companies are defined and elaborated as one factor to make the positive impact of engagement in PPECs visible to companies.

Study A focuses specifically on what is known about crisis management to date and, in particular, the preliminary work on PPECs. The results show that private actors have received too little attention in humanitarian crisis management. The PPEC concept is put into a more concrete framework on logistical requirements with game-theoretic modeling. In this context, private actors' incentives to collaborate, such as a positive reputation or a learning gain for internal BCM, are included in the modeling.

Study B looks at crises and PPECs from a company perspective. As part of an empirical study, 398 responses of companies were evaluated from the essential goods sector, as well as logistics companies. The results show that companies are highly willing to participate in humanitarian measures. Especially concerning possible cooperation with public actors, the respondents need certain conditions to be fulfilled. The willingness to contribute to a PPEC depends on the type of company, adequate compensation for the provided assistance, and consideration of the operational procedures of companies in crises as the main requirements.

Study C takes the essentially affected stakeholder, the population, into focus. In a survey of 402 randomly selected participants, the results show that the population highly values companies' involvement in PPECs. Nevertheless, the quality and quantity of corporate communication, the communication channel used, and the communication strategy strongly affect the population's perception. In addition, the results show a highly significant correlation between risk perception and approval of engagement in PPECs.

Studies D and E shift the collaborative approach of the three previous studies to the specific behaviors and incentives of the two actors, population (Study D) and private actors (Study E). As part of Study D, a representative door-to-door survey in rural communities in Baden-Württemberg, Germany, was conducted prior to COVID-19 pandemic to better understand the actual amount of stored essential goods with 330 participants. The results of the study reinforced findings suggested by other studies that the population does not stockpile enough essential goods on its own. The results of a second survey during the COVID-19 pandemic in the summer of 2021, with 402 respondents from the same communities, illustrate that COVID-19 had only short-term effects on stockpiling behavior. In the long term, stockpiling returned to similar levels as before.

Study E is an economic experiment designed to directly quantify the strength of reputational incentives (firm reliability and customer loyalty). Therefore, indirect losses due to customer churn from the direct loss caused by a disruption were isolated. A total of 262 participants took part in 13 sessions. The safety stock level of the LR-treatment is slightly higher than that of the SR-treatment. Customer loyalty is also slightly higher in the LR-treatment than in the SR-treatment.

The main implications of the dissertation are as follows. SCs worldwide are subject to potential disruption from current threats. Examples from the recent past, such as the COVID-19 pandemic, or very slowly evolving crises, such as climate change, illustrate that these threats will increase in the future. All stakeholders must adapt and improve their current protective measures and strategies. No single actor can resist, let alone manage, globally emerging crises on their own. Collaborative

approaches, particularly the PPEC concept, show enormous potential in managing crises, especially concerning the supply of essential goods to the population. Collaborations between different actors, where everyone can contribute their strengths, benefit everyone involved.

6.2 Outlook

All of the stakeholders considered in this dissertation, i.e., public actors, private actors, and the population, must be made more aware of the risk of an increased frequency of crises with serious consequences for people, infrastructures, and SCs. This realization must lead to actions taken on all sides.

The focus of this work is on the strategic, incentive-oriented level of the actors. Operational implementation and planning of the joint measures is only marginally considered. Precise implementation plans of the options elaborated in this work involve a considerable amount of human resources and coordination, which should be considered by the stakeholders, e.g., in crisis preparation meetings of public authorities or in the context of BCM measures in companies.

The different case studies focus on Germany. A transferability to other industrialized countries in the Western world can be assumed but should be verified in future work. Other forms of cooperation, such as horizontal cooperation between different companies or public partnerships with NGOs, which would be conceivable in the field of crisis management, should also be considered.

Within the modeling of reputation for private actors when engaged in PPECs, future studies could specifically consider dynamic processes. Dynamic work considering repetitions in the model could more clearly elaborate on the possible reputation gain to the private actor. Furthermore, the learning process, e.g., the gradual improvement of the BCM process within the own company, could be further illustrated.

Future studies could focus more on quantifying outcomes. For example, the quantification of the intensity of the willingness of companies to provide assistance, or the increased willingness of customers to buy from companies involved in PPEC, is of interest. Real-life data would help to get more precise planning and implementation of specific measures.

The social desirability bias typically occurrs in surveys, when the decisions of the participants are not followed by real life consequences. Due to social desirability, companies as well as the population may have given answers that are not reflected in this way in reality. For instance, actual purchasing decisions can be examined directly in the supermarket, or the actual expenditures of the companies in balance sheets. These validation tests should be taken into account as additional robustness tests for the survey results.

Summarizing the contributions of this dissertation, it evaluates different designs of collaboration and identifies potential for improvement in preventive measures from the point of view of various stakeholders. The results of this dissertation illustrate that one actor alone cannot successfully manage a crisis. Thus, in the interest of all actors, it should not be relied upon a single actor, but

on modular concepts, such as those applied in PPECs. Here, the strengths of public and private actors are combined. At the same time, the population's own responsibility for action is taken into account.

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Part II

Companion Articles

Overview of Related Publications

Study A

Diehlmann, F., Lüttenberg, M., Verdonck, L., Wiens, M., Zienau, A., Schultmann, F. (2021). Public-private collaborations in emergency logistics: A framework based on logistical and game-theoretical concepts. *Safety Science*, *141*. doi: 10.1016/j.ssci.2021.105301

Study B

Lüttenberg, M., Zienau, A., Wiens, H. O., Marcus, Diehlmann, F., Schultmann, F. (2022). How to enhance company engagement in public-private emergency collaborations in the supply of essential goods. *Submitted to a Scientific Journal*.

Study C

Lüttenberg, M., Schwärzel, A., Klein, M., Diehlmann, F., Wiens, M., Schultmann, F. (2022). The attitude of the population towards company engagement in public–private emergency collaborations and its risk perception — a survey. *International Journal of Disaster Risk Reduction*, *82*. doi: 10.1016/j.ijdrr.2022.103370

Study D

Lüttenberg, M., Klein, M., Diehlmann, F., Wiens, M., Schultmann, F. (2022). An empirical survey on the effects of a global pandemic regarding the population's stockpiling behavior. *Submitted to a Scientific Journal*.

Study E

Wiens, M., Lüttenberg, M., Baghersad, M., Zobel, C., Schultmann, F. (2022). Supply chain disruptions, firm reputation and customer loyalty – an experimental study. *Submitted to a Scientific Journal*.

A Public-Private Collaborations in Emergency Logistics: A Framework Based on Logistical and Game-Theoretical Concepts

Abstract[1]

Collaboration in emergency logistics can be beneficial for governmental actors when supply chains need to be set up immediately. In comparison to research on humanitarian-business partnerships, the body of literature on so-called Public-Private Emergency Collaborations (PPEC) remains scarce. Private companies are only rarely considered within research on emergency collaborations, although they could contribute to a more efficient supply of goods given their resources and existing communication networks. Based on this research gap, this paper develops a logistical and game-theoretical modeling framework for public-private emergency collaborations. We characterize both public and private actors' possible roles in emergency logistics based on literature research and real cases. Furthermore, we provide an overview on existing PPECs and the challenges they are confronted with. The concluding framework contains aspects from humanitarian logistics on the governmental side and from business continuity management (BCM) or corporate social responsibility (CSR) on the commercial side. To address the challenge of evaluating different objectives in a collaboration, we add a game-theoretical approach to highlight the incentive structure of both parties in such a collaboration. In this way, we contribute to the research field by quantitatively evaluating public-private collaboration in emergency logistics while considering the problem-specific challenge of the parties' different objectives.

A.1 Introduction and motivation

In 2018, earthquakes and tsunamis resulted in the loss of 10,733 lives, while extreme weather led to 61.7 million people affected by natural hazards (UNDRR, 2019). According to Worldbank (2019), global losses caused by natural hazards have quadrupled from $50 billion a year in the 1980s to

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[1] This chapter includes the article "Public-Private Collaborations in Emergency Logistics: A Framework based on Logistical and Game-Theoretical Concepts" by Florian Diehlmann, Lotte Verdonck, Marcus Wiens, Alexander Zienau, Frank Schultmann, and myself, which has been published in Safety Science (Diehlmann et al., 2021)

$200 billion in the last decade. Moreover, population growth and increased urbanization lead to rising disaster impacts (Worldbank, 2019).

van Wassenhove (2006) highlights that around 80% of all relief efforts after disasters are related to logistics. Consequently, all involved actors need to establish well defined relief logistics procedures to protect the affected population. While emergency management focuses on the management of all actions directly after the impact of a disaster (see for instance Tatham and Spens (2011)), the term "emergency logistics" can be defined as "a process of planning, managing and controlling the efficient flows of relief, information, and services from the points of origin to the points of destination to meet the urgent needs of the affected people under emergency conditions" (Sheu, 2007).

Within the limits of the concrete disaster scenario, companies can still dispose over most of their capabilities to respond to the disaster, while established supply chain structures are severely interrupted during catastrophes (Holguín-Veras et al., 2012). Higher resilience provided by public and private actors, cooperatively involved in disaster relief, can therefore help to prevent the shift from a critical or disastrous situation to a catastrophic disaster, resulting in a reduction of the burden on the population and companies.

The focus of this paper is to describe and model the scope and potential of emergency collaboration between private firms on the one hand and the government on the other, hence a Public-Private Emergency Collaboration (PPEC). Although researchers agree that multiple actors play an important role in relief logistics (Balcik et al., 2010; Kapucu et al., 2010; Kovács and Spens, 2007), real world cases that develop quantitative disaster relief models for civil protection agencies and other governmental authorities are rarely considered in the literature. One reason for this phenomenon could be that - compared to governmental agencies - humanitarian organizations are more willing to provide researchers with data that they are allowed to publish (and/or funding) in exchange for scientific knowledge and experience (Arnette and Zobel, 2019; Duran et al., 2011; Gatignon et al., 2010; Pedraza-Martinez and Van Wassenhove, 2013; Saputra et al., 2015; van der Laan et al., 2016). In contrast, data received in cooperation with public authorities and governments often contains critical knowledge that researchers might not be allowed to share publicly (Goolsby, 2005). However, an exclusive research focus on non-profit humanitarian organizations in the quantitative relief management context might lead to a trend to analyze ways to fight the symptoms instead of tackling the roots of the problem. It can be argued that the role of non-profit humanitarian organizations in humanitarian logistics primarily exists due to a lack of resilience in the market or in the public disaster management system.

From a conceptional point of view, activities of actors after a disaster can be classified as in Figure A.1 (note that real cases may vary from this - for instance due to very strong and active NGOs or comparably ineffective public or private actors). Firms deal with fluctuations in demand or supply as well as with disruptions in their supply chain in the context of their Business Continuity Management (BCM) on a regular basis (see for instance Schätter et al. (2019)). Their reactions focus on getting back to "business as usual" as soon as possible (Palin, 2017; Macdonald and Corsi, 2013). Once a disruption in supply impacts the population or critical infrastructures significantly,
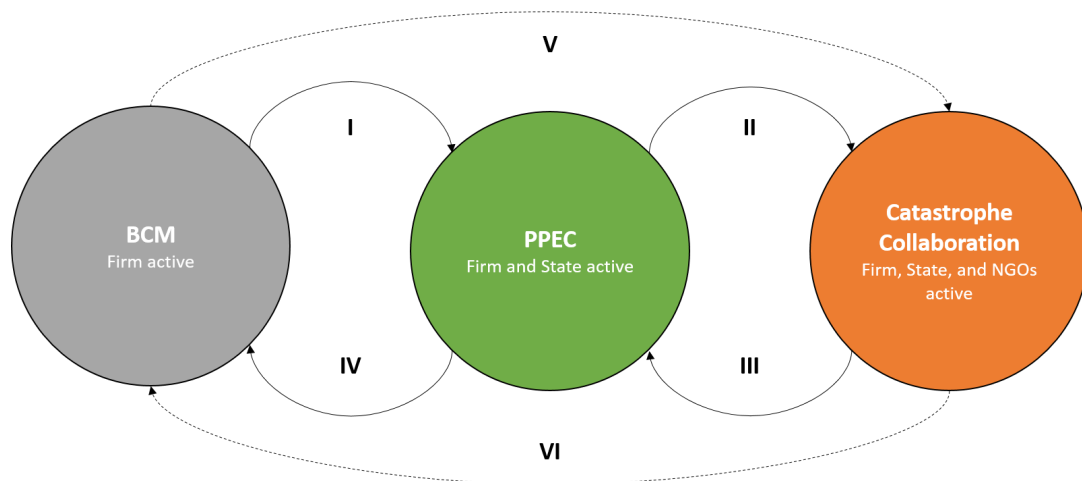
Figure A.1: Classification of phases or activities for different types of actors during a crisis.

the state needs to become active to ensure the population's well being (Wiens et al. (2018), "I" in Figure A.1). These operations can be significantly improved by a collaboration with private firms (PPEC). The importance of the private sector is underlined by Izumi and Shaw (2015), who point out that 70-85% of investments in emergency logistics are expected to come from the private sector.

While humanitarian organizations (HOs) can operate humanitarian supply chains without the occurrence of a disaster, they sometimes play an important role in emergency logistics as well. Their activity usually starts once the impact of the disaster reaches another critical threshold - for instance, because they get significantly more donations if the crisis receives more attention by the media due to increased severity, or due to the time it takes to collect donations (II). In this phase, all actors fight the situation at the same time and need to directly or indirectly work together to ensure efficient relief management (Catastrophe Collaboration). Once the disaster becomes less severe or the HOs run out of funding, HOs leave the area again (III). Finally, the private sector takes over and processes normalize again once the state stops its intervention (IV). Moreover, it has to be noted that in extremely severe situations, NGOs might become active right away (V) or stay active until the market takes over again (VI).

Accounting for these phases, improved emergency management procedures within the private and the public sector can reduce the burden on the population significantly (Papadopoulos et al., 2017). Therefore, it prevents the worsening of the situation and that the disaster turns into a catastrophe. One way to achieve improvement is to establish sustainable collaboration mechanisms, since collaboration significantly improves efficiency and effectiveness of emergency response activities (Balcik et al., 2010; Kapucu et al., 2010). However, in spite of the prominent opinion stressing the importance of multiple actors in crisis management, most of the studies in the field of humanitarian supply chain management focus on a single actor (Behl and Dutta, 2018). In our view, sustainable and – from a welfare perspective – efficient crisis management research primarily requires in-depth research on the way private firms and public organizations deal with emergencies together. While collaboration increases the efficiency of the logistical operations, incentives and a surplus for all involved partners are critical as well. Consequently, a comprehensive account on collaboration in

emergency logistics operations requires a profound understanding of both, the operational logistics perspective on the one hand and the incentive-oriented game-theoretic perspective on the other.

However, in comparison to research on humanitarian-business partnerships (Fikar et al., 2016; Nurmala et al., 2018; Tomasini and Van Wassenhove, 2009), the body of literature on PPECs remains scarce (Chen et al., 2013; Gabler et al., 2017; Stewart et al., 2009; Swanson and Smith, 2013; Wang et al., 2016; Wiens et al., 2018). Moreover, to the best of our knowledge, only two publications exist that explicitly consider logistical and game-theoretical approaches in the disaster context simultaneously (Nagurney et al., 2016, 2019). Even though the authors analyzed competition and collaboration of humanitarian organizations, they did not regard the collaboration of public and private actors in disaster management. This paper aims to fill this research gap.

The main contribution of this paper can be summarized as follows. A framework for public-private emergency collaborations is developed based on logistical and game-theoretical concepts. On the one hand, the operations research perspective on PPECs is highlighted by describing the requirements, characteristics, and challenges for logistical PPEC-models. On the other hand, game-theoretical questions are considered regarding contract design and the requirements for collaboration that are mandatory to ensure stable and efficient relationships. In this way, we contribute to the research field by quantitatively modeling public-private collaboration in emergency logistics while considering the problem-specific challenge of the parties' different objectives.

The remainder of this paper is organized as follows. Section 2 discusses the concept of PPECs. Following, we analyze the role of public and private actors involved in emergency logistics and address relevant characteristics of a PPEC from both perspectives. An overview on logistical challenges that need to be regarded in PPEC models follows in Section 4. We complete the modeling framework by considering game-theoretical aspects of a PPEC and providing an illustrative game-theoretical example in Section 5. Section 6 draws conclusions from our findings.

A.2 Public-private emergency collaborations

The concept of a PPEC is closely related to the well established concept of a Public-Private Partnership (PPP). Therefore, we first provide an overview on PPPs in general and build the bridge to PPECs in crisis management, which are confronted with specific challenges but also entail high potential for improvement of crisis operations. We discuss the potentials and limits of a PPEC from a wider economic perspective and focus on the incentives of the collaborating partners. Following, we present different forms of already established PPECs. In line with the definitions provided by Wankmüller and Reiner (2020), the term "collaboration" is preferred in the PPEC context as a collaboration aims to establish a close, intense and long-term relationship between organizations to solve problems jointly. On the contrary, "cooperation" is a short-term phenomenon, which primarily relates to partnerships established in the preparedness and immediate response phases to disasters (Schulz and Blecken, 2010).

A.2.1 Public-private partnerships in general

There is no official definition of public-private partnerships (PPPs) available in literature (Worldbank, 2018). However, PPPs follow the general principle that the collaboration of the public sector with the private sector leads to (1) efficiency gains and (2) an optimal distribution of the risk (Iossa and Martimort, 2015). PPPs ensure the involvement of private partners with both the expertise and the financial resources that may not be readily available in the public sector (Swanson and Smith, 2013). The concept of PPPs was first established in the infrastructure sector (Delmon, 2011) and the transportation sector (Grimsey and Lewis, 2004). Nowadays, they are also applied to social projects (Fandel et al., 2012), in the healthcare sector, for schooling projects, or in waste management (Spoann et al., 2019). Saussier and de Brux (2018) provide an overview on the current status of PPPs in theory and practice.

Several characteristics described in the literature are typical for PPP projects. First, PPP projects are aimed to last for a long-term period (Iossa and Saussier, 2018), typically at least for 20 years. Second, PPP projects may be divided into different organizational parts - the building part, the operating part and the financing part (Morasch and Toth, 2008). Morasch and Toth (2008) argue that the building part is usually executed by private firms, while the financing part belongs to the power of the public sector. The operating part may vary in responsibility. Furthermore, the authors emphasize that in comparison with conventional procurement, where the public sector invites tenders for orders and the whole project is divided into several minor parts that are conducted from different firms, in PPP projects, tasks are bundled and under the responsibility of a single firm. As such, the degree of bundling is higher in PPP projects. Third, in comparison with a conventional project, the cost of a PPP project can exceed or undercut (Iossa and Martimort, 2015). Iossa and Martimort (2015) further elaborate that an important cost-driver of PPPs are transaction costs which are almost uncorrelated with the total PPP volume. High transaction costs arise due to complexity of projects and contractual relationships (Carbonara et al., 2016). Therefore, Iossa and Martimort (2015) suggest that only high volume projects are relevant for consideration of a possible PPP contract. Fourth, Iossa and Martimort (2015) provide an overview on quality factors which need to be considered in PPP projects. They emphasize that every evaluation needs to be performed on a case by case basis, that the quality of the products and services that are part of the PPP contract needs to be analyzed, and that the quality is adequately specified.

To summarize this section, major factors under consideration for the evaluation of a PPP are (1) the period of time the project is forecasted to last, (2) what parts of the projects are privatized and which remain under the control of the public counterpart, (3) the complexity of the contractual design together with the resulting transaction costs (Osei-Kyei and Chan, 2015) and, (4) the quality factors of the project itself.

A.2.2 PPEC barriers, requirements and potential benefits

In general, PPECs should be consistent with the ten "Guiding Principles for Public-Private Collaboration for Humanitarian Action" acknowledged by the World Economic Forum and UN-OCHA

(World Economic Forum (WEF) and UN-OCHA, 2008). The idea is that partnerships with firms facilitate the transfer of knowledge and skills on collaborative logistics and supply chain management, leading to efficiency gains in humanitarian logistics (Nurmala et al., 2017). Moreover, PPECs may help to create more resilient infrastructure systems, thereby helping to improve the situation of the population (Boyer, 2019).

However, several real-life examples highlight that the public sector struggles to collaborate with the private sector efficiently. One case is Hurricane Katrina, in which the successful emergency response of retailers, including Walmart, diametrically opposed the insufficient performance of government agencies (Horwitz, 2009; Sobel and Leeson, 2006). Exemplary was the private sector's fast delivery of necessary goods like food and clothes to the places where they were needed, while the trucks under control of the governmental organization FEMA experienced a lot of difficulties organizing and distributing essential supplies (Horwitz, 2009). Another well-discussed case is the earthquake and tsunami hitting Japan in 2011, where the government excluded private companies from the impact zone and attempted to create entirely new supply networks. As a result, millions of people with a real need for food could not reach commercial organizations, while those outside the disaster area started hoarding (Palin, 2017). This raises the question why such collaborations between public and private actors did not succeed in the way they were supposed to. We argue that there is a significant potential for collaboration but that this potential is more difficult to identify and "extract" compared to other forms of collaboration.

The motivation for both partners to participate in disaster management differs (Gabler et al., 2017), and so do the required incentives. In the following paragraphs, we will briefly outline the basic economic prerequisites for collaboration, especially from an incentive (or game-theoretic) perspective. In Section 4, we will discuss the options for collaboration in the field of logistics and emergency logistics in more detail.

In economics, the agency theory (Milgrom and Roberts, 1992; Townsend, 1982), contract theory (Salanié, 1997) and the theory of relational contracts (Gintis, 2000; Macaulay, 1963; Macleod, 2006) form the methodological framework for the analysis of collaboration between actors with – at least partially – conflicting objectives. In addition to the theoretical foundation, behavioral experimental economics contributed enormously to this field of research over the last decades. Collaborative agreements can significantly reduce transaction cost but have to cope with agency-specific risks based on asymmetries of power and information, such as exploitation, hold-up problems, or moral hazard (Fudenberg and Tirole, 1991). Key factors for a stable and efficient collaboration are (among many others) open (Jüttner, 2005) and credible communication (Farrel and Rabin, 1996) about the partners' objectives and intentions (Falk and Fischbacher, 2006), transparent and fair allocation of risks and benefits (Fehr and Gächter, 2000) as well as the future perspective of an enduring relationship (Fudenberg and Maskin, 1986). The possibility of a longer-term relationship allows the partners to stabilize their relationship on the basis of reciprocity and parallel expectations. From a game-theoretical point of view, relational contracts are self-enforcing contracts, since no external body (such as a court) is required to enforce the contractual interests, but the contract is fulfilled by mutual agreement and in the best self-interest. The range of application

of these established concepts is broad and includes labor markets, project management, R&D collaboration and also public-private partnerships (Bing et al., 2005; Desrieux et al., 2013).

In principle, most of these mechanisms can also be transferred to collaboration in crisis management (Solheim-Kile et al., 2019). However, there are a number of special features that should be emphasized because they could make (at least in part) collaboration more difficult if they are not adequately taken into account. First, in a PPEC the interests of the partners could be even more divergent than in classical infrastructure PPPs because the state's priority is on civil protection and on the provision of services of general interest. For companies, excessive investment in disaster prevention can result in competitive disadvantages. Second, this type of collaboration serves to prepare for a future event (disaster) that is only expected to occur with a relatively low probability. Large investments for this purpose must not only be economically justified, but also legally permissible.

However, there are private companies that directly participate in or support humanitarian operations with varying intensity and frequency (see section A.2.3 for a brief account on already established PPECs). Wiens et al. (2018) summarized the four major benefits of a PPEC as follows: (1) Set up an early warning system based on real-time data, (2) allow information sharing between the partners and joint planning of evacuations, (3) avoid undesirable crowding out effects and (4) make use of the infrastructure, expertise and (technological) knowledge of the private sector. In addition to these collaborative benefits, a PPEC can help to avoid costs and provide the requirements for a more efficient crisis management and an appropriate prioritization of tasks (Pettit et al., 2010).

Additional advantages can result from an optimized division of tasks and improved coordination of logistics operations (see also Section A.4). As such, it can be concluded that a number of starting points for a public-private partnership in crisis management exist and that each of these aspects justifies an in-depth model-based analysis.

A.2.3 Already established PPECs

Even though the number of real-life cases is small, there are already a few existing examples of partnerships and networks which are (at least partly) structured as a public-private collaboration for crisis management. One example can be found in Sweden, where PPPs are implemented into the Swedish emergency preparedness management (Kaneberg, 2018). Additionally, the US National Business Emergency Operations Center works as "FEMA's virtual clearing house for two-way information sharing between public and private sector stakeholders in preparing for, responding to, or recovering from disasters" (FEMA, 2019). Participation works on a voluntary basis and is free of cost. Moreover, the German UP KRITIS - a public-private partnership focusing on critical infrastructures out of nine different sectors (e.g. water, nutrition, or energy) - has the goal to increase the resilience of these infrastructures and to fascilitate the exchange about current topics (KRITIS, 2019).

These examples highlight the high potential of PPECs to increase efficiency in emergency response. Furthermore, they show that the adequate management of involved actors is challenging and requires

thorough preparation. While this list is by far not complete, it indicates the status of partnerships that have already been established and points to the difficulties of taking into account the roles, interests and capabilities of the partners.

A.3 On the role of public and private actors in emergency management

Kovács and Spens (2007) identify six types of actors in supply networks for humanitarian aid – donors, aid agencies, NGOs, governments, military, and logistics providers. Since these groups of actors pursue different (sub-)objectives and act under different conditions, uncoordinated intervention in a crisis can quickly lead to an aggravation of the situation rather than to an improvement. Therefore, Balcik et al. (2010) highlight the need to collaborate and discuss challenges in the coordination, which are highly discussed in academic literature and which are the focus of Section A.4.

Although collaboration can happen on a voluntary, altruistic basis, the moral responsibility of private actors should not be neglected. For instance, Hesselman and Lane (2017) investigate roles and responsibilities of non-state actors during disaster relief from an international human rights perspective (inter alia, Article 25, which addresses food and shelter (United Nations, 1948), connects PPECs with human rights issues). They conclude that non-public actors in disasters are indirectly obligated to become active, even though it might be difficult to hold them directly accountable. Therefore, Hesselman and Lane (2017) suggest that it could be one of the state's core task to include non-public actors into the disaster management processes using regulations. Within this context, it is necessary to understand the roles and tasks of the respective partners.

A.3.1 The role of public actors in emergency logistics

In this paper, we define "public actors" as all types of institutions and organizations under the control of public authorities on a federal and/or provincial level. This includes – inter alia – public disaster management institutions (for instance the US FEMA or the German THW), the military, police forces and firefighters (as long as they are not privatized), and all types of ministries directly or indirectly involved in the relief process (legal, environmental, financial etc.).

In general, the function of public actors in the domain of civil protection is to "provide security against unexpected threats that individual citizens cannot meet alone" (Comfort, 2002). During emergency relief, they need to establish a safe environment for beneficiaries and relief organizations. Moreover, public actors have critical resources at their disposal (Kovács and Spens, 2007), which they use to support relief action physically (e.g. THW trucks) or financially (e.g. through the FEMA Disaster Relief Fund). Furthermore, governments can ask foreign governments or HOs for support.

At the same time, "no international action can take place if the local government does not request it" (Day et al., 2012). In some cases, governments accept foreign humanitarian work without supporting it actively (Akhtar et al., 2012) or even put up barriers to impede a HO's intervention (Kunz and Reiner, 2016). Moreover, in very drastic cases, public actors can – if the legal context of the crisis area accounts for it – enforce the right to take possession over critical goods or resources (EIAS, 2016). This can catch private actors by surprise and interfere with their planned processes significantly. Due to legislative and moral responsibilities, public actors first and foremost need to support the population during an emergency. This includes, for instance, to fight the reason of the crisis, to maintain public security, or to ensure that the population has access to essential goods.

The delivery of goods for a large amount of people requires a variety of resources (e.g. trucks, people). However, purchasing and maintaining resources is extremely costly – especially if the resources are only needed in extraordinary times. Consequently, public actors only have a comparably low number of resources at their direct disposal. Without a PPEC, public actors therefore need to hire logistics companies (for instance in the US via the Disaster Response Registry (SBA, 2020)) or buy goods directly from private companies during a crisis. In developing countries, where the private sector is not as well equipped as in developed countries, the lack of resources therefore leads to, among others, the very prominent role of NGOs in crisis management. Regarding logistical challenges of a crisis, public actors can benefit from a PPEC due to an increase in logistics capacities (Nurmala et al., 2018; Wang et al., 2016) or access to logistical competences (Qiao et al., 2010; Tomasini and Van Wassenhove, 2009).

At the same time, public actors provide special capabilities for a PPEC (see for instance Kovács and Tatham (2009)). First, public actors have specialized equipment and competences at their disposal. For instance, the German THW owns multiple mobile water purification plants (THW, 2020). Military forces can provide necessary resources, communication devices, means of transport, medical services, water supply, and strong logistical and organizational structures (Carter, 1992). Second, the government is legally empowered to enforce safety. They can do this with the help of police and/or military (Byrne, 2013), or - in the case of a very strong escalation of a crisis – by adapting the laws (see for instance Halchin (2019)).

Furthermore, the involvement of private actors in the crisis management process can speed up the recovery process and help to let the market take over again faster (Palin, 2017; Wiens et al., 2018). Strengthening these processes will help to increase the resilience of communities and supply chains (Chen et al., 2013; Mendoza et al., 2018; Pettit et al., 2010).

A.3.2 The role of private actors in emergency logistics

Emergency logistics becomes necessary if commercial supply chains are not capable to supply the population with sufficient essential goods. This could be the case due to supply chain disruptions or a sudden increase in demand. When talking about private actors in the context of emergency logistics, we refer to those firms involved in the supply of essentials like food or medicine (e.g. producers, retailers, or logistics service providers).

These companies can contribute to emergency logistics with monetary donations, products, and services which can be provided in a commercial and non-commercial way (Hesselman and Lane, 2017; Nurmala et al., 2018).

From a firm perspective, involvement in emergency logistics is an issue in BCM and CSR. BCM includes companies' planning and preparation of response and recovery to disruptions of business processes (D. Elliott et al., 2010). Even in times of crises, companies' actions are predominantly motivated by long-term profit, which is why they put the strongest emphasis on the protection of their assets and fast recovery of their business processes. In doing so, some factors are directly controllable by the company while others are not (Macdonald and Corsi, 2013; Horwitz, 2009; Li and Hong, 2019; Palin, 2017; Rifai, 2018).

CSR is a company's involvement in social topics under the expectation that social improvement will lead to long-term profit (Horwitz, 2009; van Wassenhove, 2006). CSR efforts of private firms are proven means to improve corporate reputation (Donia et al., 2017). Reputation implies both the prominence of a company – the label as *being known for something* - and the image in the sense of holding a *generalized favorability* towards other companies (Lange et al., 2011). Through CSR related actions like food donations, firm reputation might increase in or after crisis situations (Cozzolino, 2012; Dani and Deep, 2010; Tomasini and Van Wassenhove, 2009). Next to positive reputation, Binder and Witte (2007) name improvement of government relations, staff motivation and the "desire to do good" as motivation for the private sector to engage. However, Izumi and Shaw (2015) emphasize that companies would also indirectly protect themselves by being involved in crisis response and thereby mitigating crisis effects that would affect the economy, like loss of life or economic downturn. It shows that emergency logistics is included in both, BCM and CSR. The specific concept of reputation is discussed later in the game-theory part in Section A.5.1.3.

In the following, we present two real-life examples, where the private sector faced a crisis. The first example is the contamination of tap water in the city of Heidelberg, Germany, on February 7th, 2019 (Heidelberg24, 2019). The duration of the event was uncertain in the beginning. Hence, people started to hoard bottled water and buy large amounts from retail stores, which in turn had to be refilled as soon as possible (Heidelberg24, 2019). A sudden increase of demand affects different stages in the supply chain, which can cascade along the supply chain (Kildow, 2011; Snyder et al., 2016). In Figure A.2, we visualized a commercial bottled water supply chain facing a tap water failure. In personal discussions with companies from food supply chains, we found that in case of sudden demand peaks, rush orders are one measure to quickly refill warehouses and retail stores. However, rush orders would involve higher costs. Another measure would be to skip handling steps in the transport chain in order to offer larger amounts faster to customers. Here, additional coordination efforts would again cause higher costs. The case of Heidelberg shows how commercial retail supply chains can be affected by crisis situations without being directly hit. Moreover, companies' stock values might decline when announcing supply chain disruptions (Dani and Deep, 2010).

A second intensively discussed example of private sector donations during a crisis is Walmart's response to Hurricane Katrina in 2005. The retailer donated food, drinks and other goods fast and
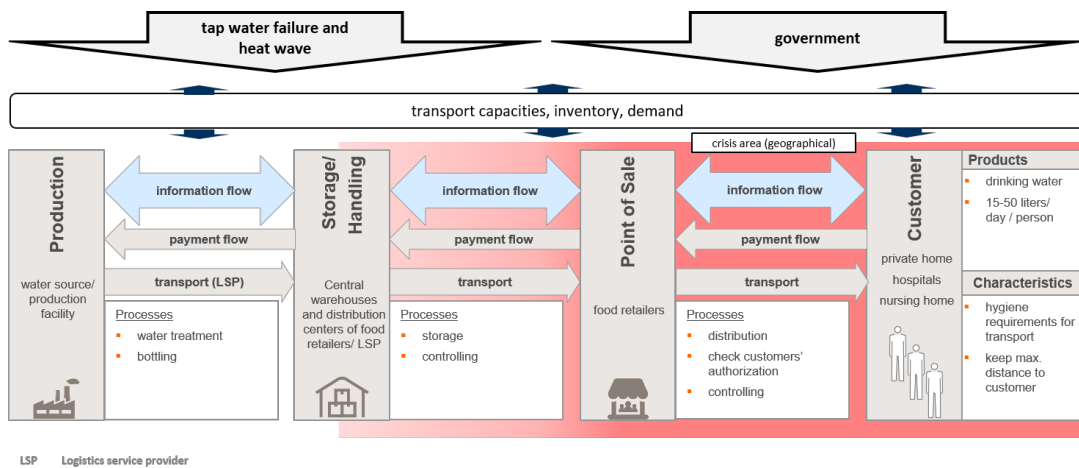
Figure A.2: Exemplary visualization of commercial water supply chains in case of tap water failure (based on Dani and Deep, 2010).

efficiently in the affected area (Horwitz, 2009). Not only in this case, supply speed compared to governmental response is seen as a core strength of private actors in crisis response (Nurmala et al., 2018). This goes along with findings from Dani and Deep (2010), who found that supply chain collaboration can help move goods faster and more efficiently during crisis.

The above examples highlight the important role of private companies during crises. However, after Hurricane Katrina, Walmart rejected the government's offer to become an "emergency merchandise supplier" (Chen et al., 2013). Among others, the huge capacities in such a business and large inventories for disaster preparedness did not fit with Walmart's corporate strategy. The authors suggest that Walmart's decline was further due to risks perceived with a contractual agreement with a strong partner, which could impede its operational freedom (Chen et al., 2013). This further hints at the importance to take the risks and incentives of the PPEC-partners into account.

The examples show that improvisation and speed are crucial for companies' efficient crisis management. The necessity to immediately react and adapt to new circumstances by possibly re-engineering supply chain processes indicates the flexibility of the corresponding processes. Thus, the more flexible a company's processes, the more resilient it is towards disruptions (Scholten et al., 2014; Snyder et al., 2016; Tomasini and Van Wassenhove, 2009; Tukamuhabwa et al., 2015). Usually, companies would lack preparation for disruptions of low probability and high consequences (Pettit et al., 2010; Izumi and Shaw, 2015; van Wassenhove, 2006) and focus on rather internal disruptions they can control (Kildow, 2011). Consequently, companies might acquire knowledge during a crisis from which they can benefit afterwards. Furthermore, collaboration with public actors can provide access to up-to-date information during a crisis with numerous uncertainties (Wiens et al., 2018). Not only access to information, but also the involvement in governmental resource control can be beneficial.

A.4 Modeling PPECs: logistical challenges

While supply chain collaboration aims to decrease uncertainty and increase efficiency, it is also confronted with multiple challenges hampering the achievement of these goals. In the next two sections, challenges associated with modeling and coordinating collaborations, in a commercial and an emergency context respectively, are reviewed and discussed.

A.4.1 Collaboration in logistics

The main goal of all commercial partnerships is to jointly generate value in the exchange relationship that cannot be generated when the firms operate in isolation. However, numerous surveys report that 50 to 70 percent of all these collaborations fail for one reason or another (Schmoltzi and Wallenburg, 2011). Because every partner remains independent, the risk of opportunism remains real.

According to Verdonck (2017), challenges related to sustainable partnerships can be divided into six groups - partner selection and reliability, identification and division of joint benefits, balance of negotiation power, information and communication technology (ICT), determination of operational scope and competition legislation.

A first challenge in the establishment of a sustainable horizontal collaboration refers to the selection of suitable partners. The analysis of the strategic and organizational capabilities of a potential partner requires knowledge about its physical and intangible assets, its competencies and skills and its main weaknesses. This type of information is often held private in the respective organization. Moreover, the amount of attainable collaborative savings is influenced by the degree of fit between the collaboration participants. When partners have been selected and the partnership has been established, uncertainty about partner reliability and their commitment to promises also contribute significantly to the complexity of the collaboration (Verdonck, 2017).

Next, it appears that partnering companies find it difficult to determine and divide the benefits of collaborating. It is essential, however, to ensure a fair allocation mechanism in which the contributions of each partner are quantified and accounted for, since this should induce partners to behave according to the collaborative goal and may improve collaboration stability (Wang and Kopfer, 2011). Besides selecting a mechanism to share collaborative benefits and costs, deciding on the operational and practical organisation of a collaboration might turn out to be a challenging task (Verstrepen et al., 2009). Partnering companies need to agree on the collaboration strategy, the allocation of resources and the applicable key performance indicators (KPIs), among others (Martin et al., 2018).

Another threat to the sustainability of a collaboration is the evolution of the relative bargaining power of the participating companies over the lifetime of the collaboration (Cruijssen et al., 2007).

A fifth challenge in the establishment of sustainable collaborations deals with the implementation of the necessary supporting ICT, which could hamper those forms of collaboration that require intensive data exchange (Cruijssen et al., 2007).

Finally, companies engaging in a collaboration project need to consider the applicable legislation on market competition. Legally binding rules prevent companies from working too closely together as this may restrict competition on the market at hand. European competition rules not only prohibit explicit collaborations, such as price-setting agreements, production limits or entry barriers, but also forbid any multi-company arrangements that have similar effects (Verdonck, 2017).

A.4.2 Collaboration in emergency logistics

We developed a framework that originates from several (review) papers, which set up frameworks for humanitarian logistics or commercial supply chains facing risks or disruptions. The first (Kochan and Nowicki, 2018; Scholten et al., 2014; Snyder et al., 2016; Swanson and Smith, 2013; Tukamuhabwa et al., 2015) and second category (Scholten et al., 2014; Snyder et al., 2016; Tukamuhabwa et al., 2015) are often discussed topics in literature. These two categories are expanded with the consideration of different characteristics of public and private actors in the context of emergency logistics. Assuming PPECs are coordinated and managed indirectly through the use of game-theoretical methods like (relational) contract design (see Section A.5), they are confronted with the following challenges: differences in strategies and motivations, complex and uncertain interactions between actors, and different characteristics of the actors' resources and capabilities (see also Figure A.3).

We will address all these aspects in the following subsections, while a detailed game-theoretical discussion of PPECs follows in Section A.5.
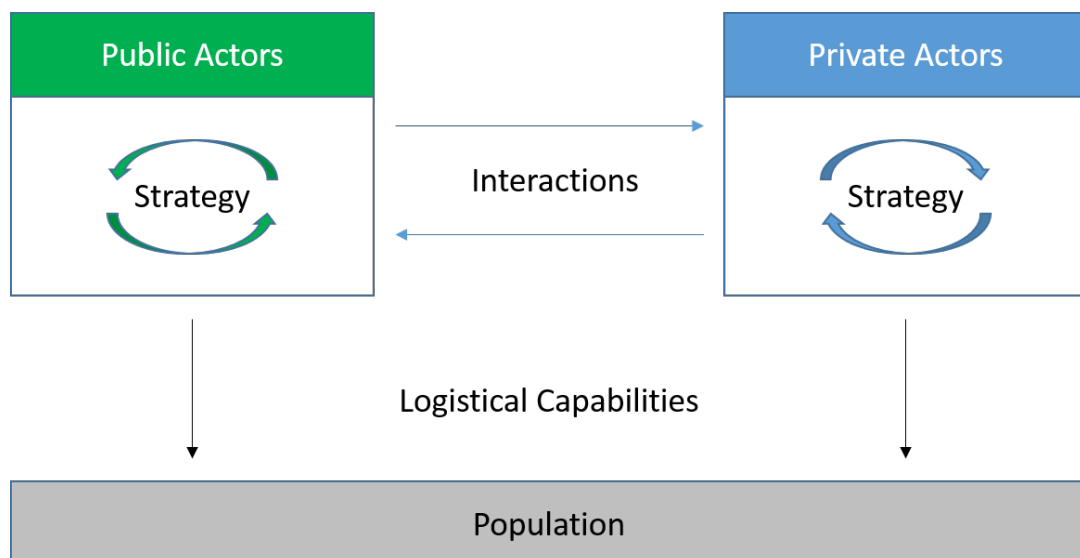
Figure A.3: Interdependencies in Public-Private Emergency Logistics.

A.4.2.1 Strategy and motivation

Public and private actors engaged in an emergency collaboration are driven by different strategies and motivations. These aspects are reflected by their different general objectives and opposing time horizons of decision making.

Multi-objective nature of logistic models

The long-term profit and efficiency orientation of the private sector is mainly modelled through a cost focus (Holguín-Veras et al., 2012). This is also the case when modeling supply chain disruptions, although this implies the challenge of quantifying the consequences (Ivanov et al., 2017; Ribeiro and Barbosa-Povoa, 2018). Usually, supply chain disruptions are analyzed by opposing models of the normal supply chain and the disrupted supply chain (Ivanov et al., 2017). In their review on disruption recovery in supply chains, Ivanov et al. (2017) classify the modeling of supply chain performance during crises into different types of costs: fixed, variable, disruption, and recovery costs.

Regarding public actors, as mentioned in Section A.3.1, the primary concern is the well-being of the population. This is closely related to the objectives of HOs, where optimization models in the literature focus on fulfilling the needs of the beneficiaries and the reduction of the misery of the population (Holguín-Veras et al., 2012). However, HOs always work on some sort of a limited budget or – dependent on their organizational structure – need to be profitable in some ways. One of the most prominent approaches regarding this setup is the social cost approach by Holguín-Veras et al. (2013). In this approach, the authors include logistics costs and combine them with deprivation costs to define "social costs". In this context, deprivation costs account for the damages that happen after being undersupplied for a long time (Holguín-Veras et al., 2013). Consequently, the minimization of social costs allows HOs to focus on both financial and non-financial aspects. Various studies include approaches that minimize some form of social or deprivation cost (Cotes and Cantillo, 2019; Khayal et al., 2015; Loree and Aros-Vera, 2018; Moreno et al., 2018; Pradhananga et al., 2016).

Furthermore, Gutjahr and Fischer (2018) were able to show that the minimization of deprivation costs leads to unfair solutions in case of budget limitations. They therefore developed an approach that includes measures similar to the Gini-coefficient to increase the fairness of the resulting allocations. Consequently, public actor's high degree of financial flexibility indicates that the focus on social cost minimization seems to be appropriate for them, while HOs optimizing on a limited budget are recommended to use the approach of Gutjahr and Fischer (2018) as a guideline.

Time horizon of decision making

A fundamental difference between the public and private perspective is the general supply chain layout and the time horizon of the actors. Private actors design their network to be profitable in normal times. However, during a crisis, they need to adapt to the specifics of the crisis quickly (Macdonald and Corsi, 2013). On the other hand, public actors do - except from long term storage

facilities - not possess established supply chain structures in normal times. Therefore, they need to set up completely new supply structures under high time pressure and at high costs (Holguín-Veras et al., 2012). Consequently, there is a high degree of flexibility in regards to location, transportation, and product portfolio selection when setting up public emergency supply chains. Moreover, mixed forms are possible, in which, for instance, public actors use the private actors' established structures to distribute goods.

A.4.2.2 Interaction between actors

Another important aspect to consider is the interactions between actors. As a substantial amount of actors is involved in emergency collaborations, the efficient coordination of their interactions is often very challenging (Balcik et al., 2010; Kabra et al., 2015). These challenges can include the fundamental power difference, aspects of trust and partner selection, the information that the actors share, or the identification and division of costs.

Power differences

Both public and private actors' involvement is determined by the power they possess in times of disaster. The public sector is only entitled to intervene if the situation provides the legal pre-requisites for an intervention. If this is the case, public authorities can have far-reaching rights which give them access to several resources (e.g. goods, transport capacities, production facilities) (Daniels and Trebilcock, 2006; Wood, 2008). Private sector involvement in emergency logistics is voluntary if not being forced through governmental seizure. However, motivated to implement CSR and BCM strategies, companies still possess their operational freedom in decision-making. Hence, they can determine their level of involvement in emergency logistics (Johnson and Abe, 2015). Moreover, power differences within commercial supply chains are crucial. For example, firms can have strong negotiation positions with their suppliers (Spence and Bourlakis, 2009), which can also affect the abilities to respond quickly in crises.

Information sharing

Research has shown that a lack of information sharing among commercial supply chain members results in increased inventory costs, longer lead times and decreased customer service (Simatupang and Sridharan, 2002). Since logistics is responsible for 80% of relief operations (van Wassenhove, 2006), coordination of information flows has a critical influence on relief chain performance (Balcik et al., 2010). As opposed to a commercial supply chain environment, however, the sources of information can be limited or even unidentifiable in the aftermath of an emergency (Sheu, 2007) and the information themselves incomplete (Yagci Sokat et al., 2018). For this reason, the UN Joint Logistics Center has been formally established in 2002 with the aim of collecting and disseminating critical information and setting up information-sharing tools (Kaatrud and Van Wassenhove, 2003).

Trust and partner selection

Collaborative relationships could also suffer from a lack of trust between public and private partners. Governmental organizations might doubt the good intentions of private companies, while the latter often perceive public partners as bureaucratic (Christopher and Tatham, 2011). Moreover, in comparison to commercial environments, the development of trust is impeded by the ad-hoc nature of the hastily formed networks (Tatham and Kovács, 2010). In line with the partner selection challenge addressed in Section A.4.1, differences in geographical, cultural and organizational policies may create additional coordination barriers (van Wassenhove, 2006). Moreover, Kabra et al. (2015) discuss management, technology and people characteristics which may hamper efficient emergency collaborations.

Identification and division of costs

Xu and Beamon (2006) identify three cost categories associated with coordination of supply chain collaborations: coordination cost, opportunistic risk cost, and operational risk cost. Coordination costs are directly related to physical flow and coordination management. Opportunistic risk costs are associated with a lack of bargaining power, while operational risk costs result from unsatisfactory partner performance (Balcik et al., 2010). A survey of Bealt et al. (2016) revealed that the cost of logistics services is considered the most important barrier in the formation of collaborative relationships between private companies and humanitarian organizations. Given the uncertain environment emergency collaborations operate in and the lack of clear visibility of required operations and resources, the magnitude of these cost levels is hard to identify. In addition, effective collaboration requires mechanisms to allocate the associated costs to each partner. Due to the non-financial aspects of emergency logistics, mechanisms developed for commercial applications, such as penalty fees, cannot be directly implemented to PPECs (Dolinskaya et al., 2011).

A.4.2.3 Capabilities and Resources

Public and private actors dispose over various capabilities and resources. In the case of severe disasters, these capabilities and resources can be limited heavily. Therefore, the specific circumstances of the crises need to be taken into consideration during the development of a logistical model. In the context of the following subsection, we assume that both public and private actors' capabilities and resources after the disaster are still available.

Capabilities

Under this assumption, commercial supply chains can still make use of their established routines, their communication network, and their knowledge of market and demand during crises (Holguín-Veras et al., 2012). Retail supply chains can quickly adapt to changes and uncertainties. Hence, they are designed to act in an environment where flexibility and speed are crucial (Bourlakis and Weightman, 2004). These capabilities are also crucial for private supply chains in their response to disasters (Kochan and Nowicki, 2018; Ribeiro and Barbosa-Povoa, 2018). Following Kochan and Nowicki (2018), such capabilities can be classified into readiness, responsiveness and recovery.

Contrary to commercial supply chains, knowledge in public supply chains can be categorized as general disaster knowledge rather than detailed market knowledge. This is highlighted by Kovács and Tatham (2010), who compared skills required for commercial logistics positions to requirements for humanitarian logisticians. They concluded that – in spite of some similarities – significant differences exist. For example, humanitarians consider problem-solving skills more important than their commercial counterparts do (Kovács and Tatham, 2010).

Furthermore, public actors need to cope with numerous uncertainties that are typical for disaster situations (Olaogbebikan and Oloruntoba, 2017). To model these uncertainties related to supply chain disruptions, Snyder et al. (2016) suggest supply, capacity, and lead time uncertainty. However, it needs to be considered that uncertainties during and after a disaster significantly exceed the fluctuations companies are normally prepared for (Holguín-Veras et al., 2012). Moreover, sudden demand peaks (Snyder et al., 2016) as well as the above-mentioned lack of preparedness for low-probability and high-consequence events can be considered in modeling PPECs.

In addition, private actors are hit by the disaster right away. In case of a shortage, retail stores try to satisfy the high demand immediately (see also Holguín-Veras et al. (2012)). In the case of the suspected contamination of the tap water in Heidelberg, this led to a time gap: until public actors set up an emergency water supply chain, commercial supply chains were the only distributor of water. However, they struggled to cope with such unexpected extraordinary demand peaks (Heidelberg24, 2019). Therefore, support from public actors would have been necessary if the crisis lasted longer.

It can be concluded that modeling commercial logistics capabilities should focus on the optimization of steady flows, while public supply chains are designed to immediately cope with large transport volumes (Holguín-Veras et al., 2012; Olaogbebikan and Oloruntoba, 2017).

Resources

Public actors have the opportunity to choose locations for warehouses and distribution points out of a large number of buildings (e.g. schools, sports arenas) and – due to the legislative option to take possession of resources and goods – indirectly over a huge variety of additional resources. However, the high flexibility goes hand-in-hand with a high degree of uncertainty. For instance, public actors could try to take possession of the goods in a warehouse without knowing about quantities and the exact product specifications beforehand. On the other hand, private actors physically possess resources and have knowledge and control over their location, while they have to work under the permanent threat of seizure.

Furthermore, there is a large difference regarding the up-scaling of available staff at different sites. Except for temporary employees, the size of the workforce of private organizations is rather fixed. Moreover, the process to hire additional employees is time consuming and challenging. Therefore, private organizations need to navigate through heavy supply chain disturbances with the staff they have at their disposal in normal times. On the other hand, public relief organizations staff consists of volunteers at a high degree. This is closely related to the risk of taking possession of physical resources since the volunteers, which are activated by public actors, cannot keep working in their usual job during the crisis and therefore the staff at companies is even further reduced.

A.5 A basic game-theoretic PPEC-approach

In this section, we approach PPECs from a game-theoretical perspective to carve out its potential and limits with a focus on the actors' incentives. Game-theory formally describes the effects and interdependencies of strategic decision makers (Myerson, 1991; Rasmusen, 2007). Similar to Seaberg et al. (2017), we argue that in the context of disaster management partners act strategically as long as their goals are not completely congruent. Although the number of articles in the area of disaster management is limited, there are some first contributions that analyze the strategic interaction among different actors in this domain, though not from a public-private perspective.

For example, Nagurney et al. (2016) and Nagurney et al. (2019) look at competition between HOs based on a game-theoretic model, which jointly integrates both logistical and financial decisions. The model sheds light on the interesting strategic position of HOs who are competing and at the same time collaborating to share resources and reduce cost (collaboration is realized by shared constraints). Compared to public and private players, HOs are non-profit and non-governmental and therefore represent a third type of actor, which is not considered by our approach (see also Section A.1). Gossler et al. (2019) apply a similar approach to determine the optimal distribution of tasks. The authors derive the optimal distribution decisions for a long-term business perspective of disaster relief organizations. Nagurney et al. (2016, 2019) and Gossler et al. (2019) all apply the rather specific concept of a Generalized Nash Equilibrium, which allows them to deal with the strategic aspects and the complexity of the decisions (with respect to the large number of restrictions).

Coles and Zhuang (2011) model a multi-actor collaboration game to establish a decision support framework in the context of emergencies. The model evaluates and selects the most valuable relationships for the emergency manager considering resource restraints. In addition to the assumption that every company is a profit maximizer, the authors also look at non-financial benefits that accrue value to the business model of a private company. Taking a similar focus on preferences and goal alignment, Carland et al. (2018) analyze the potential for collaboration between humanitarian organizations and the private sector based on a decision support framework (multi-attribute value analysis). From an HO's perspective, the objective is to engage private actors, to elicit their preferences, and to align the objectives of both sides.

The following game-theoretical model primarily serves illustration purposes and is therefore deliberately kept simple. We assume two players, the public sector and the private sector. The objective functions of both players correspond to the roles of both players in emergency logistics as discussed in Sections A.1 and A.2.

In the model, we assume two reasons for the firm to engage in a collaboration: reduction of disaster-related cost and reputation. These two variants of motivation primarily serve to illustrate the interplay of state and firm incentives in a basic model. Albeit not part of our analysis, it is promising to extend the firm's motivation in a dynamic setting. For example, one could imagine a private company that learns from the emergency context, where it collaborates with the public sector and thus ultimately establishes a more sustainable and crisis resilient business model, which

improves the company's internal BCM processes. The aspect of reputation is also touched upon only briefly to highlight the incentive effects. A detailed analysis of reputation effects requires a dynamic model that goes beyond the objective of this contribution.

The advantage of our approach to choose a basic model is that two central solutions of the game can be derived in closed form and thus directly compared: The Nash equilibrium (NE) as an individually rational solution of the game on the one hand and the loss-minimizing result, which the state primarily strives for. This raises the important question whether the outcome envisaged by the state can also be implemented by a so-called *incentive-compatible* contract. A simple *mechanism-design* approach describes the conditions under which this solution is feasible. The application of contract theory and mechanism design is important for a game-theoretic account of a PPEC because the collaboration between state and company is ultimately intended to improve crisis management, i.e. to transfer relief supplies more efficiently to people in need. As mentioned above, the main advantages of collaboration in emergency logistics are the increased resource availability and capacities, leading to a higher overall service level (Bealt et al., 2016).

A.5.1 The model

We now illustrate the potential for collaboration by choosing a basic game-theoretic framework. As outlined in the previous sections, "collaboration" means that the firm and the state jointly prepare for the disaster by coordinating their planned activities. Collaboration can avoid cost and provide the requirements for a more efficient crisis management.

In a first step, we describe the objective functions for the state and the firm. Based on the objective functions and the strategies, we derive the *NE* of the game. As a solution concept, the NE provides us with the individually optimal outcome of each player given that the co-player plays its NE-strategy, too. Thereafter, we compare the individual optimization result with the strategy combination, which minimizes under-supply in the form of (non-material) losses of the population such as suffering and deprivation. In the context of a disaster, this is the overriding goal of state crisis management. We therefore consider this *loss-minimizing*-outcome (LM) as the first-best solution out of the state's perspective as the ruling disaster management authority. Finally, we discuss under which conditions the loss-minimal solution can be implemented in an incentive-compatible way and to what extent company reputation can support a collaborative solution.

A.5.1.1 Basic structure

Assume that a disaster strikes with a probability ε and that the disaster causes a damage of size $D > 0$. We assume that ε is an independently Bernoulli-distributed random variable on the interval [0,1]. In this model, damage is understood as "deficit quantity", i.e. the quantity of essential goods that is missing to supply the population. To be able to supply the population with these goods, the state needs to acquire them on the market together with the "logistical capacity", which is needed to store, transport, and distribute the goods. As the difference between goods and logistical capacity is of secondary importance for our analysis (what matters is the fact that the state has to

purchase these resources from the company), we summarize both with the variable x which stands for "resources".

The state can acquire these resources at two points of time: It can procure *before* the crisis occurs (ex ante) and thus create an emergency reserve of x^N where the index N stands for "No crisis" or "Normal times". Procuring in normal times implies that the state has to pay the regular market price p for the resources. Alternatively, the state can wait until a crisis occurs and try to acquire the goods "ad hoc" from the firm (ex post). In most countries, such an intervention comprises confiscation and a subsequent compensation of the company (Daniels and Trebilcock, 2006; Deflem, 2012). We use the variable x^C for the confiscated items where the index C stands for "Crisis". The state compensates the firm at arm's length prices q per unit. The variable q (compensation payment) is determined by competition law and by the type of contract between the firm and the state. The compensation level can be equivalent to the market price p but don't need to be. Besides the uncertain price conditions during a crisis, the complete availability of goods during a crisis, even if the price does not rise, is uncertain. For example, in most countries, the state compensates the companies for seized goods with the market price which was observable *before* the crisis occurred.

Furthermore, since the confiscation occurs ad hoc, it causes transaction costs to both the state and the firm, which can be substantial if the intervention is not coordinated (Pelling and Dill, 2010; Wood, 2008). As explained at the beginning of this section, pre-crisis collaboration reduces these transaction costs because a PPEC reduces frictions at the company due to otherwise unprepared and abrupt changes in the business procedures. For the state, a high degree of collaboration will accelerate the availability and usability of the firm's resources. The transaction costs are given by $T_{S,F}(\theta_S\,\theta_F) = \frac{c_{S,F}}{\theta_S\theta_F}$ for the state (S) and firm (F) respectively. The variable $c_{S,F}$ denotes the combined transaction cost factor of the state (or the firm, respectively) as occurring during a crisis.

The strategy variables $\theta_S \in [0, 1]$ and $\theta_F \in [0, 1]$ are at the center of this analysis because they capture the investment in collaboration of the state θ_S and the company θ_F. Both actors choose their strategy on a continuous spectrum between full collaboration ($\theta_S = 1$ and $\theta_F = 1$) or no collaboration at all ($\theta_S = 0$ and $\theta_F = 0$). High collaboration implies that both, the company and the state, prepare the legal, technical and procedural conditions of a confiscation and hence face lower cost. For $\theta_S\,\theta_F = 1$ (bilateral full collaboration) the transaction cost for an intervention are on a minimal (but nonnegative) level c_S for the state and c_F for the firm. However, with decreasing levels of collaboration, the transaction costs increase exponentially and would even become infinitively high if one partner preferred no collaboration at all ($T_{S,F} \to \infty$ for $\theta_S\,\theta_F = 0$). We assume a multiplicative effect of collaboration, since it is not possible to collaborate unilaterally. For both actors we assume a linear cost function for collaborative investment of the form θ_S, θ_F, $\kappa_{S,F}$ ($\kappa_{S,F} \geq 1$).The variable $\kappa_{S,F}$ denotes the transaction cost of collaboration, occurred by the state or the firm.

The loss-function of the state is given by (1):

$$L(x^N, x^C) = \varepsilon\left[\mu|D - x^N - x^C| + \bar{B}^C\right] + B^N, \quad x^N \geq 0, \quad x^C \geq 0 \qquad \text{(Exp. A.1)}$$

The term $|D - x^N - x^C|$ captures the loss of the state due to a deficit of goods, which can be reduced either by the emergency stock x^N or by ad hoc confiscation x^C. The weighting parameter $\mu \geq 1$ takes into consideration that the losses, which result out of uncovered need in the population (deprivation) have a different unit than all other cost components, which are expressed in monetary units. By increasing μ, the state can give more weight to the distribution of goods compared to budget concerns; for $\mu \to \infty$ it gives absolute priority to people's needs and completely ignores budget restrictions. The terms $\bar{B}^C$ and B^N are budgets and hence monetary components of the loss function. The indices N and C again refer to "normal times" and "crisis", i.e. there is a budget B^N available in normal times and a budget for exceptional crisis situations $\bar{B}^C$. Whereas the former corresponds to the regular annual budget, which can be spent by the crisis management authorities the latter represents a highly up-scaled budget released by the government only in an emergency situation. Although $\bar{B}^C$ will certainly be a larger budget than $B^N (\bar{B}^C > B^N)$, the exact volume is unknown before the onset of a crisis, which is indicated by the expectation-bar. Before a crisis occurs, the state plans to spend the budgets as follows:

$$B^N = x^N p + \theta_S \kappa_S \qquad \text{(Exp. A.2)}$$

$$\bar{B}^C = x^C q \, \frac{c_S}{\theta_S \, \theta_F} \qquad \text{(Exp. A.3)}$$

The normal-times budget is spent for the procurement of emergency stock under regular (market) conditions and for investment in collaboration (budget equation (2)). The crisis-budget (budget equation (3)) has to cover the (expected) compensation payments for confiscated goods and the (expected) transaction cost for having emergency supply available. This way, the state's objective function represents a social cost function as outlined in Section A.4: the undersupply corresponds to the deprivation cost and the budgets reflect the financial constraints. If we solve both budget equations for the quantities of goods x^N and x^C and insert these quantities into (1) we get (4) as a modified version of the state's loss function, which now depends explicitly on the strategy variables θ_S and θ_F.

$$L(\theta_S, \theta_F) = \varepsilon \left[\mu \, | D - x^N(\theta_S) - x^C(\theta_S, \theta_F) | + \bar{B}^C \right] + B^N \qquad \text{(Exp. A.4)}$$

The firm's profit function is given by (5):

$$\pi_F(\theta_S, \theta_F) = \pi + (p - c_F) \, x^N(\theta_S) - \kappa_F \theta_F + \varepsilon \left[q x^C(\theta_S, \theta_F) - \frac{c_F}{\theta_S \, \theta_F} \right] \qquad \text{(Exp. A.5)}$$

The expression π represents the "profit in normal times" and the second term is the profit for the provision of resources for the state in normal times. The content of the square brackets $\varepsilon[\cdot]$ reflects the changes in profit due to confiscation and compensation in the case of a crisis. If there is no crisis (which is expected with a probability of $1 - \varepsilon$), these profit changes are zero. The cost term $\kappa_F \theta_F$ represents the effort in time and money for engaging in collaboration ("collaborative investment"). Note that these costs have to be incurred already in "normal times" and that the firm's collaboration cost just depends on its own effort θ_F whereas the cost reduction requires a joint collaborative effort $\theta_S \, \theta_F$.

A.5.1.2 Nash-equilibrium

In a Nash-equilibrium, both actors pick their optimal strategy given their co-player's strategy. Formally, the Nash-equilibrium is the intersection point of the best response profiles of both players. We get the best-response functions $BR_{S,F}$ by taking the first derivative of the objective functions with respect to the strategy variable of each player and considering the first-order condition (FOC) for a minimum (the state minimizes losses with respect to θ_S) or maximum (the firm maximizes profit with respect to θ_F). Expressions (6) and (7) give the best-response functions of the state and firm (the star indicates Nash-equilibrium-strategies):

$$\frac{\partial L}{\partial \theta_S} \overset{!}{=} 0 \Rightarrow \theta_S^*(\theta_F) = \sqrt{\frac{c_S\, p}{\kappa_S\, q\, \theta_F}} \qquad 0 \leq \theta_S^*, \theta_F \leq 1 \qquad \text{(Exp. A.6)}$$

$$\frac{\partial \pi}{\partial \theta_F} \overset{!}{=} 0 \Rightarrow \theta_F^*(\theta_S) = \sqrt{\frac{(c_F + c_S)\, \varepsilon}{\kappa_F\, \theta_S}} \qquad 0 \leq \theta_F^*, \theta_S \leq 1 \qquad \text{(Exp. A.7)}$$

The state has a higher incentive to increase θ_S if the transaction cost parameter c_S and the price for resources p increase. The first effect is due to the fact that collaboration reduces transaction cost and a larger p increases the cost of an emergency stock, which makes confiscation of items during a crisis more attractive. However, as collaboration reduces the transaction cost of confiscation, the state has an incentive to increase θ_S. Inversely, larger values of κ_S, q and θ_F reduce the incentive for collaboration. The effect of κ_S as the cost parameter of collaboration is straightforward. If the compensation cost q is high, the state is reluctant to rely upon confiscation and rather builds an emergency stock of resources for which collaboration is not necessary. Perhaps the most interesting effect refers to θ_F. There is a clearly negative effect of θ_F on θ_S^*: the larger the firm's contribution to collaboration, the larger the incentive for the state to *reduce* its collaborative effort. Hence, the collaborative investments of both actors are strategic substitutes. Roughly speaking, games in which the players' strategies are substitutes (as the opposite of complements) are called *submodular* games (Fudenberg and Tirole, 1991).

It is mainly this feature of the game that makes the NE-outcome inefficient.

Some effects of the model's parameters are similar for the optimal collaboration strategy of the firm. The firm increases collaboration if the transaction cost parameter c_F is high and if the collaboration cost parameter κ_F is low. Furthermore, the collaboration level of the company θ_F^* also acts as a substitute for the collaboration level of the state θ_S, i.e. the more (less) the state collaborates, the less (more) the company invests in collaboration.

However, three differences in the optimal strategies are striking: first, the firm's collaboration level is not only increasing in its own transaction cost parameter but also in the transaction cost parameter of the state c_S. Hence, the firm is partially internalizing the transaction cost of the state, which leads to a higher level of collaboration. The reason for this is that a high value of c_S increases the need for collaboration for the state but reduces the amount of resources x^C the state can acquire in times of a crisis. By increasing θ_F complementary to the increase of θ_S, the firm can keep the number of resources high and the state's frictions for use of these resources low.

Second, in contrast to (6) the influence of the transaction cost parameters are merely probabilistic, i.e. they only influence the optimal strategy of the company as an expected value. However, the disaster probability ε does not influence the state's collaboration level, because the entire first-order condition is multiplied with ε so that this parameter cancels out. Finally, while both resource prices (q and p) influence the optimal strategy of the state, they do not appear in the best-response function of the firm. This is because these parameters are linked to the state's collaboration level via the budgets whereas they are independent from the firm's collaboration level (collaboration reduces cost but does not alter prices).

Figure A.4 depicts the best-response functions of both actors. The chosen parameter-values are $D=100$, $\varepsilon=10\%$, $c_S=1$, $c_F=1$, $p=2$, $q=1$, $\kappa_S = 10$, $\kappa_F = 10$. Both response functions have a negative slope and are convex which reflects the submodular property: The less (more) one actor contributes the (higher) lower the contribution of the other actor.
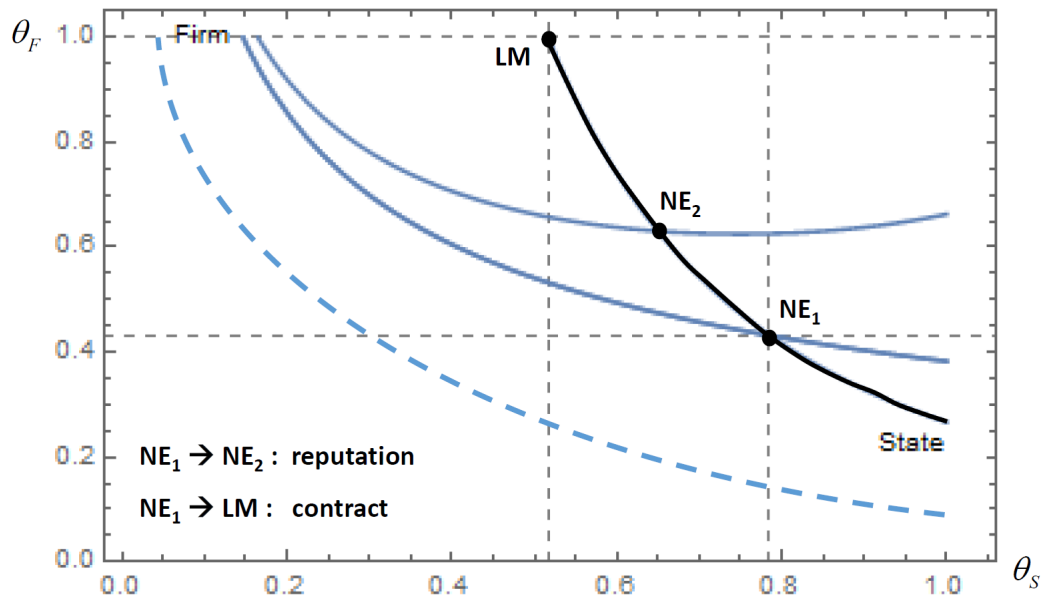
Figure A.4: Best-response functions.

The NE (NE$_1$) can be found at the intersection of both curves. For this example, the collaboration levels are $\theta_S^* = 0.79$ for the state and $\theta_F^* = 0.43$ for the firm, i.e. the state provides a larger contribution than the firm. Formally, we determine the optimal collaboration levels in equilibrium (8) and (9) by equating the best-response functions:

$$\theta_S^* = \sqrt[3]{\frac{(p^2\, c_S^2\, \kappa_F)}{(q^2\, \varepsilon\, (c_F + c_S)\kappa_S^2)}} \tag{Exp. A.8}$$

$$\theta_F^* = \sqrt[3]{\frac{(\varepsilon^2\, q\, (c_F + c_S)^2\kappa_S)}{(p\, c_S\, \kappa_F^2)}} \tag{Exp. A.9}$$

Inserting the optimal levels for θ_S^* and θ_F^* into the loss function of the state and the profit function of the company gives the individually optimal outcomes in terms of loss L^* (θ_S^*, θ_F^*) and profit π^* (θ_S^* θ_F^*). However, there is still one important note at order. The derived solutions (8) and (9) characterize the equilibrium provided the existence of a NE. A NE for this game exists if (and only if) inequality (10) is fulfilled. If expression (10) is violated, there is no intersection of the best-response functions:

$$\theta_S \geq \sqrt{\frac{\kappa_F}{(\varepsilon(c_F + c_S))}} \frac{c_S}{\kappa_S} \qquad \text{(Exp. A.10)}$$

This case is illustrated in Figure A.4 for the constellation where the best-response function of the firm corresponds to the dotted line. In this case, the company's curve is so low that it passes under the curve of the state. Such a failed-collaboration scenario is possible if, for example, the collaboration cost κ_F of the firm is very high (numerator of the right-hand side of (10) increases), the disaster probability ε is extremely low or the firm's frictions due to lack of collaboration (c_F) are not high enough (denominator of the right-hand side of (10) decreases). We can conclude that the first and most important obstacle for collaboration is a parameter and incentive constellation in which a company has no self-interest in a collaborative agreement at all.

A.5.1.3 Firm reputation

In this basic model, the firm has an incentive to invest into collaboration if pre-crisis collaboration with the civil protection authorities reduces the cost for an ad-hoc transfer of resources to the state in the moment of a crisis. In other words: If one is inevitably confronted with the crisis anyway, then it is better to approach the operations in an orderly and planned manner.

In addition to this motive, it is also possible that a company is willing to contribute due to a sense of responsibility or reputational concern. As explained in Section A.3.2, the latter is similar to the motivation of firms to establish a positive reputation for CSR. The firm can expect a positive percussion of its (publicly visible) activities if customers take note of the company's efforts and perceive these activities in a way which increases their loyalty towards the firm or their willingness to pay (Besiou and van Wassenhove, 2015). This way, the firm's contribution to public crisis management can be regarded as an investment into higher future returns.

To illustrate this effect formally, we add the reputation-term $R = \delta \bar{r} \theta_S \theta_F$ to the profit function of the firm where $\bar{r}$ represents the expected return of reputation and $0 < \delta < 1$ is the discount factor. For $\bar{r} > 0$, an anticipated reputation has a positive effect on the company's willingness to collaborate. The second Nash equilibrium NE_2 in Figure A.4 illustrates this effect: The integration of the reputation term increases the reaction curve of the company and leads to higher collaboration rates of the firm. However, as collaboration rates are (imperfect) substitutes, the state will slightly reduce its level of collaboration and can use the saved resources to increase the emergency stock x^N.

Just as in the case of CSR, reputation does not automatically increase, but actions must be credible from the customer's point of view. Since reputation is a long-term mechanism, the company must

be able to provide the externally visible resources and competence on a long-run basis. However, if customers have the impression that a company pretends to play a supportive role in humanitarian operations for tactical reasons only, this critical perception can backfire and seriously damage the firm's reputation (Stewart et al., 2009; Donia et al., 2017). In the area of crisis management, a particularly high level of sensitivity on the part of the public can be expected, as human lives are at stake here.

A.5.1.4 Loss minimal solution and mechanism design

We focus on mechanism design as a last example to illustrate how the state can lever the collaboration level in a PPEC. Mechanism design is a branch of game-theory and deals with the question on how the incentives of institutional rules influence the outcome of a group (e.g. welfare on a market or in society) and how these rules should be designed in order to improve these outcomes (Jackson, 2014; Maskin and Sjostrom, 2002; Myerson, 1989). Accordingly, the question is now, whether the individually optimal NE-outcome of the PPEC-game can be Pareto improved. In economic policy and welfare economics, an important reference solution is the so-called social-optimal outcome, which maximizes the players' joint utility (Green and Laffont, 1979; Sen, 1982).

However, the purpose of a PPEC is not to find a balanced improvement between firm and state but to minimize the undersupply, which is caused by the crisis. It is straightforward to realize that the loss-minimal outcome implies the maximal contribution level of the firm $\theta_F = 1$ (an increase of $\Delta\theta_F$ unambiguously lowers L because the cost of $\Delta\theta_F$ just affects the firm, not the state). Consequently, the loss-minimal solution $\theta_S^{LM}, \theta_F^{LM} = 1$ can be found at point LM in Figure 4. However, a higher level of collaboration reduces the firm's profit (otherwise a PPEC would also be feasible in absence of any additional incentive). To motivate the company to participate, the state has to guarantee an outcome equal to the individually optimal position $\pi^*(\theta_S^*, \theta_F^*)$ to the firm. To achieve this, the state must compensate the company in monetary terms, say by a monetary transfer t. One aspect that favors the use of mechanism design in the context of a PPEC is the fact that the party to be compensated (the company) is also primarily interested in monetary payments. In order to seek an agreement with the company that comes as close as possible to the preferred target level $\theta_F = 1$, the state solves the minimization problem (11):

$$\min_{\theta_S, \theta_F} L \quad s.t. \quad B^N = x^N p + \theta_S \kappa_S + t, \quad \pi(\theta_S, \theta_F) + t = \pi^*(\theta_S^*, \theta_F^*) \qquad \text{(Exp. A.11)}$$

According to (11), the state looks for the optimal solution that minimizes the undersupply. The company must be compensated with the transfer t for its additional expenditures. The transfer must be chosen in such a way that the company receives at least the profit of the individually optimal solution π^* and that the state can finance this transfer from the regular (normal-times) budget B^N. If a solution exists, the state can offer the contract $\langle \theta_S, \theta_F, t \rangle$ to the company, which should have no reason to reject it.

Note that for the state to be able to finance the transfer t, it must either reduce the emergency stock x^N or its collaboration level θ_S. Both have problematic implications. The reduction of the

emergency stock increases the dependence on the company and requires a high degree of confidence in the willingness of the company to actually implement the concluded contract in an emergency. Since this trust – as in any collaboration – only develops over a longer period of time, the readiness for such a measure will already require a certain depth and duration of the collaboration (Gintis, 2000; Hardin, 2002). In this case, the formal contract would be supplemented by a relational contract between the company and the state, which is primarily stabilized by the long-term nature of the collaborative relationship.

If, however, the state reduces its own collaboration level, this could be viewed with suspicion by the company. Discussions between the authors and company representatives (as part of the NOLAN project on public-private collaboration in Germany (IIP, 2019)) revealed that under certain conditions, companies are prepared to support the state in emergencies. Nevertheless, they also see the danger that the state could misuse such collaboration to delegate governmental tasks to the companies. These arguments show that the practical implementation of derived solutions requires an intense stakeholder dialogue.

A.6 Conclusion

Public-Private Emergency Collaborations provide tremendous opportunities for public and private actors in disaster relief. However, no study on logistical or game-theoretical models exist, which explicitly deals with this specific form of collaboration in disaster management. Therefore, we developed a logistical modeling framework that defines the context of logistical PPEC models.

In the framework, we discuss the different logistical characteristics of public and private actors in relief logistics, regarding their strategy and motivation, the way they interact with each other, and their capabilities and resources. By that, we provide a base for quantitatively modeling emergency logistics problems considering both public and private actors.

Moreover, we developed a basic game-theoretic PPEC model that gives more precise insights into the motivation and incentives of the partners. Inspired by game-theoretic accounts of conventional PPPs, this model sheds light on the partners' participation constraints (which define the scope of collaboration), the effects on the outcome if the partners' contributions are strategic substitutes, and on reputational effects. Finally, it was illustrated how a mechanism design approach can be used by the state to transform the firm's incentives into lower levels of undersupply or deprivation.

With the present paper, we are able to define a variety of opportunities for future research. However, the developed framework and model could work as an orientation for upcoming research. Especially with the help of real world data and case studies, the modeling framework can be further tested, extended, adapted, and optimized.

In a nutshell, it can be concluded that, with the help of well defined PPEC-concepts, processes in relief logistics can be understood better, supply chains can become more resilient, and public actors can ensure that the population is supplied as good as possible. Therefore, research on PPECs promotes the shift from fighting the symptoms of the population's undersupply during

crises towards fighting the course of the problem, leading to an increase in resilience of public and private actors.

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B How to Enhance Company Engagement in Public-Private Emergency Collaborations in the Supply of Essential Goods

Abstract[1]

Crises like the COVID-19 pandemic or climate change can significantly disrupt supply chains. In severe crises, public actors must take responsibility for the population's supply of essential goods. Companies can be valuable partners in these cases. To better understand under which circumstances companies would participate in public-private emergency collaborations, we empirically investigate German companies' expectations and motivation regarding emergency collaborations with authorities. A total of 398 companies from the food, healthcare, and logistics sectors replied to a questionnaire of 25 closed questions. We find that most companies have been active and are willing to engage in crisis management, preferably by providing resources, physical or informational. However, they also want to ensure that their business processes are maintained. Further clarification and commitment from public actors is needed though, to pave the way for more collaborative crisis management and company engagement. Among the most promising incentives for public actors to set are monetary compensation for provided resources and an improved communication policy. Logistics companies can be motivated more by relaxing regulations than others, while healthcare companies value reputation measures higher than the average. Our insights provide the basis for stable collaborations and raise awareness for the potential of public-private collaboration during crises. Moreover, it promotes the systematic implementation of public private emergency collaborations, as opposed to short-term, spontaneous forms of public-private partnerships.

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[1] This chapter includes the preprint of the article "How to enhance company engagement in public-private emergency collaborations in the supply of essential goods". This article was written in collaboration with Alexander Zienau, Marcus Wiens, Ole Hansen, Florian Diehlmann and Frank Schultmann. It was submitted to a scientific journal as Lüttenberg, Zienau, et al. (2022).

B.1 Introduction

Sudden-onset disasters like floods or hurricanes, or long-term, ongoing events such as climate change or the COVID-19 pandemic confront supply chains with serious challenges. Crises like these can disrupt demand or supply in abrupt and persistent ways and go far beyond what companies are typically prepared for (Sodhi and Tang, 2021; Ye et al., 2020; Hecht et al., 2019). This becomes problematic when supply chains that deliver essential goods like food or pharmaceuticals are affected and the companies operating these supply chains are not able to resolve the disruptions themselves. When these disruptions within different supply chains as a sum threaten to endanger the supply of the essential goods to the population, it is the public actors' responsibility to step in and manage the crisis. Public actors are in this sense the government and related public authorities on state or regional level, which are in charge of crisis management and civil protection. This reveals one of the central challenges of crisis management in regards to supply chains: While private companies make up, own and operate the supply chains, public actors are supposed to address and solve problems which are often very supply chain specific. At the same time, these public actors do not and can not have knowledge of how complex supply chains operate and the challenges they face on a daily basis. Especially companies in supply chains of essential goods take on an unique role in public crisis management (Sodhi and Tang, 2021). They control large amounts of products needed for basic supply and operate in established communication structures.

Accordingly, efficient company involvement concerning existing networks and supply chain resources can support public crisis management in promising ways (Qing et al., 2012). Hence, as N. Busch and Givens (2013) put it, there is a strong need for collaboration between public actors and companies. Competencies, resources, and information required to address crises adequately can be gathered in a complementary way if public actors and companies join forces (Kapucu et al., 2010). These aspects are typically challenging for public actors to face on their own in newly created public emergency supply chains (Diehlmann et al., 2021).

As a counterexample, Palin (2017) illustrates the consequences of avoiding collaboration for crisis management. She traced the case of the earthquake and tsunami hitting Japan in 2011: The public actors excluded private companies from the impact zone and tried to set up entirely new supply networks. This attempt failed, and as a result, millions of people could not reach retail stores to get basic supplies. As a cascading effect, people living in neighboring areas started hoarding products which further contributed to the shortage. Although requesting private support in this crisis was an evident option, public actors avoided collaboration.

Consequently, one would expect collaborations between public actors and companies to be the standard operating procedure in (public) crisis management, or at least very common. However, few long-term collaborations between public actors and companies in crisis management exist in reality (Diehlmann et al., 2021). One possible reason for this is that the participation in public actors' crisis management is typically not within the scope of a company's duty or business model. Also, collaboration with public actors can be special from a company perspective due to power differences, as public actors can be allowed to make legislative decisions that impact the company's operations (Diehlmann et al., 2021; Fontainha et al., 2016). Regarding the short term, there is

more evidence of collaboration. On the one hand, numerous examples of voluntary engagement in relief operations prove companies' fundamental willingness to support (Johnson et al., 2011; Fontainha et al., 2016; Binder and Witte, 2007). For example, corporate help is tracked by the U.S. Chamber of Commerce Foundation (2021), which established the Disaster Corporate Aid Tracker and aimed to track business-related assistance within relief and recovery efforts. On the other hand, Walmart quite successfully supplied the population with essential goods on its own during hurricane Katrina. Although Walmart highlighted the need for stronger relationships with public actors and did emergency training with state governments, it rejected contract offers to become states' emergency merchandise supplier. Maintaining large stocks that are possibly not needed would not fit Walmart's business model (Horwitz, 2009; Rosegrant and Leonard, 2007). According to (Horwitz, 2009; Rosegrant and Leonard, 2007), it can be suggested that Walmart's faster lower-level and local decision-making and demand for stronger public support in crisis preparedness were further reasons not to formalize collaboration with public actors.

We argue that the voluntary involvement of companies in a long-term collaboration is subject to identifying the required conditions and the right incentives (Tomasini and van Wassenhove, 2009). Throughout this paper, we will use the concept of public-private emergency collaboration (PPEC), which was proposed by Wiens et al. (2018); Diehlmann et al. (2021). It means coordinated public and private crisis management in regards to resources, like finished goods, trucks and information and competencies, like production and transportation planning and legislation for more effective and efficient supply of essential goods. It is pointed out, that this type of collaboration needs to be executed in a planned-committal long-term basis (Wiens et al., 2018), so that public actors can include reliable company contributions in their crisis management plans.

To foster more collaboration, it is crucial to better understand the companies' motivation and their risks perceived behind engagement in collaborative crisis management. As an example for an incentive, participants from public institutions mentioned during a series of workshops, that numerous German companies inquired, motivated by the COVID-19 pandemic, whether they would be recognized as critical infrastructure by public actors. This was important for them, as such a status would imply certain advantages when dealing with public actors (regulations etc.) and could also positively influence supplier negotiations. We derive that companies see an advantage in cooperation with public actors. Whether or not a company is recognized as part of the critical infrastructure could and would most likely be resolved in a long-term collaboration with public actors. Moreover, participants of the workshop from companies also saw general advantages in establishing communication structures with public actors. As an example for a possible barrier keeping companies from engaging in collaborations during (long-term) crisis management, data privacy concerns were often mentioned in the workshops. Hence, a condition for taking part in a PPEC for companies could be that the public actors involved offer some kind of guarantee regarding confidential data handling. Our conjecture is that the lack of (long-term) collaborations between public actors and companies in crisis management at least partly results from a gap in the understanding of what could motivate companies to take part in such a collaboration and further, what actively keeps them from doing so.

Critics might say that there is a contradiction between potential benefits and the limited practical implementation of long-term collaborations. From our point of view, this argument just underlines the need for further research. Traditional forms of collaboration between public and private actors for dedicated projects (e.g., public-private partnerships for infrastructure projects) represent only minimal reference points. A collaboration such as a PPEC touches on two usually mutually exclusive areas of responsibility. With its primary focus on civil protection, the crisis context makes public-private collaboration a sensitive and ethically challenging issue. We reckon that this is one reason why research on durable and established collaboration between governmental institutions and companies regarding crisis management is scarce, as of yet. As mentioned before, such forms of collaboration are also still relatively rare, if not even non-existent, in practice. In order to leverage the potential for PPECs, requirements for successful collaboration like motivation, opportunities, and limitations need to be further investigated. In particular, existing research lacks a systematic empirical study that identifies drivers for companies to engage in a PPEC.

With the present work, we fill this gap by answering the following research questions: (1) What are positive incentives and barriers to collaboration from a company's perspective? (2) What can be done to enable and promote more PPECs? (3) Which are efficient contributions of companies in PPECs? We investigate this topic through a survey with 398 participants from Germany's producers, logistics service providers, and retailers from supply chains of essential goods. We examined the willingness and motivations of private companies to participate in crisis management with public actors. Furthermore, the survey explores how companies assess their risks and their potential contributions towards a collaborative crisis management.

Overall, this study contributes to the existing literature and crisis management in three ways: First, it empirically carves out requirements as well as favorable and unfavorable conditions for companies to participate in a long-term collaboration with authorities. While we find that the willingness to participate in collaborations is generally high among companies, they also assign a high priority to maintaining their business processes. Additionally, further clarification and commitment from public actors is needed to pave the way for more collaborative crisis management. We show that providing resources, physical or informational, is the preferred way of companies to collaborate. However, the results also indicate that companies wish to receive monetary compensation for supplied resources. Moreover, an improved communication policy of public actors is perceived as important. Another finding is that when it comes to collaboration, companies prefer to help during a crisis rather than in a preventing manner. Second, these insights can be used to design and operationalize PPECs in an optimal way with respect to the companies' incentives. There is for example evidence for industry specific preferences - we find that while logistics companies favor the relaxation of regulations, healthcare companies are motivated by reputation aspects more than others. These combined insights are the prerequisite for a stable contractual basis. Third, our study raises awareness for the potential of public-private collaboration during crises and promotes the systematic implementation of PPECs, in contrast to rather spontaneous forms of public-private interworking.

The remainder of this paper is organized as follows. The next section provides the theoretical background on public-private partnerships in crisis management from a company perspective.

From that, we derive research questions and underlying hypotheses for our survey. This is followed by the presentation of the study design. The section after that presents our results. Next, we discuss the results and derive theoretical and managerial implications for the implementation of PPECs. Finally, we look into limitations of our study suggest further research directions in this area and conclude with the main findings.

B.2 Theoretical Background

B.2.1 Crisis Management

B.2.1.1 Public Crisis Management

In crises, public actors' primary objective is to avoid or reduce negative effects for the population. Especially in times of more frequent, unexpected large crises, proactive preparations for different types of crises to be made in advance become more and more important. For example, public actors can set up physical resources like stocks of goods or transport equipment to ensure the population's supply with essential goods. Financial resources can be deployed, for example, in the FEMA Disaster Relief Fund in the US. Furthermore, the state possesses legal resources to adapt laws when the need arrives (Kovács and Spens, 2007; Diehlmann et al., 2021). Public actors can also gather and combine up-to-date crisis information from companies, research institutes, other public actors and inform crisis management decision processes and the population in general.

From a long-term perspective, the state can shape the readiness for crises through political instruments. Anticipatory collaboration with other actors, public and private, is a promising approach for increasing the resiliency of supply networks and can be fostered by political initiative. Another, more direct approach to public intervention in existing commercial supply chains can occur through the formulation of sector-wide regulations or policies (Sodhi and Tang, 2021; Quarshie and Leuschner, 2020). These interventions can happen both in anticipation of or during an event, as was and still is the case during the COVID-19 pandemic. From a short-term perspective, if the legal situation allows, even confiscation of critical private resources can become possible (Wendelbo et al., 2016). In general, the government and its public authorities have various tools at their disposal to react to and manage crises.

Another question is which role the government intends to take in different crises and their management. Quarshie and Leuschner (2020) summarize the different potential roles the government can take as an organizer, supply network member, and facilitator. As an organizer, the government would, for example, command public authorities, regulate company activities, or convene and coordinate relief staff, which can be done both during and in preparation for a crisis. As a supply network member, governments could take a more active role in supply chains and, for example, connect buyers with suppliers or manage flows by ensuring the required infrastructure. These are mainly measures for times of crisis, however. The role of the facilitator, which consists of communication, collaboration, training, or learning, means higher investments for governments.

In the supply of essential goods, it would require, among others, industry-specific knowledge for efficient interaction with companies and market knowledge to identify effective measures that are accepted by the market participants. Therefore, we argue that this role is the least observed role of governments in supply chain-related crisis management.

In general, a unique strength of public crisis management is the access to information about a crisis. Public actors have access to information about crisis dynamics and potential emergency plans or future measures. On the other hand, public actors hardly possess sufficient production and logistics capacities to supply the population with essential goods. Therefore, public actors rely on companies and would thus primarily coordinate and support them to maintain commercial supply chains. Such support can happen, for example, on an economy-wide level or, more specifically, on a company level. For more specific support, public actors require more detailed insights into complex and dynamic commercial supply chains, which they would often lack, such as the time and financial effort required for additional production and transport of the required goods as well as the technological know-how (Diehlmann et al., 2021).

B.2.1.2 Company Crisis Management

During a crisis, a company's very first motivation is to protect, maintain or recover business processes (Palin, 2017; D. Elliott et al., 2010). The goal of keeping the business running during disruptions is at the center of business continuity management (BCM). Moreover, the company can and should also be interested in avoiding or reducing negative effects on the population, just as the public actors. Protecting staff and customers arises from social responsibility but also from narrow self-interest. It lies in a firm's self-interest because "business as usual" is nearly impossible if customers and probably also a large share of the own employees are affected by the crisis. In addition, corporate social responsibility (CSR) is another important motivating factor for a company.

Due to this study's focus on supplying essential goods to the population, we focus on supply chain management as a specific area of BCM. This also includes supply chain risk management (SCRM), which is defined by Tang (2006) as 'the management of supply chain risks through coordination or collaboration among the supply chain partners to ensure profitability and continuity'. Following Christopher and Peck (2004), risks can be categorized into supply, process, demand, control, and environmental.

In response to more and more large-scale crises recently, Sodhi and Tang (2021) introduced the term *extreme supply chain management* (ESCM) for supply chain management for severe crises, which goes beyond supply chain risk management. It would be applied in severe demand and/or supply increase or drop. Further, in such cases, not only a single company is hit by the crisis, but multiple companies or even parts of society (Sodhi and Tang, 2021). This underlines the need to adapt supply chain management to current developments from a company perspective.

Moreover, during large crises, companies can engage in social activities like donations. From a CSR perspective, this can lead to an increase in the companies' reputation or staff motivation and thereby

to long-term economic benefit (Porter and Kramer, 1999; Madsen and Rodgers, 2015; Besiou and van Wassenhove, 2015). Therefore, we use the term company crisis management covering supply chain-related BCM and CSR in the following.

In non-crisis and crisis times, companies in commercial supply chains can not only fall back on the necessary physical resources to produce and distribute essential goods (e.g., raw material, production sites, trucks, warehouses), but also on established communication structures with other supply chain members. Companies use advanced technologies to monitor demand and use track-and-trace systems and industry standards for information flow (Bealt et al., 2016).

However, the companies' scope of action in a crisis outside established supply chains is some-what limited compared to public actors. Setting up new business processes can take time, and collaboration with competitors might even be forbidden by competition law.

The strength of companies is to be prepared to cope with everyday fluctuations in demand or supply. However, despite concepts of SCRM and ESCM being known, companies typically lack preparedness for disruptions or events of high impact and low probability (Izumi and Shaw, 2015a; Scala and Lindsay, 2021). Recent crises have led to a stronger focus on SCRM among companies though (R. Elliott et al., 2021). There is however evidence that larger companies are better prepared than smaller ones, which can lack formal emergency plans due to lack of time or expertise (Hecht et al., 2019).

Hence, one can conclude that the roles and strengths of public and private actors complement each other in terms of resources, coordination opportunities, and preparedness.

B.2.2 Company Collaboration in Crisis Management and the Concept of PPECs

Companies can increase their resilience through collaboration with other companies, including their competitors (Scholten and Schilder, 2015). Collaboration in general and especially information-sharing can lead to greater visibility and flexibility and thereby improve resilience along the whole supply chain (Christopher and Peck, 2004; Sodhi and Tang, 2019; Kleindorfer and Saad, 2005; Scholten and Schilder, 2015). Many possible collaboration measures are known. Some examples are resource-sharing, collaborative communication, goal congruence, decision synchronization, incentive alignment, and joint knowledge creation (Scholten and Schilder, 2015).

Collaborative relationships in crisis management are more and more encountered between companies and non-governmental organizations (NGOs) (Bealt et al., 2016). Madsen and Rodgers (2015) found that companies that partner with an NGO in their crisis-related CSR activities would receive more stakeholder attention than companies not partnering with an NGO. However, for the case of logistics service providers, CSR activities like donations of free capacity or employee volunteering are only one way to engage. More proactive and competence-based commercial roles like a third-party logistics provider (e.g., transportation, warehousing, or customs clearance) or a

fourth-party logistics provider (e.g., inventory management, transport coordination) are possible. They can offer new business opportunities (Vega and Roussat, 2014).

Formal collaborative relationships between companies and the public sector are, however, rarely observed (Diehlmann et al., 2021). Such a relationships is defined by Wiens et al. (2018) as a PPEC. It would combine commercial supply chains for essential goods with public relief supply chain management and include joint supply chain planning, knowledge management, and the use of resources. Moreover, it is 'designed for improved crisis management by joint coordination and cooperation between private and public representatives. A PPEC would additionally require thorough and joint preparation of both parties' (Diehlmann et al., 2021), which distinguishes it from spontaneous collaboration.

Only a few examples of collaborations similar to a PPEC exist (Diehlmann et al., 2021). In Sweden, public-private partnerships are part of the national emergency preparedness management (Kaneberg, 2018). In addition, a German public-private partnership called "UP KRITIS" aims to increase the resilience of critical infrastructure (KRITIS, 2019). "UP KRITIS" does not address supply chain management, however.

Some research exists about collaboration between public and private actors supporting the current relevance of PPECs. For example, Sodhi and Tang (2021) suggest several similar research streams with government involvement in commercial supply chains in the context of crisis management: government subsidy and support schemes, joint coordination of an exit from a lockdown, and programs about re-shoring production of essential goods. Based on public-private collaboration observed during the COVID-19 pandemic, Scala and Lindsay (2021) argue that supply chains should be seen as critical infrastructure and be managed collaboratively by government and companies. de Moura et al. (2020) propose further research on public-private collaboration and the type of resources shared as well as how much know-how from both parties could be used to improve response to emergencies.

Furthermore, numerous spontaneous collaborations between public and private actors happened during the COVID-19 pandemic. As the following examples show, public actors got involved in essential good supply chains in many countries. Healthcare, the government, and government agency collaboration, enabled by the government, would have been critical to respond to the COVID-19 pandemic in the Scottish health care system (Scala and Lindsay, 2021). The Chinese retailer JD.com and the government of Hubei province collaborated and used a platform to track production, inventory, and distribution of emergency supplies, which improved the matching of demand and supply (Shen and Sun, 2021). In the UK, a last-mile delivery concept for the vulnerable population was developed and set up collaboratively during the COVID-19 pandemic between the government, retail companies, and the affected population (Department for Environment, Food and Rural Affairs, 2020). The German Ministry of Transport lifted cabotage regulations and discussed the logistics sector's capacity on a more than weekly basis with logistics associations (Bundesverband Güterkraftverkehr Logistik und Entsorgung e.V., 2020). We refer to Diehlmann et al. (2021) for further examples beyond the COVID-19 pandemic.

However, little is known from practice about companies' motivation to engage in these collaborations nor the collaborations' success and potential benefits from a company perspective. In addition, we assume that these collaborations have not been prepared in normal times but were rather spontaneous and set up during the COVID-19 pandemic.

Existing research provides some suggestions for designing PPECs and some assumptions about companies' motivation. Stewart et al. (2009) suggest that companies become involved in a public-private partnership for disaster response mainly for two reasons: The first reason is to fulfill a government contract and the second reason is to protect their assets, customers, suppliers, or other interests in the disaster area. Breitbarth et al. (2021) propose a PPEC for coordination of vehicles across logistics service providers for last-mile delivery during pandemics. The authors name intrinsic motivation and compensation of additional expenses as incentives for companies to collaborate with public actors. Further, Löffel et al. (2022) propose joint warehousing of food for emergency preparedness and list existing partnerships in food supply for different countries. In food warehousing with public actors, companies could, next to financial compensation for their services, benefit from improving resilience by getting up-to-date crisis information about demand or supply through established communication channels (Wiens et al., 2018; Löffel et al., 2022; Mehrotra and Schmidt, 2021). Potential subsidies, staff training and development, and publicity could be further benefits (Carland et al., 2018; Löffel et al., 2022).

However, barriers for companies to join a PPEC might be similar to those to collaborating with humanitarian organizations. Often governments are skeptical of companies and their willingness to provide help (van Wassenhove, 2006). Steyer and Gilbert (2013) claim that companies would rarely take over the responsibility to prevent society's risks. Large companies would be more proactive, but on the other hand, large multinationals would be 'insensitive to local concerns' and often lack legitimacy (Steyer and Gilbert, 2013). On the downside, companies see inefficiencies in public relief supply chains (van Wassenhove, 2006). The latter underlines the case of hurricane Katrina, where US retailer Walmart outperformed public relief supplies in the immediate crisis response and delivered goods into the crisis region several days earlier. Later, Walmart rejected the government's offer to collaborate in the long term (Swanson and Smith, 2013; Horwitz, 2009).

Hence, empirical research about the benefits or risks that companies see in engaging in a PPEC and the incentives required to make a PPEC attractive to companies has not been conducted to the best of our knowledge. Since the issue has been recently raised more and more in literature, a deeper understanding of the companies' perspective is needed.

Of course, this perspective is not identical for all companies. For essential goods supply chains, it is important to understand how food, healthcare and logistics companies differ in requirements to engage in a PPEC. Moreover, companies within every industry have different sizes, customers, supply chain structures, and logistics networks, which might cause specific requirements for a PPEC.

B.3 Research Questions and Hypotheses

B.3.1 Research Questions

Research and practice need to understand better why and under which conditions companies would want to collaborate with government agencies to support crisis management. Information about the companies' incentives enables both parties to establish a realistic and thus stable collaborative relationship.

Furthermore, with improved knowledge, public actors can better motivate companies to join a PPEC and design PPECs, in which companies find incentives to act as reliable partners.

To this end, we set up three main research questions (RQ) (see Figure B.1) which focus on various aspects of a PPEC that both public actors and companies need to understand in order to make such collaboration stable and reliable.

The first research question is derived from the identified research gap as detailed in Section B.2 and was raised by public actors in workshops on several occasions.

RQ 1: *What are incentives and barriers for companies to collaborate with public actors?*

Within this research question, we will first examine a record of incentives and barriers for companies to participate in a PPEC. RQ 1 refers to a company's whole business model. Hence, we look at all relevant areas in which companies can assist in the emergency context (provision of goods, logistics services, storage capacities, personnel, coordination, and information exchange). For example, a potential barrier to a company's willingness to support in a crisis is that companies' business models need to be protected or stabilized. This was well illustrated during the COVID-19 pandemic, where an extreme demand and supply volatility overwhelmed most preemptive measures enacted by companies to mitigate disruptions in their supply chains (Dohmen et al., 2022). In such a situation, setting up a spontaneous collaboration is more time-intensive and less effective than using an existing collaboration framework where players know their roles and aligned emergency strategies may be rolled out immediately.

We ask the companies questions around the importance of different business-related actions, relationship-management, profit and reputation considerations as measures and motivators for a particular crisis reaction.

RQ 2: *What can be done to enable and promote more PPECs?*

In RQ 2, we focus on measures of public actors as options to make a PPEC more attractive to companies. In particular, public actors have a number of measures at their disposal to facilitate firms' participation in a PPEC. These measures comprise e.g. regulatory relief, financial compensation

or an official testimony of a firm's engagement. How should public actors deploy their bundle of measures and thus design attractive and acceptable framework conditions for companies?

We asked questions concerning the type of emergency help, the financial conditions, and the time frame for the intended help. In particular, we want to find out how companies weigh financial reimbursements and positive public recognition and, if at all, in which phase of a crisis they would prefer to collaborate.

RQ 3: *Which are efficient contributions of companies in PPECs?*

The third RQ deals with companies' contributions to PPECs. Assuming that companies have the willingness to participate in a PPEC: In what role and function do they believe they can make the most meaningful contribution? We differentiate between three ways how companies could contribute during a crisis: by providing goods, transportation resources, or participating at emergency planning (e.g. co-development of operational plans together with public actors).

We ask questions on these three types of emergency measures in terms of willingness to provide them and under which financial conditions. Moreover, we investigate the companies' perception of how the private sector can best complement public crisis management and also the other way round: What do companies believe, public actors need the most help within the categories presented. From the company's point of view, it is essential to know how a PPEC is designed and which tasks and responsibilities need to be fulfilled.

Within RQ 3, we also want to identify the strengths of different types of companies: Which type of company (e.g. with respect to a specific sector) sees itself particularly well suited for participation in a PPEC? This knowledge helps public actors to identify more specific fields of collaboration and better understand companies' perceptions of their contribution.

B.3.2 Hypotheses

To answer the research questions above, we developed six hypotheses (see Figure B.1). Clues and prior knowledge that led to these hypotheses were derived from literature and expert workshops with practitioners from the public and commercial fields. For example, regarding the COVID-19 pandemic, practitioners from companies struggled with the unavailability of business critical information and point of contacts with the authorities. Furthermore, it was added that assistance offered in the past could not be provided in the possible form due to legal requirements or excessive bureaucracy. Authorities also missed the lack of linkage with logistics companies.

The first hypothesis refers to a fundamental motivational tension, which firms have to face when they are confronted with a crisis which causes a lack of supply. On the one hand, companies need to run profitably in the long run to withstand competition. On the other hand, it is harder to balance different priorities in times of high uncertainty in their supply chains (Wu and Pagell, 2011). Given that managers show some genuine concern about the distressed population and consider providing

RQ1: What are incentives and barriers for companies to collaborate with public actors?	**RQ2**: What can be done to enable and promote more PPECs?	**RQ3**: Which are efficient contributions of companies in PPECs?
H1: During crises, companies consider contractual business relationships as more important than mitigating suffering of population.	**H3**: Companies prefer the permission to advertise with their PPEC-role to reimbursements of costs from public actors.	**H5a**: Companies prefer provision of resources to coordinating assistance.
H2: Companies see reputation from a PPEC engagement as a benefit rather than a risk.	**H4**: Companies expect to better support governments in crisis response than in crisis preparedness or crisis recovery.	**H5b**: Companies expect public actors to need resources from companies rather than coordinating assistance.

Figure B.1: Research questions and corresponding hypotheses

assistance: Are they willing to sacrifice daily business obligations for it? Framing it differently, we are curious to determine if the urge to help is high enough so that a responsible manager puts everyday business on the back burner and is thus prepared to accept substantial losses in the short term. Even though it is clear that a company can never sustain such prioritization of postponing daily business in the long term, the short-term willingness to do so is an essential prerequisite for voluntary contributions to crisis management.

According to Porter and Kramer (2011), corporate rewards for private sector involvement in PPPs go beyond tax savings and immediate profit. They acknowledge the potential value derived from assisting the company's stakeholders. It has long been known that CSR should be considered an important motivational factor for a sustainable value chain. It increasingly is an integral part of companies' objectives, which goes beyond short-term financial success (Madsen and Rodgers, 2015; Dahlsrud, 2008). According to Swanson and Smith (2013), CSR provides insights into why companies participate in PPPs even without government pressure and without the prospect of short-term economic benefit. Therefore, it can be assumed that such companies, for which CSR goals are critical, also show a higher motivation for private sector involvement in crisis management. von Behr et al. (2021) found indicators for altruistic behavior during the COVID-19 pandemic in companies, contradicting - or at least complementing - the standard paradigm of pure profit orientation. Others, such as Zhao (2021) analyzed the effectiveness and rationale of mandatory CSR approaches in the course of COVID-19 and introduced 'corporate social competence' as a new compliance principle that should be integrated into corporate law. This consideration assumes that companies still have much catching up to get done in the CSR area since they must be legally obligated to show social competence.

For our first hypothesis, H1, we therefore expect that companies instead put social concerns aside to be able to follow their business priorities even in a crisis.

H1: *During crises, companies consider contractual business relationships as more important than mitigating suffering of population.*

A company's reputation is a precious asset. A positive reputation is reflected in a premium on the valuation of the company (Arora et al., 2019; Donia et al., 2017; Groening and Kanuri, 2013). It

is the basis of a strong brand (Lange et al., 2011) and a decisive factor for young talents to join a company (Donia et al., 2017), which are both among the most important factors for running a successful business model in the long-run.

Social and humanitarian engagement is an essential component of CSR activities for an increasingly large number of companies (Dahlsrud, 2008; Johnson et al., 2011). Bealt et al. (2016) identified three key drivers of corporate engagement in disaster relief operations: internal ethical drivers, external stakeholder drivers, and internal corporate drivers. By providing aid to society in times of a crisis, a company protects its staff and customers or can create new business opportunities (Izumi and Shaw, 2015). Hence, by investing in societal resilience, firms can improve their corporate reputation, which could pay off in the long term. In contrast, humanitarian activities are not always easy to assess in public perception. They can be risky for a company for at least two reasons: First, promoting corporate involvement can appear incredible from the public's point of view creating suspicion that the company in question is seeking to make a profit at the expense of those affected (crisis capitalism). Interestingly, this opportunity of "crises gains" has vehemently denied being in consideration of any emergency engagement by some of the practitioners we talked to. Second, uncoordinated crisis involvement without experience can also be risky for companies in that mistakes (e.g. distributing goods to non-affected and non-vulnerable people) can happen easily, which in turn damage their reputation.

As the evidence hints at a preponderance of potential reputation benefits we assume that companies expect positive net reputation effects (H2):

H2: *Companies see reputation from a PPEC engagement as a benefit rather than a risk.*

Contributing resources during a crisis comes at a potentially high cost, comprising delivery of goods, staff involvement, and equipment usage. These cannot be used for ongoing business activities at the same time. However, the proper promotion and the role of a company in the eyes of (possible) customers is of high importance to the financial performance of the company as well (Green and Peloza, 2015). If the expected positive reputation effects of H2 are confirmed, then the question arises for authorities whether they should also explicitly allow companies to promote with a PPEC participation towards their stakeholders (involving potential employees, members of their own SC, and customers). Possibly, this option could already be incentive enough for some companies to participate in a PPEC. In H3, we have explicitly formulated this conjecture:

H3: *Companies prefer the permission to promote with their PPEC-role to reimbursements of costs from public actors.*

According to the United Nations Disaster Cycle, disaster management has four phases - mitigation, preparedness, response, and recovery (Seaberg et al., 2017; van Wassenhove, 2006). Since each of these phases requires different tasks and resources, it is important for civil protection agencies to

know which phase companies can best be deployed in and, more importantly, at what stage they are most likely to engage in a PPEC?

According to Swanson and Smith (2013), the private sector overall has responded to disasters more efficiently and effectively than government agencies. Based on these findings from the literature, we see at least three reasons why the response phase should be the phase that companies would most prefer for a PPEC contribution:

(I) Preparedness measures require lengthy ex-ante coordination and involve high uncertainty about the actual need. However, in immediate crisis response, firms can quickly adapt to the need that becomes apparent relatively soon during an acute crisis. (II) Preparedness measures are permanent (implying a permanent cost factor) and have to be raised before a potential crisis, so that these measures will most probably be too expensive from a firm's point of view. (III) Focusing on the response phase is the more effective way to gain attention for the engagement because it is visible and in urgent need (promoting effect). For example, Madsen and Rodgers (2015) argues that disaster relief activities that promptly address disaster-created needs receive more stakeholder attention. The costs are difficult to justify internally. Based on these considerations, we formulate our fourth hypothesis:

H4: *Companies expect to better support governments in crisis response than in crisis preparedness or crisis recovery.*

The basic idea behind a PPEC, as outlined in Diehlmann et al. (2021); Sodhi and Tang (2021); Wiens et al. (2018) is that companies are specialists in their respective fields of work and have the appropriate resources and know-how. As discussed above, firms can in principle contribute to a PPEC in a number of ways, but some of these options will be more attractive to them than others. On the other hand, in a crisis, governmental actors have to coordinate numerous companies and establish a suitable distribution of tasks in a PPEC. These crisis-related coordination efforts are time-consuming. Company participants at the workshop feared that a PPEC could be characterized by too much bureaucracy and too little flexibility. In contrast, providing resources (e.g., delivery of goods) should be a comparatively easy way to contribute, making companies more independent.

We argue that it is easier for a company to divert resources (which are under its control, companies can decide on their own) than to coordinate prioritization, information exchange, and action planning with public actors. Concerning companies' role in humanitarian operations, Diehlmann et al. (2021) identify ownership of physical resources and their control as a key factor in crisis management. Given these considerations, it is reasonable to conclude that companies see their role in a PPEC as a resource provider rather than a coordinator of relief efforts. In general, making monetary or product donations is common for companies themselves or in collaboration with NGOs (Bealt et al., 2016).

Furthermore, in a change of perspective in H5b, we want to find out whether companies also *believe* that they are *expected* to contribute resources or whether the state requires them to provide coordinative, planning support. Hence, we propose our fifth hypothesis regarding two different

perspectives on the nature of willingness to help:

H5a: *Companies prefer provision of resources to coordinating assistance.*

Furthermore, in a change of perspective, we want to find out whether companies also *believe* that they are *expected* to contribute resources or whether the state requires them to provide coordinative planning support. Consistent with H5a, firms should expect that crisis needs will also primarily revolve around resources. We investigate whether a company would prefer providing what they perceive to be most helpful or rather push through their preferred way of contribution. Hence, we propose our sixth hypothesis H5b regarding this second perspective on the nature of willingness to help:

H5b: *Companies expect public actors to need resources from companies rather than coordinating assistance.*

B.4 Data Collection

B.4.1 Survey Design

The survey contains 13 questions that are based on the hypotheses. Additionally, 12 characteristics of the respondents and their company, such as revenue, industry, and the number of employees, were surveyed. The survey's target were companies from the following industries:

food retail (including wholesale), food production, healthcare retail (including wholesale), healthcare production, and logistics.

The survey was developed with the research institute Allensbach (IfD Allensbach). The institute took over the final implementation, and data collection was carried out in July and August 2021.

From a sample which is representative for German companies from the targeted industries, about 9,000 companies were randomly selected and contacted online. This yielded 398 valid replies (response rate of 4%). The survey was conducted in German and translated into English for publication (see e-companion for questions relevant for hypotheses).

We used closed questions with predefined possible answers and assumed the answers to be metric data (de Campos et al., 2020). In six cases, the participants were allowed to provide additional comments. A Likert scale with the number of options dependent on the content of the possible answers was used. The development of variables and items was partially self-constructed. We validated the relevant topics and related questions in several workshops with experts. Among other things, we defined the various categories of business support options, such as support with warehousing, goods, or personnel. Other variables we set up based on literature, such as the

question on the different phases of helpfulness, which are based on the four phases classified within the *the disaster management cycle* (Coppola, 2011).

Additionally, participants were asked to select options from a given list.

We asked questions within the areas of: (1) behavior in the event of a crisis, (2) lessons learned from the COVID-19 pandemic, (3) willingness and ability to provide assistance in a PPEC, (4) requirements to engage in a PPEC, (5) communication with public actors in the event of a crisis.

B.4.2 Characteristics of the Participating Companies

The characteristics of the sampled companies are shown in Table B.1. In terms of industry, 36.7 % were part of the grocery industry, slightly fewer companies operating in the healthcare field, and the least were logistics companies (24.4 %). About two-thirds of the grocery companies were in production, whereas this composition was the opposite for the healthcare companies. Regarding their size, nearly half of the companies had 10-20 employees (46.0 %) and only 9.4 % of the companies employed more than 100 people. These data correspond with the data on the employee size classes of all German companies (n=3,374 million), of which 86.87% have fewer than 10 employees and another 10.46% have up to 50 employees (Statista, 2021). In terms of annual revenue, it can be observed that nearly two-thirds of the sample (64.3 %) had an annual revenue below 10 Mio €, followed by 22.7 % of the companies with annual revenue of 10 Mio to 50 Mio €. The vast majority of the companies were family businesses (83.9 %).

In addition to the companies' characteristics, we asked for the area of responsibility of the company's respondents, where multiple answers could be selected. Roughly three out of four respondents were (top-) management. Respondents responsible for business continuity management or logistics/ SCM made up about one-third, and only 23.6 % of the respondents had responsibilities regarding corporate social responsibility.

We can therefore assume a strong approximation of corporate decisions from management representatives and a considerable expertise in the field of company crisis management. The large number of respondents being responsible for business continuity management exceeded our expectations.

Variable	Sample companies	
	Number	Percentage (%)
Industry		
Grocery	146	36,7
thereof: Production	*91*	*22,9*
thereof: Retail	*55*	*13,8*
Healthcare	125	31,4
thereof: Production	*46*	*11,6*
thereof: Retail	*79*	*19,8*
Logistics	97	24,4
thereof: Grocery	*9*	*2,3*
thereof: Healthcare	*7*	*1,8*
thereof: Others	*80*	*20,1*
No answer	30	7,5
Employees		
$1 - 10$	41	10,3
$11 - 20$	183	46,0
$21 - 100$	136	34,2
> 100	37	9,4
No answer	1	0,3
Annual revenue		
< 10 Mio €	256	64,3
10Mio - 50 Mio €	90	22,7
>50 Mio €	36	9,0
No answer	16	4,0
Family business		
Yes	334	83,9
No	55	13,8
No answer	9	2,3
Area of responsibility of respondent (multiple answers possible)		
(Top-)Management	301	75,6
Business Continuity Management	140	35,4
Logistics or SCM	131	32,9
Corporate Social Responsibility	94	23,6
Other	34	8,5
No answer	16	4,0

$n = 398$

Table B.1: Companies' characteristics

B.5 Results

We evaluated our main research questions using a confidence interval of $\alpha = 95\%$ for directly testable hypotheses, if not stated otherwise. To increase readability, we shortened most of the items within the text passages. A complete list of the unabriged items can be found in the e-companion.

We also conducted correlation analysis concerning SC stage (retail or production companies), different industries (food, healthcare, and logistics), and the company revenue for each hypothesis. Based on Moore et al. (2013), we interpret a correlation of two variables up to $|0.3|$ as low, between $|0.3|$ and $|0.5|$ as medium, and $| > 0.5|$ as strong, and correlations as statistically significant with ρ-values < 0.05.

B.5.1 Incentives & Barriers

H1: *During crises, contractual business relationships are considered more important than mitigating suffering of population.*

We asked the respondents to rate the importance of several requirements in case of a crisis on a likert scale from one (*very important*) to five (*not important*). Sequence of items correspond to the sequence in the questionnaire

Contrary to our expectation, the respondents rated *reducing suffering of the population* ($Mean = 1.43$ and $SD = 0.68$) higher in importance than *not endangering contractual business relationships* ($Mean = 1.73$ and $SD = 0.85$) (see Table B.2). A one-sided t-test revealed a significant difference with a p-value of 0.000.

If you needed to react to a crisis, how important would the following aspects be for your company?	Mean	SD
Maintaining operational business processes	1.28	0.62
Not endangering short-term profit	2.96	1.05
Not endangering long-term profit	1.79	0.8
Not endangering contractual business relationships	1.73	0.85
Avoiding disadvantages for customers	1.63	0.78
Avoiding loss of reputation	1.97	0.96
Improving reputation compared to competitors	2.87	0.97
Reducing suffering of the population	1.43	0.68

$n = 372$, $1 =$*very important*, $5 =$*not important*

Table B.2: Priorities in company crisis management

Hence, we reject H1, which points to companies having an altruistic motivation in crisis management, or at least, to have a functioning CSR profile. Nevertheless, at least part of this motivation can be profit-oriented, too, as healthy customers and employees are an important requirement for companies to perform business.

Looking at all items of the table, it can be concluded that in a crisis, to protect processes ($Mean = 1.28$), help people (customers ($Mean = 1.63$), and citizens in general ($Mean = 1.43$)) are seen most important. Profit concerns appear to be only subordinate while *long-term* ($Mean = 1.79$) considerations are significantly more important than *short-term* ($Mean = 2.96$) ones (p-value of a t-test is 0.000).

As expected, we can further observe a stronger correlation between *long-term profit* and *not endangering contractual business relationships* ($r = 0.21, p = 0.000$) than between *short-term profit* and *not endangering contractual business relationships* ($r = 0.14, p = 0.006$). This finding points to the fact that contractual business relationships are seen as a long-term commitment, an essential contribution to the long-term success of the company. Short-term, deviations from obligations from contractual business relationships may be possible.

In addition, a significant and medium degree of correlation exists between *short-term* and *long-term* profit ($r = 0.36, p = 0.000$). Hence, it can be suggested that the more sensitive respondents are to long-term profit, the more sensitive they are to short-term profit and vice-versa. This result could indicate a general sensitivity not to endanger profit among some respondents.

To test whether our variables are predictors of an outcome, we performed regression analyses at various points in the statistical analysis - for example, whether "long-term profit" or "short-term profit" explained the respective other variable as an independent variable. The results were not significant with a value of $R^2 = 0.13$ (should be at least > 0.2) in each case. Korre In contrast to the highly significant correlation analyses, no significant causalities could be identified in any of the regression analyses performed.

Moreover, *endangering companies' operational processes* and *long-term* profit can be universal barriers to companies engaging in crisis management. Interestingly, the importance of *reducing the suffering of the population* and *not endangering contractual business relationships* does not differ significantly between industries, supply chain stages, and company size (in terms of revenue), and no significant correlation exists among both questions.

H2: *Companies see reputation from a PPEC engagement as a benefit rather than a risk.*

To test H2, we asked the respondents about the advantages and disadvantages of collaborating with public actors. In terms of reputation, we asked whether they see a *positive reputation effect* vis-a-vis the wider public in one question, and in a separate question we asked, whether they rather fear a possible *damage to reputation*. Both questions could be answered with a *YES* or *NO*. From

the $N = 398$ respondents who answered both questions, the approval rate for *increase of reputation* showed $Mean = .41$ and $SD = .493$. A one-sided t-test reveals that this is significantly higher ($p = 0.000$) than for *damage to reputation* with a $Mean = .28$ and a $SD = .451$. Although these findings show that reputation is not the predominant concern for firms in both directions, with the comparative result we do not reject H2.

Somewhat surprising at first glance, we find a low but significant positive correlation between both variables with $r = 0.231, p = 0.000$. One explanation for this finding might be the general relevance of reputation for the companies. A company that possibly recognizes a positive reputation in collaborative emergency management is somewhat aware of the possible negative consequences of misunderstood or failed relief efforts.

When it comes to the question of *damage to reputation*, differences in the answers of retail companies ($Mean = 0.36, SD = 0.481, n = 134$) and production companies ($Mean = 0.25, SD = 0.434, n = 137$) are noteworthy: The risk of possible reputation damage is rated higher by retail than manufacturing companies, which is plausible. Retail companies are more in the focus of the public eye and are therefore exposed to greater risks in terms of possible reputation losses towards private customers. By contrast, manufacturing companies do business rather in a B2B context and therefore do not focus on the reputation aspects of a PPEC to the same extent.

B.5.2 Enabling Factors

H3: *Companies prefer the permission to promote with their PPEC-role to reimbursements of costs from public actors.*

To test H3, we asked the respondents on a likert scale from one (*very important*) to five (*not important*) how important several conditions would be if they collaborated with public actors. *Incurred costs need to be reimbursed* was rated higher than the *Permission to promote* ($Means$ 1.95 vs 2.97 see Table B.3 for further details). A one-sided t-test shows a significant difference with $p = 0.000$.

Hence, we reject H3, for respondents from every industry, supply chain stage, and company revenue. Moreover, a weak positive correlation exists between responses to both questions ($r = 0.172, p = 0.001$), indicating the more important cost reimbursement is to a respondent, the more important the permission to promote is and vice-versa. This may be due to the fact that for most companies, basic requirements for a PPEC are decisive, such as protection of processes or company data, but only a subgroup of these also requests explicit benefits like compensation for costs and the opportunity to present themselves in a favorable light in public, which may be part of its CSR strategy.

Respondents rate *Cost reimbursement* and *Risk sharing* on a similar level. We further find a significantly higher rating of reimbursement of investments among small companies ($Mean =$

How important would the following conditions be in a collaboration with public actors?	Mean	SD
Operational processes must not be endangered	1.42	0.71
Competitors must not have access to internal corporate information	1.46	0.79
Incurred costs need to be reimbursed	1.95	0.83
Permission to promote with the relief	2.97	1.05
Public actors need to take over some of the risks associated with the company's investments in crisis management	2.02	0.92
Willingness of public actors to grant special rights (e.g., opening or driving times)	1.51	0.71

$n = 375$, $1 = $*very important*, $5 = $*not important*

Table B.3: Conditions for collaboration with public actors

1.91) than among large companies ($Mean = 2.31$) through a t-test with $p = 0.048$. This finding could be explained by the fact that large companies generally possess a higher liquidity and more options for financial diversification (Soboleva et al., 2018).

In alignment with H1, respondents rated *Operational processes* highest within this question, followed by *No internal information to competitors* and *Public actors grant special rights* as more important. Compared to the general importance they attach to operational process continuity, they rate its importance in a PPEC slightly but significantly lower (t-test: $p = 0.000$, $Means = 1.28$ vs 1.42). When collaborating with public actors, one could interpret it as goodwill, sacrifice, or increased tolerance towards operational interventions.

From these findings, we conclude that public actors should focus on designing compensation regulations and providing a high degree of confidentiality to enable more PPECs rather than enabling publicity. Moreover, public actors might have to pay even more attention to the continuity of companies' operations, e.g., by relaxing regulation, which is valued higher than monetary compensation.

H4: *Companies expect to best support governments in crisis response rather than in crisis preparedness or crisis recovery.*

We asked companies during which crisis phase their company could best support public actors. In these questions, we applied a likert scale from one (*we can support public actors very well*) to four (*we can barely support public actors*).

The respondents significantly prefer *immediate crisis response* to *permanent crisis preparedness* and *preparedness during an emerging crisis* (see Table B.4). For both comparisons, one-sided

t-tests reveal statistical significance of the difference in means ($p = 0.000$). Hence, we do not reject H4.

When do you think your company could best support public crisis management?	Total		Food		Healthcare		Logistics	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Permanent crisis preparedness	2.39	0.89	2.56	0.85	2.16	0.89	2.36	0.85
Preparedness during an emerging crisis	2.30	0.83	2.51	0.82	2.09	0.79	2.2	0.77
Immediate crisis response	1.99	0.77	2.14	0.81	1.81	0.69	1.99	0.7
Recovery from long-term consequences of a crisis	2.34	0.81	2.48	0.84	2.14	0.79	2.40	0.73

$n = 373$, 1 =*we can support public actors very well*, 4 =*we can barely support public actors*

Table B.4: Support in different crisis phases

In addition, we find that respondents from healthcare companies show a significantly higher preference for all four queried disaster phases (*permanent*, *preparedness*, *immediate* and *recovery*), in particular for the *immediate crisis response* phase, than respondents from the food industry (t-test: $p = 0.000$). This indicates that the healthcare industry more strongly believes in a successful collaboration with public actors than the food industry. A reason for this could be the experiences of the healthcare sector with public actors during the COVID-19 pandemic. A statistically significant difference between logistics and healthcare companies can only be found for the *recovery* phase (t-test: $p = 0.012$), which might be due to less urgent logistical activities in the last phase.

From the answers of the companies (see Table B.4), we conclude that companies prefer to avoid intense, long-term involvement. Interestingly, the correlation analysis shows a strong and significant correlation between the firms' assessments concerning support in all four phases of a crisis (see Table B.5).

When do you think your company could best support public crisis management?	Permanent crisis preparedness	Preparedness during an emerging crisis	Immediate crisis response	Recovery from long-term consequences of a crisis
Permanent crisis preparedness	1			
Preparedness during an emerging crisis	0.721**	1		
Immediate crisis response	0.563**	0.564**	1	
Recovery from long-term consequences of a crisis	0.453**	0.474**	0.501**	1

$n = 398$, ** Indicates significance at $p < 0.05$

Table B.5: Correlation analyses of support in crisis phases (H4)

This indicates that some companies are willing to help at all stages, while others are generally less willing to help (regardless of stages). The more companies prefer to provide immediate support, the more they would also prefer to help in preparation and recovery. Hence, supportive companies tend to provide contributions and commitment throughout the disaster cycle.

B.5.3 Efficient Design

H5a: *Companies prefer the provision of resources to coordinating assistance.*

To answer H5a, we developed an index of *Resources* and an index of *Coordination*. For the exploratory factor analysis, see Table B.7) - the same variable composition per index was used for both H5a and H5b. *Mean* values and *SD* from the different types of assistance are provided in Table B.6.

Type	For each type of assistance mentioned, please indicate the conditions under which you would be willing to provide it.	Mean	SD
Resources	Providing goods	1.75	0.512
Resources	Providing transportation capacity	1.70	0.594
Resources	Providing storage	1.62	0.696
Coordination	Tactical planning	1.93	0.883
Coordination	Strategic planning	1.59	0.608

$n = 381$, 1 =*free of charge*, 2 =*against reimbursement*, 3 =*No willingness at all*

Table B.6: Contributions in a PPEC

Regarding the question whether companies would prefer provision of *Resources* to engaging in *Coordination*, the willingness to provide *Resources* is significantly higher than to partake in *Coordination* activities ($Mean = 1.69$, $SD = 0.43$, $n = 381$ compared to $Mean = 1.76$, $SD = 0.63$, $n = 381$; one-sided t-test with $p = 0.016$). Hence, we do not reject H5a.

Among the listed resources of table B.6, *Providing Storage* is underpinned with the highest willingness to contribute ($Mean = 1.62$, $SD = 0.696$). Looking into different industries, using an ANOVA Mean comparison, we find only slight differences, which are not significant ($\rho = 0.357$). Healthcare companies responded with a $Mean = 1.56$ and a $SD = 0.69$, Logistics companies with a $Mean = 1.59$ and a $SD = 0.66$, and Food companies with a $Mean = 1.68$ and a $SD = 0.71$. These results may be surprising as one could assume logistics companies have the largest storage capacities and thus should display a higher willingness to share them in a PPEC. One explanation for this observation might be that it is exactly because providing warehousing services is the core of their business model. A lower availability would seriously affect these firms if they had to provide these capacities without reimbursement. ANOVA Mean comparison again shows no significant differences between the three industries in consideration. Interestingly, *Strategic Planning* is the most preferred relief measure by respondents. This shows that companies' willingness to support *Coordination* assistance varies concerning the time horizon. While tactical planning is closely linked to the firms' operational processes, which they consider particularly important and untouchable, strategic planning can improve ex-ante coordination. With *tactical planning*, we refer to, for example, capacity planning for production and logistics in the next

weeks and months. *Strategic planning* comprises, for example, planning of emergency stockpiling of certain essential goods. Although we can confirm H5a, the extensive range between *Tactical Planning* and *Strategic Planning* indicates the need for evaluating carefully the way how companies should support in a PPEC. The relatively high SD for *Strategic Planning* also indicates a controversy among respondents.

Coordination also includes the exchange of information. To deal with this topic, which requires substantial discretion and trust on the part of the companies, we asked additional questions. It became apparent that *Information exchange with public actors* ($Mean = 1.27, SD = 0.55$) correlates significantly ($\rho < 0.01$) and on a high level of 0.64 with *Information exchange with companies from own SC* ($Mean = 1.28, SD = 0.54; n = 380$). Both answers are significantly ($p = 0.000$) different from the companies' willingness to do *Information exchange with competitors* (the willingness here is smaller with a $Mean = 1.62$ and a $SD = 0.79$). From these findings, we conclude that during a crisis, companies would share information with public actors with the same high willingness as with actors of their own SC and therefore trust public actors.

H5b: *Companies expect public actors to need resources from companies rather than coordinate assistance.*

In the same way, as analyzed in H5a, we shifted the perspective. Also, we asked the companies about their expectations, and whether public actors are more likely to need resources than coordinating support.

Exploratory factor analysis was conducted to examine whether the measurement items correlate with deriving a meaningful index for further analysis. As the analysis revealed, the Kaiser-Meyer-Olkin (KMO) criterium was 0.594, and Bartlett's test of sphericity was significant ($\chi^2(15) = 356.941, p = 0.000$) (Backhaus et al., 2016). According to the results of these indicators, the sample was considered adequate, and all five items suitable for conducting an exploratory factor analysis.

For the complete set of items, the calculation of factor analysis yielded two factors explaining a cumulative sum of 48.810% of variance. Factor 1, comprising the equally weighted items of '*production of goods*', '*transportation of goods*' and '*storage capacities*', explained 28.724% of the variance with factor loadings from 0.797 to 0.487 (the statistical results of the exploratory factor analysis using maximum likelihood and varimax rotation are presented in table B.7). This table also shows the mean values and standard deviations of the responses to the different items. Factor 2, which comprises the equally weighted items '*tactical planning*' and '*strategic planning*', explained 20.086% of the variance with factor loadings from 0.775 to 0.698.

For Factor 1, we obtain a Cronbach's α of 0.684 ($n = 398$) and for Factor B 0.702 ($n = 398$) respectively. Both values are acceptable according to (Grau, 2007). We conclude that both

Type	Where do public actors need support from private companies in crisis situations?	Mean	SD	Factor Loadings	
				Factor 1	Factor 2
Resources	Providing goods	0.69	0.465	0.487	
Resources	Providing transportation capacity	0.69	0.464	0.797	
Resources	Providing storage	0.54	0.499	0.675	
Coordinating	Tactical planning	0.40	0.490		0.775
Coordinating	Strategic planning	0.50	0.501		0.698

$n = 398$, 0 =*No support needed*, 1 =*support necessary*

Table B.7: Factor analysis for *Resources Index* and *Coordinating Assistance Index*

perspectives, what companies want to provide (H5a) and what they think that public actors need from them (H5b), go into the same direction and thus appears consistent. When asked about the needs of public actors, companies responded with a $Mean = 0.639$ and a $SD = 0.373$ ($n = 398$) in favor of the *Resources*, which is significantly higher (one-sided t-test with $p = 0.000$) than *Coordination* ($Mean = 0.451$, $SD = 0.436$; $n = 398$).

Again, no significant correlations are observable in SC stage, industries, or company revenue.

All in all, we do not reject H5b. To sum up the results from H5a and H5b in order to answer RQ3 (*Which are efficient contributions of companies in PPECs?*), public decision-makers need to consider the preferences of companies when it comes to the type of relief measure. We found in H5a that companies prefer to support with *Coordination* rather than with *Resources*. Given the fact that companies expect public actors to need support in *Resources* rather than in *Coordinating*, one can conclude that rather little compensatory regulation might be necessary for public actors. However, depending on the actual need of public actors, for individual support measures like e.g., *Providing Goods*, companies expect a relatively high need of public actors, but at the same time a relatively less willing to support in this area free of charge. This would mean a greater need for compensatory regulation in *Providing Goods*.

B.6 Discussion and Conclusion

The core of the PPECs concept, as introduced by Diehlmann et al. (2021) and shown in Section B.2, depends on vibrant and long-term collaboration between government and private actors in the essential goods sector, including coordinated communication, knowledge management, joint supply chain planning, and the coordinated deployment of resources.

In this study, we focused on an important prerequisite for a stable and functioning PPEC: the perception of the pros and cons as well as the incentives for private companies to participate in such a collaboration.

B.6.1 Theoretical Implications

Our sample of 398 surveyed companies showed a high willingness to contribute to crisis and humanitarian operations. However, the firms need clarification and commitments from public actors with respect to the concrete design and implementation of PPECs. Regarding the division of tasks (cf. indices of resources and coordination) and the type of contribution, we found differences in the willingness to engage in possible tasks as well as different ideas regarding the perceived "optimal" contribution. The results of this study complement the now very extensive literature on humanitarian logistics. The involvement of companies in this field is often limited to a few "big players", such as DHL, UPS or FedEx, which have specialized in global emergency operations with a logistical focus (Binder and Witte, 2007). In local crises, however, spontaneous assistance is also often provided by regionally based SMEs, which is rarely documented in the literature due to its case-by-case nature, and of which civil protection authorities and researchers just learn about by chance through their network (Hunt and Eburn, 2018). As our study showed, also among small and medium companies there is a clear and measurable willingness of companies to get involved in a PPEC. A large survey thus provides a more comprehensive picture of the pattern of this important motivation.

It is also evident that a number of requirements from collaboration between the humanitarian sector and the private sector are also highly relevant to public-private collaboration (Fontainha et al., 2016). This applies, for example, to the frequent problem of unspecified (or insufficiently specified) needs, as well as attention to the core competence of the companies with which they are involved in the collaboration. As our study showed, companies not only have a clear idea of what they can best deliver, but also of what is likely to be needed in an emergency. Tomasini and van Wassenhove (2009) propose a metrics system (similar to a scorecard) for this purpose, which can help to better match partners' fit in terms of motivation, needs and competencies. Although it is not possible to predict in advance the exact needs of the next crisis event, even rough categories are very helpful. The categories used for our survey can serve as an initial orientation and contribute to the basic concept of such a scorecard. Just as in NGOs' collaboration with private firms, public-private collaboration can benefit from close coordination, organizational learning and reputation capital (as part of an innovative CSR strategy) (Fontainha et al., 2016; Johnson et al., 2011). However, as most firms prefer one-off contributions to long-term contractual obligations, the potential to develop a mutual understanding, trust and joint learning seems to be rather limited, at least on aggregate. In general, companies have fewer reservations about entering into collaborations with humanitarian organizations compared to partnering with public authorities (Binder and Witte, 2007). The national context of our study is thus characterized by significantly higher barriers for companies, as collaboration with government authorities is initially associated with a high level of power asymmetry. This makes it all the more important to take into account the incentives and preferences of firms. At the same time, collaboration directed by public authorities offers the advantage that there is a partner "who sets the direction" (Kapucu et al., 2010). Common problems from the humanitarian sector, such as coordination failure, unwanted competition or incompatible

publicity do not occur here; instead targeted contributions can be guided under the leadership of the collaboration by the public actors. On this basis, the design power of public authorities and the opportunities for funding or compensation can facilitate crisis collaboration.

B.6.2 Managerial Implications

When asked for preconditions to engage in a PPEC, companies put the highest priority on the protection and stabilization of their business processes. In particular, the continuity of their processes and the protection of internal data towards competitors are most important to companies. Going beyond that, companies wish to be granted special rights in a PPEC.

This need for law adjustment and regulatory relief was highlighted particularly by logistics companies, which might indicate that they perceive their operations as especially regulated by governments. Relaxing these regulations thus offers public actors leverage for collaboration with logistics companies in times of crisis. Moreover, especially logistics companies do not want to endanger contractual business relationships in a crisis. Reasons for that might be the prevalence of performance-related payments in the logistics sector together with contract negotiations with customers and the competitive transportation market in Europe. This lack of flexibility can impede short-term collaboration with public actors. Therefore, the latter should either set up specific, flexible contractual agreements with logistics companies or find gentle ways of collaboration which do not endanger the logistics company's business relationships. A possible scenario would be for a public actor to provide a driver for a logistics company's truck that is not in use, as it was observed recently in the UK during the Brexit-induced shortage of fuel truck drivers where soldiers were used to drive trucks (Kennedy, 2021).

The same applies for large companies of any industry, which are more afraid to endanger existing business relations through a PPEC than small companies. Hence, if public actors aim to collaborate with large companies, they should focus on ways of collaboration that minimize the risk of undermining the partaking companies' other business relationships. This could be done by taking into consideration availability restrictions on the side of the companies. As an example, public authorities could jointly with a production company set up additional production capacities that do not endanger production orders of commercial customers. In comparison, although small companies are likely to possess less resources, their answers can be interpreted as a greater flexibility in their operations towards public actors.

These aspects underline the importance of business continuity in the eyes of the companies. It will certainly be easier for public actors to collaborate with companies with robust operations where the impact on operations is lower compared to less robust firms. Although it will be difficult to identify such companies, this aspect indicates that there are two reasons at the same time to favor companies with an already high competence in crisis management: First, these companies could most effectively contribute to a PPEC and second, these firms have comparatively low opportunity

cost for their engagement due to robust and agile operations. Due to more and more large-scale crises and a growing application of supply chain risk management, it is quite plausible to expect that more robust supply chains lead to greater acceptance of a PPEC being part of companies' operations.

Regarding potential contributions to a PPEC from the company's side, our results generally meet public and private characteristics described in Section B.2 and show that companies of all types would see themselves in a PPEC as a provider of storage and transportation resources and goods rather than coordinating assistance. However, we conclude from Table B.4 for companies in the food industry that more clarification from public actors might be necessary about potential fields of collaboration, what can be done by the companies, and how the companies may benefit from such collaboration.

For such support, companies demand monetary compensation. Especially for small companies, it is important that a PPEC is financially compensated. Hence, public actors should set up an environment in which this is possible and then, consequently, be willing to pay up - even for such things as provided data as part of a long-term collaboration.

However, we observed that the more benefits respondents see in a PPEC, the less monetary compensation they expect for their contribution to a PPEC. This suggests that public actors' communication of a PPEC's benefits towards public can lower companies' compensation claims. For the public sector, therefore, a dual strategy is recommended: on the one hand, it should try to first optimize the non-financial conditions for the most suitable companies and communicate their contribution extensively. On the other hand, it should be made possible by law to reimburse the particularly costly activities and contributions as quickly and with as little bureaucracy as possible.

Besides monetary compensation, companies also perceive an increase in reputation as an opportunity from a PPEC. Although this is of comparably low importance to companies, it provides a lever for public actors to approach certain company types and should certainly be considered by companies as part of a sustainable CSR strategy.

For healthcare companies, it is more important than for others to avoid a loss of reputation in crises. In line with that, a potential increase of reputation through a PPEC is a stronger incentive for them. Moreover, retail companies are more concerned about a reputation damage from a PPEC than production companies. When approaching healthcare and retail companies, public actors could therefore develop strategies for public communication with society to satisfy these demands by for example positively highlighting a company's involvement. Due to the great importance of a professional communication strategy in times of social media and the possible negative consequences of mistakes, the close collaboration with communication and media experts is recommended. Companies could take advantage of this consulting service free of charge if they participate in a PPEC.

One major insight of the study is that 91% of the respondents replied to the question, under which circumstances they would exchange information with public authorities in a crisis (H5a), with *free of charge* or *against reimbursement of costs* would also provide government agencies with company data in case of a crisis. Companies would be willing to share information with public actors to a larger extent than with competing companies (77%) and to the same extent with companies from their own supply chain (91%). This openness is high across industries, supply chain stages, and company sizes. However, according to public authorities, there is currently no such format in which companies could transfer their data. Consequently, public actors need to build upon this potential and show ways and initiatives for structured and safe data transfer. Since companies would like to avoid costly long-term involvement in crisis preparedness, data transfer should happen with a data structure and a technological solution that keep effort for companies at a minimum.

This touches on the general preference of companies to keep their effort in a PPEC low in non-crisis times and become active in immediate crisis response. The companies' profit orientation also reflects the great importance of the time dimension: Companies of all types consider long-term profit as more important than short-term profit in a crisis. Therefore, public actors can expect most company initiative if they set up a PPEC framework of low effort for companies in non-crisis times (e.g., establishing data transfer and developing communication networks but reducing or avoiding crisis exercises and extra resources), which becomes logistically active in crisis response. Since companies fear legal risks and unclear consequences of participating in a PPEC most, public actors should additionally be precise and transparent about the company's tasks and obligations.

On the business side, corporate managers can use the implications of the study as support for their own decision whether to collaborate with public actors, and interpret them as a benchmark attitude of companies. Experts from the research project have validated the findings from the study as reasonable. Insights from Table B.2 about general priorities in a crisis can be used by corporate managers to better coordinate a company's crisis management with its suppliers, customers, and logistics service providers. The high willingness to share data in a crisis across all companies (with companies from their own supply chain and public authorities) should encourage companies to intensify data exchange with other companies to increase resilience along their supply chains.

B.6.3 Limitations and Future Research

We faced a relatively low response rate of below 5%, leading to a possible self-selection bias and non-response bias. The non-response bias, meaning to have in a sample a relevant difference between respondents who answered and those who chose not to answer, could be investigated with bonferroni adjustments to test statistical power of data (Clottey and Grawe, 2014). Although response rates between 5%-10% are rather the rule than the exception for corporate surveys, we cannot rule out that mainly companies involved or at least interested in emergency collaborations have answered our survey. Hence, they would be exceptionally committed in this area in one way or another. However, this aspect is less of a problem for our study since our goal is precisely to

identify suitable company candidates for such a collaboration. Self-selection thus supports the identification task.

The responses were mostly homogeneous across company sizes, type of industry, and supply chain stage (see Section C.5). However, with regards to reputation aspects, especially the healthcare industry results have to be carefully evaluated, as this industry was and is in the focus of public attention during the COVID-19 pandemic. This might imply an increased importance of the topic for the healthcare industry.

We cannot exclude the issue of social desirability bias, especially when it comes to the aspects of humanitarian engagement, reputation, promotions, and other related fields, which we consider in our study. While we fully believe the answers of our participants to be honestly given, the mere conviction, opinion or attitude on a subject is ultimately only of limited reliability, since entrepreneurial decisions of this kind have to be made under strong restrictions (competition, cost pressure, etc.). In addition, we cannot rule out that some of the questions may be answered in a way making the company contributions or willingness to contribute look better (more intense) than it actually is. We have tried to minimize this problem, as the survey was conducted completely anonymously by a neutral third party (IfD Allensbach). In this way, we motivated participating companies to give honest answers without being afraid of receiving bad publicity.

To better quantify the actual willingness to help in PPECs, future research might look into specifically investigating the amount ("how much") of help, money or effort can be offered by both, the companies and public actors. Further details on this topic would be obtained from additional qualitative interviews with company representatives.

The scope of our study was on companies within Germany and the data on the employee size classes corresponded with the data of all German companies. For further studies, it could bring useful insights to conduct surveys in other countries to investigate companies' attitude towards collaboration with respective public authorities and governments. Furthermore, additional validations by other studies are necessary, as well as a complimentary survey to gather insights from public actors and analyze their corresponding perspective on PPECs.

B.6.4 Conclusion

Summing up our main results: First, we found out that most of the companies we asked have been active and are willing to engage in humanitarian actions. Second, companies prefer to help when a crisis has occurred and not in a preventing manner. Third, these companies were open to discussing and implementing PPECs to improve crisis management. Fourth, when it comes to concrete actions, companies prefer spending resources to coordinate tasks and are open to sharing data but do not do it currently. Public actors need to consider the financial hurdles and provide compensation for any resources and coordinating tasks that arise for the respective companies.

Thereby, our study is the first to provide an overview of the attitude of companies operating in the fields of logistics, food, and healthcare industries towards PPEC.

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(n.d.-a).

(n.d.-b).

(n.d.-c).

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C The Attitude of the Population towards Company Engagement in Public-Private Emergency Collaborations and its Risk Perception — A Survey

Abstract[1]

Governmental actors benefit from collaboration with companies in emergencies. Even though there are good reasons for companies to support state disaster response, research on so-called Public-Private Emergency Collaborations (PPEC) is still rare. In particular, companies are currently unable to assess to what extent the population values their involvement in such PPECs. We characterise corporate social responsibility (CSR) concepts, emergency cooperation and risk perception from a structured literature research. A survey of 402 participants examines the perception of consumers to link CSR and the associated involvement in emergency cooperation with the economic success of the company. We find that companies' involvement in PPECs is in general highly valued. Nevertheless, the quality and quantity of corporate communication as well as the communication channel used and the communication strategy strongly affect the population's perception. In addition, we uncover a highly significant correlation between risk perception and approval of engagement in PPECs. We are contributing to the underexplored field of research by evaluating the involvement of companies in PPECs from the perspective of the population, to take account of the decision-makers in companies as to whether an involvement can be advantageous for them in the long term.

C.1 Introduction

Climate change and the accompanying increase in frequency and intensity of extreme events are leading to devastating effects in today's societies (Kovats et al., 2014). Even in countries like Germany that have, compared to other countries such as the United States, been rarely affected by large-scale natural disasters in the past, the intensity of disasters increases (für politische Bildung, 2021). Events like heavy rainfalls in July 2021 which led to severe flooding with more than 180 deaths and economic damage of around 5 billion € are becoming a cause of concern for governments, companies, and the society at large (Kreienkamp et al., 2021). The COVID-19 pandemic led to worldwide impacts on individuals, society, and the economy, highlighting the vulnerability of systems and structures (World Bank Group, 2020).

These crises can lead to a shortage of supplies for the population due to the destruction of infrastructures (Goodman and Chokshi, 2021). We consider governmental actors and private companies as possible actors when solving this problem. Managing urgent threats to fundamental societal values and protecting the safety of citizens and property during emergencies, disasters, and extreme events are primarily the responsibility of a country's government (Boin, 2005; Quarantelli, 1988). In Germany, governmental authorities play an essential role in supplying the population in a crisis, especially in the event of a foreseeable shortage of supplies (BBK, 2020). Private companies are mainly driven by profit-oriented motives and fulfilling the interests of their stakeholders (Qiao et al., 2010). However, the COVID-19 pandemic illustrates the ability of the private sector to provide solutions in times of crisis by developing new products or through the strategic use of existing resources that contribute to disaster preparedness and crisis development (Dreier and Nelson, 2020; Bernardo et al., 2021).

Crisis management systems vary greatly, depending on the country's development level and historic exposure to disasters. In Germany, governmental actors are obliged by law to help the suffering population, and companies are not required to do so (BMI, 2015). However, there are several reasons for companies to provide support in crises. The available resources and know-how to manage threats as short-term supply and demand fluctuations, as well as disruptions in the supply chains (e.g., in the area of food production, transport, or the sale of products), are considered critical resources of the private sector at times of crisis (Wiens et al., 2018). As Izumi and Shaw (2015) have already stated, besides possible altruistic reasons, companies are interested in protecting their value chain and those involved in it, as well as improving their reputation or the perception of stakeholders through good social engagement. A higher reputation may lead to higher sales in the long-run. These motivations have been conceptualized by Wiens et al. (2018) in the form of a Public-Private Emergency Collaboration (see Section C.2.1). This concept builds on the well-known public-private partnership model and applies the collaborative work of public and private actors to emergency management.

The expectation of improving their reputation, or stakeholder perception, through good corporate citizenship (Izumi and Shaw, 2015) is a critical factor for companies to get involved in crisis

management. Similarly, Hamann and Strittmatter (2014) and Swanson and Smith (2013) argued that the private sector engages in the social sector (meaning areas such as education, care for the elderly or to fight poverty) to increase positive perception and, thereby, gain a long-term economic success. However, little is known so far about how the public perceives the emerging forms of public-private partnerships in emergency management (Boyer, 2019; Boyer et al., 2015).

Our approach is inspired by the work of Madsen and Rodgers (2015), who used the concept of stakeholder theory and Maignan (2001) who examined consumers' perceptions. Thereby, she managed to link Corporate Social Responsibility (CSR), the impact on consumers, if and how they react to it, and the related economic success on the company (see also Young and Makhija (2014). We build upon these relationships within our survey. We argue that the possible crisis management relief of companies we are investigating is closely related to the concept of CSR, which is a better known concept and therefore offers possibilities for transferability. Therefore, we analyzed CSR and the population's perspective on CSR activities in Section C.5. In addition, an adapted concept of risk perception from Slovic (1987) was added to account for the specifics of a crisis like the COVID-19 pandemic for the consumers.

To shed light on this underestimated topic, we first analyzed the concepts of CSR with regard to the population's perception towards company engagement, i.e. their positive attitude, and the population's risk perception by a structured literature review. In addition, we designed an empirical study to derive whether companies' involvement in crisis management with government authorities (thus engagement in a PPEC) received the respondents' positive attitude and to explore the extent to which the persons' characteristics, in particular risk perception, affects their positive attitude. The data covers 402 respondents in Germany surveyed by an online questionnaire between November 2020 and January 2021.

The main contribution of this paper can be summarized as follows. We empirically investigate how the population perceives company engagement in a partnership between public and private actors in a crisis context. We figured out that the population positively evaluates this kind of engagement and increases purchase intention. The information gained from the empirical survey helps to show reasons and recommendations for companies to engage in emergency collaborations with governmental actors and how the population should be informed about this engagement to consider it as trustworthy information.

The remainder of this paper is organized as follows. Section C.2 provides an overview of the underlying concepts of the topics under investigation in our study. We then define our research question and derive the hypotheses from being tested in Section C.3. In Section D.3.3, we report our study design. In Section C.5, we present the results of our study and evaluate the hypotheses. Discussion of the results and recommended actions for companies resulting from the study follow in Section D.5.1. Section 7 first discusses the limitations of this work and possible future directions for research and concludes our findings.

C.2 Theoretical Background

C.2.1 Concept of Public-Private Emergency Collaborations

As shown in Figure C.1, the process of disaster management characteristically involves four phases: Mitigation, Preparedness, Response, and Recovery (Coppola, 2011). Mitigation and preparedness phases include measures taken prior to a disaster to prevent, prepare, and detect future emergencies. A disaster requires specific predefined actions, including immediate communication and coordination of all involved. The recovery phase finally includes all efforts of reconstruction to ensure the return to normal conditions.

Figure C.1: Disaster management cycle

The German Federal Office of Civil Protection and Disaster Assistance (BBK) argues that one key focus should be placed on personal emergency preparedness and the self-sufficiency of the population (Elkady et al., 2022). This involves adequate stockpiling of water, food, and hygiene products in case of emergency (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2021). Wiens et al. (2018) describe one possible role of companies as part of crisis management within the concept of a PPEC. Companies are assigned a far more substantial role in the disaster management cycle compared to the current situation where companies are at best occasionally involved in relief operations. A PPEC essentially starts in the preparedness phase concerning the disaster management cycle. An attempt is made to create a long-term level of coordination between the authorities and the companies and, therefore, to react better in the response and recovery phase in an emergency. Possible collaboration between governmental actors and companies is particularly relevant with companies specializing in supplying essential goods and services such as water, food, and medicines (Fang and Norman, 2014; Shokr et al., 2021). Other possible areas of collaboration

also extend to the supply of hygiene-, communication-, and security-related goods, as these goods are also essential during an emergency. PPECs can be integral in limiting epidemics, lootings, and emotional suffering (Mithani, 2017) and can be seen as a specific form of CSR. The financial and reputational benefits for companies from CSR will be discussed in the next Section C.2.2.

C.2.2 Positive Attitude towards Company Engagement in Crisis Management

As we want to explore the population's attitude towards company engagement in crisis management, the already mentioned and closely linked concept of CSR will be introduced first.

Although research has been conducted over several years, there is, according to McWilliams et al. (2006) and Dahlsrud (2008) still no consensus on a universally adopted definition of CSR. Commonly, the term CSR encompasses corporate actions which appear to serve some societal good and go beyond the interest of a company and legal requirements (McWilliams and Siegel, 2001; McWilliams et al., 2006). However, the most frequently applied and most comprising CSR definition goes back to Carroll's ((1979)) conceptualization of CSR (Dahlsrud, 2008). Following Carroll (1979), organizations have to meet four dimensions of responsibilities: economic, legal, ethical, and philanthropic. Whereas the economic dimension determines the responsibility for businesses to be profitable, the legal obligation refers to doing economic businesses within legal requirements. Ethical responsibility requires adherence to established ethical norms and principles. Philanthropic responsibilities, in turn, correspond to the overall assumptions of society concerning a decent citizenship role for organizations (Carroll, 1979). Proactivity can also be seen as an important factor (Mojtahedi and Oo, 2017). Furthermore, according to Dahlsrud (2008) any discussion of CSR should necessarily include an environmental dimension. That is why he proposes the conceptualization of the CSR concept into the dimensions of environmental, social, economic, stakeholder and voluntariness.

In the next step, to obtain an overview of the empirical research on corporate social responsibility with a specific focus on the population's attitude towards this engagement to date, we systematically reviewed the databases Web of Science and Scopus for suitable studies within this field. Since we were primarily interested in survey studies dealing with consumer's perception and attitudes towards socially engaged companies, the search string we employed was: *(("corporate social responsibility" OR "CSR" OR "engagement") AND ("consumer awareness" OR "consumer attitude" OR "consumer perception" OR "consumer behavioral intentions" OR "purchasing criteria") AND "survey").*

Our initial search resulted in 261 unique publications since 2000, which we further analyzed and refined based on their title and abstract. We excluded studies that were either not identified as research articles, not written in English, or did not turn out as empirically conducted survey studies. This resulted in a remaining set of 18 articles (Supplementary Material C.8.2) that we used for further analysis.

Several of these studies have been carried out to investigate the general level of awareness towards socially responsible companies (K.-H. Lee and Shin, 2010; Maignan, 2001; Van et al., 2020). Mainly, these studies report a generally low level of awareness towards companies' engagement practices due to a lack of understanding and obtaining information on CSR initiatives of organizations (Kolkailah et al., 2012; K.-H. Lee and Shin, 2010; Lee et al., 2019; Van et al., 2020). As it has been shown that the awareness could be positively linked to supporting a company's CSR initiatives, a growing number of publications highlights the need for comprehensive communication programs, including tactics, strategies, or channels to raise the level of awareness (Becker-Olsen et al., 2011).

Taking a closer look at consumers' support of socially responsible companies, both favorable and critical attitudes can be discerned. In this regard, it is frequently considered how consumers evaluate a company's ability to meet its stakeholders' expectations about corporate practices (Lichtenstein et al., 2004; Maignan, 2001). Consumers expect companies to fulfill different kinds of societal obligations, such as environmental protection (Grimmer and Bingham, 2013), (local) community involvement (K.-H. Lee and Shin, 2010) or disaster relief support (Guzmán and Davis, 2017). However, most of the reviewed studies do not focus on the perception of a particular CSR activity. Instead, they apply the idea of Carroll (1979) that companies must meet four dimensions of obligations: economic, legal, ethical, and philanthropic. To examine consumers' evaluations of these responsibilities, Maignan (2001) developed a detailed measurement concept that has been further used in numerous other empirical studies (Arli and Tjiptono, 2014; Kolkailah et al., 2012; Lichtenstein et al., 2004; Ramasamy and Yeung, 2009; Shukla et al., 2019). In particular, these studies highlight that the fulfillment of consumer expectations may result in positive attitudes. In contrast, consumers may evaluate a company's initiatives as unfavorable if its behavior violates social norms and individual economic or ethical expectations (Kim et al., 2019). Additionally to expectations, the perception of corporate motives for engaging in CSR activities may influence the respondents' evaluation (Kolkailah et al., 2012). Whereas perceived value-driven motives are reported to induce positive attitudes among consumers, motives associated egoistic-driven and profit-generating may diminish these positive attitudes (Kolkailah et al., 2012).

Overall, it was revealed that the adoption of CSR initiatives has a significant effect on consumer behavior. First, evidence has been found that CSR can enhance consumers' satisfaction and loyalty with companies and their brands through the consumers' perceived value of CSR (Rivera et al., 2019; Schramm-Klein et al., 2016; Servera-Francés and Fuentes-Blasco, 2016). Second, an even larger number of studies has revealed a positive relation between CSR and consumer's purchasing behavior (Hsieh, 2014; K.-H. Lee and Shin, 2010; Lichtenstein et al., 2004; Maignan, 2001; Schramm-Klein et al., 2016; Van et al., 2020). If consumers feel good about an organization, they will be more inclined to buy and even willing to pay more for products or services of a socially or environmentally responsible company, which will, in turn, affect a company's revenue and financial performance (Grimmer and Bingham, 2013; Ramasamy and Yeung, 2009; Shukla et al., 2019; Van et al., 2020). All the literature above gives valuable input to the field of CSR and how it interacts

with consumers. However, to the best of our knowledge, and despite our systematic literature search, there is currently no research about CSR in connection with emergency collaborations, which is the focus of this study.

C.2.3 Risk Perception

In this Section, we present the concept of risk perception as this is expected to have driving influence on perceived attitude of collaboration for disaster response. In general, it refers to people's views, judgment, and evaluations associated with a particular hazard to which they are or may be exposed (Rohrmann and Renn, 2000). Considering the emergence of risk perception, two approaches have been commonly applied: a socio-cultural and psychometric approach (Slovic, 1987). According to cultural theory, social structure embeds individuals, thus shaping individual risk perceptions by beliefs and values of their social context (Douglas and Wildavsky, 2010). In contrast, the psychometric approach understands the perception of risk as a multidimensional construct, based on the combination of several subjective, qualitative perceived characteristics of a hazard (Slovic, 1987). Fischhoff et al. (1978) first introduced an approach to systematically examine and differentiate between these various perceived risk characteristics, called *psychometric paradigm*. In line with the paradigm, non-experts individually judge the riskiness of a threat on various assorted perceived risk attributes such as controllability, severity, personal impact, or dread of a risk (Slovic, 1987). Using statistical analysis and scaling techniques, quantitative representations or cognitive maps of risk attitudes and perceptions can be created to classify and understand the individual risk perceptions of various hazards (Slovic, 1987).

Next, we employed a systematic literature approach to understand the current state of previous research on population's risk perception. Accordingly, we again searched the Scopus and Web of Science databases for relevant empirical studies using the search term *("risk perception" AND "population survey" AND ("emergency" OR "crisis" OR "disaster" OR "natural disaster" OR "flood" OR "wildfire" OR "pandemic" OR "nuclear energy" OR "climate change")*. To confine the results, we only focused on the research field *Business Economics*. The initial search resulted in 35 publications since 2000, which were further limited based on their title, abstract and full-text. We again prioritized empirical English-language publications, resulting in a remaining set of 11 relevant articles (Supplementary Material C.8.3).

Within the reviewed risk perception literature, studies have surveyed a broad set of hazardous occurrences, including technological hazards such as nuclear power plants and nuclear energy (Yeo et al., 2014), environmental threats related to climate change, and global warming (Akerlof et al., 2013; Sullivan-Wiley and Short Gianotti, 2017; van Loenhout et al., 2021) as well as natural hazards like floods (Doocy et al., 2013), wildfire risks (Champ et al., 2011), epidemics and pandemics (Tooher et al., 2013). Overall, these studies are primarily concerned with investigating factors influencing the adoption of precautionary measures to prepare for disasters. Besides sociodemographic characteristics, risk perception is thereby found to be an important determinant of adjustment and disaster

mitigation behavior (DeYoung et al., 2020; Doocy et al., 2013; Hoffmann and Muttarak, 2017; Sullivan-Wiley and Short Gianotti, 2017; Tooher et al., 2013). According to the psychometric approach, most of these research studies demonstrate that the perception of risks varies regarding sociodemographic, psychological, and cognitive factors of the perceiver of a certain risk. Regarding cognition, for example, personal experience is a significant predictor of risk perception. Akerlof et al. (2013) and Champ et al. (2011) provide empirical evidence that having both personally experienced global warming (Akerlof et al., 2013) and having previously experienced wildfires (Champ et al., 2011) result in higher risk perceptions, which in turn led to taking more action to reduce risk. In addition, Becker (2011) seeks to find if gendered differences in risk perception automatically lead to differences in women and men ranking hazards of their community and finds no significant differences in terms of gender. However, several other, particularly sociodemographic parameters (e.g., level of education, livelihoods), were found to relate to the ranking of hazards. As a result, targeted communication with as many people as possible in the risk reduction process is crucial (Becker, 2011). Gerhold et al. (2019) who find that within Germany, the risk perception of a supply shortage is not macrosocial, but differs on individual perceptions, reach a similar conclusion. To assess the individual levels of risk perception, the authors apply the psychometric paradigm of Slovic (1987). To the best of our knowledge, there is currently no risk perception research output in the context of PPECs.

C.3 Research Questions and Hypotheses

C.3.1 Research Questions

PPECs are an innovative approach to deal with emergencies. So far, PPECs have not been studied along the lines of attitude and risk perception of the population. Educating companies particularly about this issue represents a significant contribution to promoting PPECs. Since, from the point of view of the companies, the population represents the potential buyer group for their products, the perception of this engagement on the part of the population is of essential importance for the companies. To this end, we analyzed the following research questions (RQ):

- **RQ1**: With which attitude does the population perceive company activities in the context of PPECs?

- **RQ2**: What is the influence of people's characteristics, in particular risk perception of the population and how does it relate to their attitude in the context of the COVID-19 pandemic?

C.3.2 Hypotheses

Our approach is inspired by the work of Maignan (2001). As already indicated in Section C.2.2, she analyzed how consumers perceive CSR activities and revealed that there are economic, legal,

ethical, and philanthropic responsibilities a company needs to fulfill. Guzmán and Davis (2017) built on this approach by examining the extent to which consumers respond to companies' CSR activities and how they affect brand equity. Thereupon, we extended and applied this approach by implicitly integrating disaster relief into the research design as a social cause. We asked our participants about the perception, interest, meaningfulness, and effectiveness of PPECs based on these findings. To answer RQ1, we formulate our first hypothesis:

- **H1**: The engagement of a company in a crisis management collaboration with governmental actors (PPEC) is rated with a **positive attitude**.

We further developed Slovic's ((1987)) concept of the individual's risk perception (see Section C.2.3). We applied it to the area of crisis management within the COVID-19 pandemic, which was ongoing at that time. Therefore, we asked participants about their fear of the pandemic, the severity of the consequences of infection, and the general uncertainty caused by the pandemic. We used the answers to these questions to explore and form a COVID-19 related *risk perception index*. Gerhold (2020) argues that there are two ways for individuals to cope with risk, a problem-focused approach that involves objectively dissecting the risk factors and an emotion-focused approach that seeks to mitigate the risk based on one's feelings. Our questions concerning risk perception include both approaches. To answer RQ2, we propose 2 hypotheses, H2 and H3. Based on the former mentioned *positive attitude index*, the *risk perception index* as well as demographic characteristics (age, gender), we formed our second hypothesis:

- **H2**: The respondent's positive attitude towards the engagement of a company in a PPEC **significantly** correlates with the perceived risk, age and gender.

Madsen and Rodgers (2015) argued that according to stakeholder theory there should be a relationship between CSR and corporate financial performance (CFP) which the authors elaborated on through a mediation variable Stakeholder Attention that was measured through newspaper mentions and applied the whole model to the corporate disaster relief CSR context. Cho et al. (2019) studied 191 sample firms listed on the Korea Exchange and found a positive correlation between CSR engagement and CFP of these firms. Therefore, we propose our third hypothesis:

- **H3**: The respondents' positive attitude towards the engagement of a company in a PPEC with governmental actors has a **significant** correlation on their purchase intention towards products of a company engaged in a PPEC.

C.4 Study Design

We conducted an online survey with two primary foci to attain our research objective. One focus is on people's attitudes towards company engagement in crisis management, and the other is on the implications of an individual's risk perception. Since to the best of our knowledge our study is the

first which systematically explores these issues, we designed a questionnaire applying and adapting already existing concepts and measurement scales. The questionnaire consisted of 22 questions (including demographic characteristics) divided into three parts. Mainly, we used closed questions with a predefined number of answer options. In three cases, the participants were allowed to provide additional comments. Most of the questions were asked on a 5-point Likert scale format (dependent on the type of question, we asked for probabilities or agreement). The complete questionnaire was subsequently implemented and published using the online application *LimeSurvey*. The study population is aimed to be a representative sample of the overall population of Germany. Therefore, individuals aged 16 or older with web-access were recruited as sample using active and passive techniques. In combination with a cover letter containing an introduction and information on the purpose, duration, and anonymity of the survey data collection, the link to the questionnaire was actively distributed via the authors' private network, as well as disseminated on social networks to solicit widespread online responses. No (financial) incentives were given for participation in this questionnaire.

In the introduction of the questionnaire, individuals were presented with a hypothetically constructed scenario, which we described as:

Natural disasters, financial crashes or fuel shortages - any of these scenarios could lead to a shortage of essential goods such as drinking water or food. To cope with such crises, it is conceivable that private-sector, such as retailers, freight forwarders, or manufacturers, become active and support. [...] contributions can be spontaneous or planned; they can be initiated by the company itself or in close coordination and collaboration with the state civil defense authorities. We would now like to know your opinion on the deployment of private-sector companies in crises. We are particularly interested in whether and under what conditions you view them positively or rather critically.

Based on this hypothetical scenario, we asked the subjects attitudinal questions to determine whether they regard these company engagements as positive. First, we asked for the general perceived likelihood of such a crisis and the respondents' awareness and personal experience with socially committed companies during crises. Furthermore, the degree of agreement to various statements regarding the interest, perception, expectations, meaningfulness, and effectiveness of PPECs have been set up inspired by previous work of Arli and Tjiptono (2014); Guzmán and Davis (2017); Hsieh (2014); Kolkailah et al. (2012); K.-H. Lee and Shin (2010); Maignan (2001); Ramasamy and Yeung (2009); Shukla et al. (2019). These items were all measured using Likert-scaled questions ranging from 1 ("strongly disagree") to 5 ("strongly agree").

In addition to the scenario-specific components, the second part of the survey investigated participants' risk perception. Following the psychometric approach of Slovic (1987), we have adopted the psychometric paradigm as the measurement concept for this purpose. To consider the specifics of a crisis for the participants, we applied selected risk characteristics of the concept to the COVID-19 pandemic. Respondents were again asked to indicate their agreement on a 5-point Likert scale

with a series of statements regarding their perceived risk. In this Section, we also asked about their knowledge of an own COVID-19 infection, as well as whether anyone in their social network had been infected with COVID-19. Moreover, we assessed the respondents' purchase intention towards goods from a company engaged in a PPEC by asking whether they were more likely to purchase from an engaged company. In addition, we asked the participants whether they were also willing to take a detour to purchase from the dynamic company.

The last part of the questionnaire asked for the respondents' demographic characteristics, including gender, age, educational level, household characteristics, occupation, and residential area.

C.5 Results

We carried out the online survey between November 29, 2020, and January 09, 2021. In total, 877 respondents started the survey. We excluded 475 missing data questionnaires from further analysis of these submitted responses. Thus, our final data sample consisted of a total number of 402 valid responses. The average time required to complete the questionnaire was 16.46 minutes. To test the research hypotheses, descriptive analysis procedures and correlation and regression analyses have been employed. The survey results were analyzed using IBM SPSS 25 statistical software and are presented below.

C.5.1 Demographic Characteristics of the Respondents

The demographics of the sampled respondents are shown in Table C.1. In terms of gender, slightly more females (53.73%) participated in the survey than males (44.28%). Age-wise, it can be observed that the sample comprises most participants in the age group of $16 - 25$. However, the age groups between 26 and 65 contain almost the same number of participants. Regarding the level of education, the majority of the respondents have either graduated from high school (22.64%) or received a master's degree or similar (22.89%). Postgraduate degree holders accounted for 2.24% of the total sample. In addition, we asked respondents about their residential area. The share of participants from rural areas (population $\leq 10,000$) was slightly above the proportion of those who lived in urban areas (population $> 10,000$).

Variable	Sample population[1]	
	Number	Percentage (%)
Gender		
Female	216	53.73
Male	178	44.28
Diverse	3	0.75
No answer	5	1.24
Age		
< 16	–	–
$16 - 25$	101	25.12
$26 - 35$	75	18.66
$36 - 45$	66	16.42
$46 - 55$	78	19.40
$56 - 65$	68	16.92
> 65	14	3.48
No answer	–	–
Education		
Secondary General School	2	0.50
Secondary School	39	9.70
High School Diploma	91	22.64
Apprenticeship	78	19.40
Bachelor's degree	86	21.39
Master's degree	92	22.89
Doctorate Degree	9	2.24
No answer / No degree	5	1.24
Residential Area		
Rural Area (Population $\leq 10,000$)	217	53.98
Urban Area (Population $> 10,000$)	185	46.02
No answer	–	–

[1] Total sample size $n = 402$

Table C.1: Demographic characteristics of the respondents

C.5.2 Testing of Hypotheses

In order to test **H1**, we started by deriving the positive attitude index. To measure the attitude, we asked respondents to indicate their agreement with 10 statements on a 5-point Likert scale (Table C.2).

Of the 349 respondents who have responded to all 10 items regarding the attitude towards company engagement in crises, a general interest in whether companies are involved in such collaborations with state authorities was indicated by 231 respondents (66.19%). In the case of collaboration, 76.79% of respondents reported they would consider a company's activities as a demonstration of social responsibility concerning the perception of the engagement. 278 people (79.66%) agreed that their company's perception would improve. Nevertheless, some respondents also showed concerns, with 50 individuals (14.33%) being apprehensive that the company merely wants to enrich at the expense of the suffering population. Even more respondents (34.96%) agreed to perceive the engagement as tactical calculus to enhance the company's image. Regarding the meaningfulness of the engagement, the majority of the respondents (86.53%) agreed that companies would provide useful support to government crisis management. Additionally, according to 266 people (76.22%), government crisis management could better accomplish its tasks through the supportive involvement of private companies. Most respondents (85.96%) believe that crisis management could succeed more efficiently through private companies' involvement.

Next, exploratory factor analysis was conducted to explore a sound index to examine whether the measurement items correlate. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.810, thus above the recommended value of 0.6, and Bartlett's test of sphericity was significant ($\chi^2(45) = 795.833, p = 0.000$) (Backhaus et al., 2021). Given the results of these indicators, the sample was considered adequate, and all 10 items suitable for factor analysis. Thus, all 10 items relating to the attitude towards company engagement in a PPEC were analyzed through exploratory factor analysis using principal axis factoring and varimax rotation in order to estimate new commonalities that replace the old commonality estimates to the moment the convergence criterion for extraction is satisfied (Backhaus et al., 2021). According to the statistical results of factor analysis presented in table C.2, the analysis yielded two factors explaining a cumulative sum of 37.861% of variance for the complete set of variables. Factor 1, explaining 28.149% of the variance, included seven items with factor loadings from 0.476 to 0.698.

To test the reliability of the composite items, Cronbach's α was computed. A resulting value of 0.778 for all seven items ($n = 349$) demonstrates that the measurement scale meets a satisfactory level of composite reliability (Cortina, 1993). Exclusion of one of the items leads to a reduction of Cronbach's α, so we keep all seven items in the index (see table C.6 in the Supplementary Material Section for a detailed overview). These seven items were used for an index formation which we called *positive attitude index*. Using these seven items is consistent as they cover the categories of interest, perception, meaningfulness, and effectiveness. These are the various necessary areas that require serious support of this topic.

Item	Agreement Rate[1] (%)	Mean	SD	Factor Loadings Factor 1	Factor Loadings Factor 2
The state crisis management can better fulfill its tasks through the supportive participation of private companies.	76.22	4.03	0.901	0.698	0.193
Then crisis management can succeed more efficiently.	85.96	4.26	0.771	0.644	0.087
I see such actions as a sign of social responsibility on the part of this company.	76.79	4.07	0.976	0.607	−0.001
Companies can provide useful support for state crisis management.	86.53	4.26	0.837	0.540	0.144
Is this an opportunity for the company to take social responsibility.	85.67	4.26	0.819	0.517	0.088
My perception of this company is improving.	79.66	4.06	0.911	0.508	0.182
I am interested in whether companies engage in collaboration with state authorities.	66.19	3.81	1.000	0.476	0.133
I fear that this company only wants to enrich itself at the expense of the suffering population.	34.96[2]	3.70[3]	1.149	0.178	0.786
I see it as a tactical calculation to strengthen the image.	14.33[2]	2.97[3]	1.190	0.000	0.642
For me, this is a form of "privatisation" of emergency care, which I fundamentally reject.	10.89[2]	3.90[3]	1.091	0.305	0.439

[1] The values 4 and 5 on the 5-point Likert scale count as 'Agreement'

[2] The values 1 and 2 on the 5-point Likert scale count as 'Agreement'

[3] Item values recoded for factor analysis

$n = 349$

Table C.2: Results of factor analysis for *positive attitude index*

The remaining set of three items assigned to the second factor, given by the explorative factor analysis, is not investigated anymore as a meaningful factor after further evaluation with Cronbach's α leads to a value of 0.663.

Overall, the Agreement Rate of the *positive attitude index* was 79.57% and the mean level was 4.1064 ($n = 349$, $SD = 0.58353$). Based on these findings, the hypothesis that the engagement of a company in a crisis management collaboration with governmental actors (PPEC) is rated with a **positive attitude** can not be rejected.

With regard to **H2** we analyzed how the individual's risk perception correlates with the previously considered attitude. As mentioned, we were inspired by the work of Slovic (1987) as well as Gerhold et al. (2019); Gerhold (2020) to assess respondents' risk perceptions. Considering the then ongoing COVID-19 pandemic, we asked respondents to indicate their level of agreement on a 5-point Likert scale to six items shown in table C.3. Again, we assumed that a response of values 4 and 5 counts as agreement on an item.

Among the items set up to measure risk perception, we first asked respondents about their fear and uncertainty towards the COVID-19 pandemic. Of the 373 individuals who have responded to the entire six items, 142 (38.07%) stated they were afraid of the pandemic and possible virus infection. Additionally, 147 respondents (39.41%) felt unsettled by the pandemic. Considerably more people (242; 64.88%) regarded the consequences of possible virus infection as severe. In terms of geographical distribution, more than half of the respondents (60.59%) agreed that the COVID-19 pandemic would affect the urban population worse than the rural population.

Concerning the distribution between different labor sectors, 90.08%, thus the majority believes that employees in the low-wage sector (e.g., in the hotel industry gastronomy) are particularly affected by the COVID-19 pandemic economic losses. Moreover, 286 people (76.68%) believed that the consequences of government policies (e.g., contraction of dept, lock-down) would weigh heavily on future generations.

Once again, to examine whether the measurement items correlate, exploratory factor analysis was conducted to explore a sound index. To confirm the application, the Kaiser-Meyer-Olkin (KMO) criteria was 0.614, and Bartlett's test of sphericity was significant ($\chi^2(15) = 356.865, p = 0.001$) (Backhaus et al., 2021). According to the results of these indicators, the sample was considered adequate, and all six items suitable for conducting an exploratory factor analysis.

The statistical results of the exploratory factor analysis using principal axis factoring and varimax rotation are presented in table C.3. For the complete set of items, the calculation of factor analysis yielded two factors explaining a cumulative sum of 40.327% of variance. Factor 1, comprising the items of 'Fear of the pandemic and virus infection', 'Uncertainty due to the pandemic' and 'Perceived severe consequences of a possible infection', explained 27.646% of the variance with factor loadings from 0.937 to 0.600. For all three items, Cronbach's α value of 0.756 ($n = 373$) was obtained and is demonstrating that the measurement scale is reliable overall (Cortina, 1993).

Using these three items, which cover the categories of fear, uncertainty, and consequences, and thus the various necessary areas required to illustrate the characteristics of risk perception is meaningful related to the content validity of the index.

The remaining set of three items assigned to the second factor, given by the explorative factor analysis, is not investigated anymore as a meaningful factor after further evaluation with Cronbach's α leads to a value of 0.322 ($n = 373$). Even if the item with the lowest loading (related to the urban population) is excluded, the other two items still lead to an unsatisfactory reliability level (Spearman-Brown Coefficient $\rho = 0.477$, $n = 373$)

Item	Agreement Rate[1]	Mean	SD	Factor Loadings	
	(%)			Factor 1	Factor 2
I am afraid of the pandemic and a possible infection with the virus.	38.07	2.99	1.259	0.937	0.021
I feel unsettled by the COVID-19 pandemic.	39.41	3.08	1.226	0.623	0.044
I consider the consequences of a possible infection to be serious/severe.	64.88	3.84	1.096	0.600	0.003
I believe that workers in the low-wage sector are particularly affected by the COVID-19 pandemic due to economic losses.	90.08	4.57	0.765	0.117	0.762
I believe that the consequences of the government's COVID-19 measures will weigh heavily on future generations.	76.68	4.18	1.008	-0.019	0.405
I believe that the COVID-19 pandemic will hit the urban population harder than the rural population.	60.59	3.56	1.268	0.000	0.181

[1] The values 4 and 5 on the 5-point Likert scale count as 'Agreement'

$n = 373$

Table C.3: Results of factor analysis for *risk perception index*

Overall, the Agreement Rate of the *risk perception index* was 47.45% and the mean level was 3.3029 ($n = 373$, $SD = 0.98023$).

After exploring the *risk perception index*, we examined whether there is a correlation between the *risk perception index* and the *positive attitude index*. The intention is to examine the coping strategy of the respondents, following the work of Gerhold (2020). We aimed to determine a relationship between heightened risk perceptions and agreement for company engagement in PPECs. We summarized the results in table C.4. It can be seen that there is a significant correlation ($p = 0.000$) between the *risk perception index* and the *positive attitude index*.

To analyze correlations between the *positive attitude index* and respondents' age or gender, we computed up the Eta coefficients. These were for the age $Eta = 0.149$ ($n = 366$) with an Eta^2 of 0.022 and for the gender $Eta = 0.041$ ($n = 364$) with an Eta^2 of 0.002.

Thus, we can only partially not reject hypothesis 2.

Measure	Mean	SD		Correlations		
				1.	2.	3.
1. *Positive Attitude*	4.0982	0.03144	Pearson's r	1	0.160	0.315
			p-value		0.002	0.000
			N	366	363	355
2. *Risk Perception*	3.3049	0.05232	Pearson's r	0.160	1	0.068
			p-value	0.002		0.186
			N	363	397	382
3. *Purchase Intention*	3.2472	0.06008	Pearson's r	0.315	0.068	1
			p-value	0.000	0.186	
			N	355	382	387

Table C.4: Mean, standard deviation and correlation of our indices and the purchase intention

An interesting side note: For the *risk perception index*, there is a difference in the average mean values for respondents who know someone in their social network who had a COVID-19 disease ($Mean = 3.3457$, $SD = 0.932$, $n = 274$) and those who do not know anyone in their social network ($Mean = 3.1792$, $SD = 1.075$, $n = 84$).

H3 concerns whether companies have an economic incentive to engage in such partnerships. To determine the respondents' purchase intention, respondents were asked to indicate on a 5-point Likert scale (1) whether they were more likely to purchase from an engaged company and (2) whether they were willing to take a detour to purchase from an engaged company. Of the 393 respondents who answered the first statement, 265 people (67.43%) indicated they would consider the company's engagement in a PPEC as a reason to be more likely to purchase from the company. Among 390 participants who responded to the second item, 125 individuals (32.05%) agreed on

their willingness to take a detour to purchase from an engaged company. In contrast, another 102 people (26.15%) indicated a neutral opinion in this regard.

To derive economic incentives for companies, we have then tested whether a positive attitude towards an engaged firm, measured by the previously established *positive attitude index* (seven items, Cronbach $\alpha = 0.778$), leads to an increased purchase intention on a company engaged in a PPEC. Regarding the purchase intention, with a Spearman-Brown Coefficient of 0.812, we combined those mentioned above described two items, resulting in a new variable with a mean value of 3.208 ($SD = 1.1489$, $n = 387$) (Eisinga et al., 2013).

First, findings revealed a significant correlation between the *positive attitude index* and the respondents' purchase intention towards an engaged company ($r = 0.315, p = 0.000$). Second, a standard linear regression was performed to test whether the positive attitude significantly predicts respondents' purchase intention. The results showed a significant regression equation ($F(1, 353) = 38.984, p = 0.000$) with a quite weak $R^2 = 0.099$. It was found that the positive attitude significantly predicts the respondents' purchase intention from an engaged company ($\beta = 0.315, p = 0.000$). We cannot reject hypothesis 3.

We computed the Eta coefficients to analyze correlations between the Purchase Intention and respondents' age or gender. These were for the age $Eta = 0.088$ ($n = 387$) with an Eta^2 of 0.007 and for the gender $Eta = 0.102$ ($n = 382$) with an Eta^2 of 0.010.

	Coefficient (B)	Standard Error	95% CI[1]	β	t	p-value	ANOVA
							$F(1, 353) = 38.984$
							p-value $= 0.000$
(Intercept)	0.760	0.402	$[-0, 30, 1.551]$		1.891	0.059	
positive attitude index	0.606	0.097	$[0.415, 0.797]$	0.315	6.244	0.000	

Notes: $R^2 = 0.099$, [1] 95.0% confidence interval for B, $N = 355$

Dependent Variable: Purchase Intention

Table C.5: Results of regression analysis for positive attitude on purchase intention

C.6 Discussion, Further Results and Managerial Implications

This Section discusses our previously obtained results and puts them into context. Considering further insights from our study, we derive managerial implications for those companies in the area of essential goods that have already pursued CSR issues in the past with their business model or want to use CSR in the future increasingly.

Regarding the probability of a shortage of essential goods due to a natural disaster, most of the 402 respondents considered this to be very unlikely (32.08%). Only 18 people perceived the occurrence

as very likely (4.48%). Based on our research findings, we confirmed the current view obtained from the literature that population awareness can be positively linked to supporting a company's CSR initiatives. However, following our findings from Section C.2, current research suggests a generally low level of population's awareness towards companies' CSR engagement practices due to a lack of knowledge (Kolkailah et al., 2012; K.-H. Lee and Shin, 2010; Lee et al., 2019; Van et al., 2020). We argue in the same direction as a growing number of publications, which is to highlight the need for comprehensive communication programs e.g. (Selmier et al., 2015). This includes tactics, strategies, or channels to raise the level of awareness (Becker-Olsen et al., 2011). Therefore, we asked for the knowledge on companies that engaged in PPECs. 219 respondents (54.48%) were already aware of projects worldwide in which private companies engage in PPECs. However, only 49 individuals knew specific companies involved in such partnerships. Our data also suggest that those known partnerships mainly referred to short-term set-up partnerships in the COVID-19 context. At this point, one could argue in the direction of the companies: If PPECs become much better known, which, e.g., also current examples like known partnerships from COVID-19, show, then the whole topic of CSR and PPEC engagement could gain more attention in the future. This, in alignment with our research results on purchase intentions, would also promote companies' economic interests. To shed some light on this issue, as a first step, we asked participants the following about the credibility of various activities in company engagement in PPECS:

In what cases do you consider engagement credible, in the sense that the company's actions are primarily motivated by a motive to help, rather than tactical or similar considerations?

By far, the highest credibility was expressed for companies that take action over the longer term, i.e., not just on a one-time occasion ($n = 399$) with a mean score of 4.34 ($SD = 0.847$), followed by the use of diverse resources ($n = 397$) with a score of 4.11 and $SD = 1.012$. If a company does little advertising with its commitment ($n = 399$), this was rated with an agreement of credibility of 3.68 and a $SD = 1.170$. The company's announcement on its website to help in the future was only ($n = 394$) rated as weakly credible with 2.34 and $SD = 1.052$.

In addition, we asked the population which sources of information they find particularly trustworthy. Unsurprisingly, with an approval rating of 4.32 and a standard deviation of 1.029 at $n = 401$, the highest credibility was expressed when the commitment could be seen with one's own eyes. Behind them were educational brochures from government agencies and their websites ($n = 399$) with 3.97 and $SD = 1.028$. In the midfield were annual reports ($n = 394$) with 3.15 and $SD = 1.289$, and particularly low trustworthiness was given to advertising that discussed the engagement ($n = 397$) with 2.01 and $SD = 1.009$.

The results presented in this Section and the findings from the previous Section illustrate that respondents not only rate company engagements in PPECs generally positively, but also that it is highly correlated to their risk perception. These are the main results to answer our two research questions. Furthermore, it was found that a respondent's positive attitude towards company

engagement in PPECs was associated with an increased purchase intention from that specific company. It represents the economic potential of this form of collaboration and is to be added to the factors of securing the value chain and improved perception already mentioned. Even though corporate engagement in PPECs is highly valued, it also depends on the quality and quantity of corporate outreach. In addition, even the best-intentioned assistance measure can be misreceived by the buyer group if the associated communication strategy does not appear trustworthy or is not used as an information source at all. Every company should consider these aspects when considering a possible involvement in a PPEC. We could find out a correlation between the risk perception and the agreement to a company's PPEC engagement. We determined a relationship between heightened risk perceptions and agreement for company engagement in PPECs, as one of the population's coping strategies.

Another critical factor, when it comes to the economic evaluation of CSR engagement, Madsen and Rodgers (2015) emphasize, is that the financial performance will relatively certainly not pay off in the short term. However, these investments can be more than compensated for in the long term.

C.7 Limitations, Future Research, and Conclusion

C.7.1 Limitations and Future Research

A few limitations to our research design can serve as starting points for further research in this area. First, we only conducted the study in Germany in an online format. Although we collected the participants' demographic data, the quality and scope of the study could be enhanced by a representative design, possibly including other geographic destinations such as other European countries or the United States. Although it can be assumed that similar results would be achieved in these Western countries, the political and structural differences are worth considering in future studies. With the same argument, the transferability of our results to countries from different cultures and economic backgrounds is doubtful. The age structure in our study, which is skewed in comparison to the German population, suggests divergent results for the total German population (Destatis, 2021). In addition, we only conducted this survey for a limited period at the turn of 2020-2021. Interesting conclusions could be drawn from re-surveying with the same group of participants. By conducting a comparative study after the COVID-19 pandemic, we could find out what has changed in the population's eyes and to evaluate if there are any changes recognizable at all.

A general problem with surveys, which also affects this survey, is the problem of social desirability. Since, in an ethical sense, CSR is often perceived as the right thing to do, a desirability effect can overstate CSR-related attributes in surveys and bias the results, creating a gap between attitudes and actual behavior (Auger and Devinney, 2007; Kuokkanen and Sun, 2016). Especially when it

comes to questions concerning purchase intentions, one may argue that the stated intentions are consistent with actual behavior, but nevertheless, intention to buy answers in empirical studies have not necessarily shown the actual purchasing behavior afterward (Carrington et al., 2010). Finally, it can be noted that controlling for potential bias and asking for additional factors in future surveys could provide revealing information. For example, implementing more specific willingness to purchase questions based on different product categories or attributions would provide additional recommendations for companies. In addition, in the related research field of consumers' willingness to pay (WTP), which we did not explore in our survey, approaches exist to reduce bias between hypothetically measured and actual WTP. Both, Schmidt and Bijmolt (2020) and Hofstetter et al. (2021) analyze direct and indirect measurement procedures of WTP. The latter authors propose a de-biasing single question approach that could be considered for further investigations (Hofstetter et al., 2021). One could also specifically examine past purchasing behavior in the form of an examination of individual purchases, for example at the supermarket.

In our *risk perception index*, we focused only on a portion of items relevant to our study. An extension of these risk perception items, also about Slovic's model, could provide additional information on the risk perception of the population due to the ongoing COVID-19 pandemic. In addition, within the *risk perception index*, we have focused only on the COVID-19 pandemic. We decided to give participants a concrete, current event to use as a guide for evaluating this question. Future studies could also analyze risk perception in other crises or a more general view of risk perception. Finally, additional research results on the general risk perception of the population in combination with CSR would be welcome.

C.7.2 Conclusion

We have addressed a very crucial issue with this study, which is particularly important in light of the COVID-19 pandemic that is still ongoing at this point. Public actors in crisis management can better serve the population with the help of companies in so-called PPECs. With our study, we have made an essential contribution to how the population evaluates companies' engagement in PPECs and could derive managerial implications for companies.

The main findings of our study are that the population generally rates the involvement of companies in PPECs positively and that we were able to uncover a correlation between this agreement and the risk perception of those involved, but not between approval and sociodemographic factors such as age or gender. As a critical insight for companies, we found that the respondents' agreement also leads to an increased purchase intention among consumers, so companies should price the economic component of this involvement into their business planning.

In a nutshell, with the present work, we have taken the particular approach to evaluate corporate engagement in PPECs by raising the stakeholder approach from the population's perspective. In the long run, they are the ones providing the profits to the companies. We found that the population

highly values company engagement in PPECs, but it also depends significantly on the quality and quantity of company outreach. The right communication channel and strategy are essential to promote PPEC engagement. We could find a correlation between the risk perception and the agreement to a company's PPEC engagement to determine if there was a relationship between heightened risk perceptions and agreement for company engagement in PPECs, as one of the population's coping strategies. Thanks to our study, companies can better understand how their engagement is pereceived by customers and adjust their strategy accordingly to achieve a better return on their investments in CSR.

C.8 Supplementary Material

C.8.1 Supplementary Material 1 - Cronbach's Alpha if Item is Deleted

Item	Cronbach's α if item is deleted
The state crisis management can better fulfill its tasks through the supportive participation of private companies.	0.727
Then crisis management can succeed more efficiently.	0.744
I see such actions as a sign of social responsibility on the part of this company.	0.745
Companies can provide useful support for state crisis management.	0.754
Is this an opportunity for the company to take social responsibility.	0.761
My perception of this company is improving.	0.755
I see it as a tactical calculation to strengthen the image.	0.763

Cronbach's α for all 7 items = 0.778

Table C.6: Cronbach's alpha for *positive attitude index* ($n = 349$)

C.8.2 Supplementary Material 2 - Literature Review Positive Attitude

Author(s)	Method	CSR dimensions	Main Finding(s)
Arli and Tjiptono (2014)	survey among consumers in Indonesia ($N = 254$)	four dimensions of CSR according to Carroll (1979)	consumers' perceptions of legal and philanthropic responsibilities significantly explained their support for responsible businesses
Becker-Olsen et al. (2011)	survey among consumers in Mexico ($N = 480$) and the U.S. ($N = 480$)	not defined	in both countries, consumers shared belief in the value of CSR and an expectation that company should be engaged in the community; consumers will reward companies for successfully communicating CSR
Grimmer and Bingham (2013)	survey among population in Australian ($N = 698$)	environmental	consumers will express a greater purchase intention towards products from companies that act in a socially responsible manner
Guzmán and Davis (2017)	survey among millennial undergraduate business students in the U.S. ($N = 370$)	not defined	emotional and functional components of a brand play an important role in determining how CSR affects consumer attitudes, which in turn build brand equity
Hsieh (2014)	survey among mobile phone consumers in Taiwan ($N = 558$)	four dimensions of CSR according to Carroll (1979)	purchase intentions are significantly influenced by consumer–company identification and consumer perception of CSR commitment, which mediates the relationship between consumer–company identification and purchase intention
Kim et al. (2019)	survey among consumers in the U.S. ($N = 473$)	economic, ethical	in contrast to people with economic CSR expectations, people with ethical CSR expectations perceive corporate misconduct as morally wrong; consumers' motivations to engage in communication behaviors about the crisis were influenced by economic and ethical CSR expectations

Kolkailah et al. (2012)	cross-sectional survey among consumers in Egypt ($N = 259$)	four dimensions of CSR according to Carroll (1979)	consumers in Egypt are aware of socially responsible companies and are inclined to develop positive attitude towards social responsible companies; economic evaluative purchasing criteria (i.e. affordability) were found to be more important than social criteria
K.-H. Lee and Shin (2010)	survey among consumers in South Korea ($N = 215$)	corporate social, environmental and local community contribution	confirmation of a positive relationship between consumers' awareness of CSR activities and purchase intentions (in particular in terms of local community contribution)
Lee et al. (2019)	survey among population in Korea ($N = 1.298$)	13 different types of CSR activities	Korean public does not show much experience with or awareness of CSR activities in the pharmaceutical industry; among CSR activities, the highest preferences were found for "promoting public health" and "emergency disaster relief support"
Lichtenstein et al. (2004)	four studies including one field based survey among customers of a national food chain ($N = 1.000$)	supporting nonprofits (check writing in response to nonprofit fund-raising, charitable activities)	CSR behavior can result in a variety of corporate benefits (e.g., more favorable corporate evaluations, increased purchase behavior)
Maignan (2001)	cross-cultural survey conducted in France ($N = 169$), Germany ($N = 94$) and the U.S. ($N = 145$)	four dimensions of CSR according to Carroll (1979)	respondents in France and Germany were significantly more inclined to support responsible organizations in their shopping activities than those in the U.S.; consumers in all three countries were willing to make specific efforts to buy products from responsible organizations

Ramasamy and Yeung (2009)	survey among consumers in Shanghei ($N = 136$) and Hong Kong ($N = 121$)	four dimensions of CSR according to Carroll (1979)	in comparison to the results of Maignan (2001), evidence shows that Chinese consumers are more supportive of CSR; economic responsibilities are found to be most important while philanthropic responsibilities are of least importance
Rew and Cha (2021)	survey among consumers in Texas ($N = 194$)	four dimensions of CSR according to Carroll (1979)	verification of a positive relationship between CSR and consumer attitude; resilience and familiarity play an important role as mediators in the relationship
Rivera et al. (2019)	survey among consumers in Spain ($N = 251$)	economic, social and environmental CSR activities	CSR associations have a direct, positive impact on loyalty, and an indirect impact through their positive effect on brand awareness and consumer satisfaction
Schramm-Klein et al. (2016)	survey among consumers in Germany ($N = 3.313$)	not defined	in retail practice, CSR has a positive impact on customer loyalty and consumer purchasing behavior
Servera-Francés and Fuentes-Blasco (2016)	survey among consumers in Spain ($N = 408$)	not defined	CSR activities of a retailer increase consumers' perceived value, trust, commitment, satisfaction and loyalty
Shukla et al. (2019)	survey among consumers in India ($N = 1.033$)	instrumental, non-voluntary, normative, legal	instrumental and normative CSR have a positive impact on consumer purchase intentions and willingness to pay, legal CSR has a negative impact on purchase behavior and non-voluntary CSR has no influence on consumers
Van et al. (2020)	survey among consumers in Vietnam ($N = 222$)	CSR towards employees, products, environment, community, business honesty	CSR awareness of consumers influences their attitude toward an organization which in turn leads to an increased purchase intention

C.8.3 Supplementary Material 3 - Literature Review Risk Perception

Author(s)	Method	Main Finding(s)
Akerlof et al. (2013)	survey among adult residents in the U.S. ($N = 765$)	personal experience of global warming, especially in one's community can significantly predict risk perceptions, above the effects of political polarization and cultural issues
Becker (2011)	structured interviews among residents in El Salvador ($N = 69$)	women and men did not significantly rank threats differently; several other parameters were found to have significant associations with the ranking of hazards, indicating that there are multiple dividing lines affecting risk reduction priorities beyond gender
Champ et al. (2011)	survey among residents in Colorado, U.S. ($N = 421$)	when purchasing a home in a fire-prone area, most respondents were aware of the risks and concerned that wildfires could damage their properties; wildfire experience and perception of wildfire risk were both related to taking more risk mitigation actions during wildfires
DeYoung et al. (2020)	survey among Cambodian- and Laotian-American communities ($N = 445$)	well-being was influenced by sense of community and age; perception of risk, trust in government, confidence in engaging household preparedness and ability to cope with a financial crisis were significant predictors and positively associated with disaster preparedness
Doocy et al. (2013)	survey among disaster-affected populations in Eastern Uganda ($N = 800$)	mortality was significantly higher in the landslide-affected populations as compared to flood-affected populations; the majority of respondents felt that both their communities and the government were unprepared to respond to disasters
Gerhold et al. (2019)	survey among population in Germany ($N = 1.979$)	Germans perceive food shortages not as macrosocial risks; German population can be based on their individual levels of risk perception categorized into four different preparedness types (self-confident all-rounders, unsure non-prepared, unconcerned optimists and risk-oriented independents)
Hoffmann and Muttarak (2017)	survey among population in Thailand ($N = 1.310$) and the Philippines ($N = 889$)	disaster experience, which is influenced by the geographic location of the home, is a key predictor of the adoption of precautionary actions; education increases preparedness by improving risk perception and social capital

Sullivan-Wiley and Short Gianotti (2017)	survey among farming households in Uganda ($N = 426$)	factors shaping smallholder risk perception vary among specific hazards; increased risk perception can result in greater understanding, self-efficacy and motivation for protective action
Tooher et al. (2013)	literature review of cross-sectional or repeated population surveys during or following H1N1 pandemic	whereas awareness of a pandemic was high, level of knowledge, concerns and risks were moderate; the most common factors influencing the adoption of recommended behavior were increased risk perception, older age, increased pandemic knowledge and female gender
van Loenhout et al. (2021)	cross-sectional survey among population in Tunisia ($N = 417$), Georgia ($N = 420$) and Israel (N= 556)	heatwave-protective knowledge was highest in Israel and lowest in Georgia; knowledge of heatwave-protective measures was highest in Tunisia; most respondents who named certain protective measures had also applied these during the last heatwave
Yeo et al. (2014)	two surveys among residents in the U.S. ($N = 2.338$ and $N = 2.806$)	the events in Japan were interpreted differently by ideological groups (e.g. liberals and conservatives); the ideological effects were dependent on the levels of media attention; conservatives paying more attention to media perceived less risk post Fukushima

C.9 Conflict of Interest Statement

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D An Empirical Survey on the Effects of a Global Pandemic regarding the Population's Stockpiling Behavior

Abstract[1]

Public authorities recommend that everyone should store a supply of food, drinking water, and Medicines to mitigate the risk of a supply failure. However, a variety of surveys indicated that the average citizen does not follow this recommendation. To gain a better understanding of the actual amount of stockpiled goods, we conducted a house-to-house survey in rural municipalities in the federal state of Baden-Württemberg in Germany. A first survey round with 330 participants took place in early 2020. The results support the claim of a lack in stockpiling. In addition, we were able to identify different clusters of people stockpiling goods based on sociodemographic factors. Moreover, the start of the COVID-19 pandemic right after we finalized our survey offered us the chance to further investigate the effects of a global pandemic on the stockpiling behavior. Therefore, we conducted a second house-to house survey with 402 participants in the summer of 2021, in which we followed the same streets as in the first survey. The two survey rounds enabled us to perform inter-subject comparisons, which which were supplemented by intra-subject analysis within S2. Counterintuitively, the results indicate that COVID-19 has only caused short-term effects on stockpiling behavior, while, in the course of the pandemic, stockpiling came back to similar levels as it was before.

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[1] This chapter includes the preprint of the article ""An empirical survey on the effects of a global pandemic regarding the population's stockpiling behavior". This article was written in collaboration with Miriam Klein, Florian Diehlmann, Marcus Wiens, and Frank Schultmann. It was submitted to a scientific journal as Lüttenberg, Klein, et al. (2022).

D.1 Introduction

The outbreak of the COVID-19 pandemic, resulting in disturbances in global supply chains and local lockdowns, has led, at some points, to empty shelves in supermarkets (CNN Business, 2022). Although shortages first appeared with the onset of the pandemic in early 2020, they continued to persist since supply chain recoveries were followed by new lockdowns and supply problems for different products. In industrialized countries, where customers have a wide choice of products for everyday use, these shortages confronted them with an unfamiliar situation. As reasons for supply disruptions may be manifold, like blackouts, political instabilities, or pandemics, civil protection organizations, such as the Federal Office for Civil Protection and Disaster Relief (BBK) in Germany, are aware of such threats independent of COVID-19. Already for a long time, the BBK has recommended that the population should stockpile food, drinking water, and medicines on its own responsibility to be prepared for supply chain disruptions.

These so-called essential goods are needed in disasters but often cannot be delivered at short notice. Thus, the self-help capacity of the population yields a high potential for increased resilience. If people can successfully mitigate shortages in the supply of essential goods for a certain period, it allows the civil protection authorities to establish alternatives to shift focus on other important tasks.

In this regard, the state and the population should engage in coordinated disaster prevention to gain up-to-date information on the level of preparedness. In particular, the state needs to be informed about the population's stockpiling behavior to identify vulnerabilities. Contributing to this issue, our main research question examines how people are ready and prepared for possible disasters by quantifying the status quo of the population's stockpiling according to the BBK's recommendations. Since quantifiable information, especially focusing on the influences of COVID-19 on peoples' stockpiling behavior, is scarce, the need to perform quantitative analysis on this subject became obvious.

For this study, we conducted a quantitative population survey in small municipalities (< 10.000 inhabitants) in southern Germany in the federal state of Baden-Württemberg. We started survey round 1 (S1) before the first COVID-19 lockdown in Germany (January/February 2020). With the ongoing pandemic in 2021, we decided to go for a second survey round (S2). We executed this second round between July and September 2021. Both surveys were conducted in the form of a house-to-house survey based on a random-walk algorithm.

We designed the survey based on the recommendations of BBK (i.e. availability of private stockpiles according to 8 different categories of food and water) to contribute to crisis management by evaluating the population's preparedness for disasters regarding their stockpiling behavior. The obtained data is useful for decision-makers in public authorities to initiate and control appropriate measures. Furthermore, we can determine which categories of essential goods need extended stockpiling in particular and cluster the participants into different groups of stockpiling behavior.

By performing an inter- and an intra-subject comparison, we gather insights from the COVID-19 pandemic and draw consequences for other crises. In addition, we give recommendations to the population with insights on general stockpiling and in which areas individual stockpiling needs to be improved.

The remainder of this paper is organized as follows. The next section outlines the theoretical background on stockpiling behavior and the influence of the COVID-19 pandemic. We derive our survey's research question and underlying hypotheses and describe the study design. Afterwards, we present the study's results, discuss managerial implications for public authorities, and suggest further research directions. We close the study with conclusions.

D.2 Theoretical Background

We gathered current studies on stockpiling behavior of the population with a specific focus on the COVID-19 pandemic. Literature in this area is very new and scarce and comes from peer-reviewed journals, scientific newspapers, and authority information. For Sections D.2.2 and D.2.3, we conducted a structured literature review using a keyword approach to search the Web of Science database. The search was restricted between 2010 and 2022. Using the keywords listed in Table D.1, the search string led to 88 results.

Category	Search string
Stockpiling	(Stockpiling OR stockpile OR safety stock) AND (preparedness OR behavior) AND (personal OR individual OR population OR consumer OR customer) AND (disaster OR emergency OR crisis OR catastrophe)

Table D.1: Search string for stockpiling

In the next step, the papers' abstracts were analysed. We pre-classified according to their assumed relevance to the context of stockpiling actions by the population in preparation for or during extreme events. This resulted in 30 remaining papers. Subsequently, the final classification of the papers' relevance was compiled, and the main topics alongside used methods were extracted. After that, only 24 papers were still classified as relevant. As a result of the literature review, two main research areas can be identified: *Links between personality traits and stockpiling behavior* (Section D.2.2), and *Influence of external effects on stockpiling behavior* (Section D.2.3).

D.2.1 Stockpiling Behavior & COVID-19 Pandemic

For the event of a crisis, public actors around the world tackle the issue of bringing essential goods to the population differently: For example, the US-American Federal Emergency Management

Agency (FEMA) stockpiles ready to eat meals (MREs) to supply the population, for example, after a hurricane (National Public Radio, 2012). In Germany, the civil emergency reserves consist of long-lasting cereals, rice, peas, lentils, and condensed milk. These are cheaper to store than MREs but must be further processed before consumption (Bundesministerium für Ernährung und Landwirtschaft (BLE), 2022). However, in both countries, BBK and FEMA strongly recommend the population stockpile essential goods on its own for some time (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2016; U.S. Department of Homeland Security, 2022). This self-help capacity is seen as necessary in times of a crisis event when commercial supermarkets are closed. Public authorities, even if they can deliver some essential goods, would at least need a couple of days to establish an alternative supply (necessary time to establish an overview of the crisis, set up a crisis team, and move the required resources from A to B based on the still existing infrastructures). According to Gerhold (2021), specific protection targets are defined for critical infrastructures. In the area of food, these are divided into first and second value-added stages as well as trade.

As the topic is crucial, some surveys on population stockpiling have already been conducted during the last decade in Germany. Surveys from 2013 and 2014 examining participants' grocery shopping behavior, private preparedness, and risk perceptions showed that only 31.3% of surveyed households had supplies that lasted longer than ten days (Gerhold et al., 2019; Gerhold, 2021). According to another survey on risk perception and coping strategy, 50% of the surveyed households had a stockpile that lasted longer than the recommended ten days (Gerhold, 2020). A survey by G. Busch et al. (2020) found, 43.8% of participants in June 2020 and 45.7% of participants in November 2020 had sufficient quantities of food. Other surveys examining stockpiling behavior during the COVID-19 pandemic showed only a slight improvement in stockpile size during the crisis event (Gerhold, 2020; G. Busch et al., 2020).

However, to the best of the authors' knowledge, no other comparable study has analyzed the population's stockpiling behavior in such quantifiable detail. Due to dynamic situations, disaster planning cannot be performed on a household level, so it can be advantageous for civil protection organizations to have insights into aggregated factors that influence stockpiling behavior to react adequately. Thus, the following subsection investigates studies linking personality traits to stockpiling behavior.

D.2.2 Links between Personality Traits and Stockpiling Behavior

As indicated in the section before, personality traits play an important role when it comes to the stockpiling behavior of individuals. Using an online survey, descriptive analysis, and probit regressions, Valente de Almeida et al. (2020) examined stockpiling behavior at the beginning of the COVID-19 pandemic in Portugal and found that stockpiling behavior was associated with being younger and highly educated. Ben Hassen et al. (2021) analyzed factors triggering stockpiling behavior using logistic regression based on questionnaire data. They concluded that sociodemographic factors like gender and household size influenced stockpiling behavior, which was enforced

by negative emotions such as depression or fear. Interestingly, in contrast to most studies, they found that more women stockpiled than men. However, this was explained by women being the family member doing most of the grocery shopping.

In contrast, Dammeyer (2020) did not find any association of stockpiling with sociodemographic characteristics like age, gender, household situation, or level of education. Instead, he figured out that low scores on conscientiousness and openness to experience and high scores on neuroticism and extraversion correlate with stockpiling behavior. All named characteristics comprised two main factors for stockpiling through an explorative factor analysis of survey data: Panic and action. Micalizzi et al. (2021) came to similar results using hierarchical multiple regression. They investigated individual predictors of stockpiling behavior in response to the pandemic and found that people who are more conservative, less socially distanced, and worried more about the pandemic were more prone to stockpiling. Moreover, they are lower in agreeableness and collective consciousness. Age was not found as a predicting factor; however, male individuals stockpiled more than females, and the size of the household also influenced the behavior. Columbus (2021) assessed stockpiling behavior as an expression of personality traits linked to prosocial behavior. Using a survey and generalized linear mixed model, he found that people with high scores in honesty-humility were weakly associated with refraining from stockpiling and behaving more prosocial. Harada et al. (2021) used a survey and multivariable logistics regression to examine the link between health practices and food stockpiling behavior and found a positive correlation. Additionally, it was found that stockpiling was associated with higher income, higher education, advanced age, and being male. Focusing on preparedness measures, Hoffmann and Muttarak (2018) concluded that education promotes disaster preparedness, especially if the individual has no prior disaster experiences. The study used cross-sectional survey data and logit models.

In conclusion, the results of existing studies on personality traits and stockpiling behavior do not show a clear trend. They are sometimes contradicting, so further research on this issue is required. In addition to personal traits, an external effect also might influence the stockpiling behavior, outlined in the following section, where we review papers dealing with external influences on stockpiling behavior.

D.2.3 Influence of External Effects on Stockpiling Behavior

We start with the current literature related to the COVID-19 pandemic and afterward present literature from other contexts. Ahmadi et al. (2021) examined the influence of cultures on stockpiling behavior during the COVID-19 pandemic. Using regression, they found that cultures that promote myopic thinking, emphasize restraint, motivate people to reduce uncertainty, and focus on their personal needs more than on society's were more prone to stockpiling. Increased media coverage of crises and changing availability of goods lead to panic buying and stockpiling and, therefore, consumption displacement. Rudert and Janke (2021) used longitudinal surveys and regression to predict future stockpiling of individuals. The two main predicting factors were previous behavior

and the perceived behavior of others. They found that perceived threat is less predictable by the means of stockpiling than vice versa. The contingent valuation study of Wang et al. (2020) found that consumers' risk perception and, therefore, their stockpiling behavior is triggered more by reduced availability of supplies than by price increases since individuals are more willing to pay during emergencies. The influence of the perceived threat was the subject of the study of Song et al. (2021) as well. They simulated multiple pandemic waves to find that high-risk-perception leads to hoarding and irrational purchasing behavior. Hall et al. (2021) found consumer spending patterns related to this irrational behavior. Sheng et al. (2021) also identified consumer segments depending on their characteristics and behavior in response to the pandemic using latent class analysis. Especially social media seems to be positively correlated to panic buying, as shown in the study of Naeem (2021). He used a purposive sampling technique to show that social media can create social proof such as suggestions or advice, which results in stockpiling behavior since seeing other people stockpiling becomes contagious very fast.

This was already shown by Desmarchelier and Fang (2016) who studied diffusion networks to capture the market and social panic after food scarcity. The study of Pan et al. (2020) found that precautionary stockpiling behavior depends on supply-side characteristics such as product variety or retail network, demand-side characteristics such as disaster experience and income, and disaster characteristics such as hazard intensity or proximity. They used an event analysis methodology for their study. Hao et al. (2020) used a bivariate probit model to study the influence of e-commerce channels on food stockpiles. They found that online channels are more likely associated with panic stockpiling than offline channels, possibly due to low supply capacities, and peer influences enforced stockpiling intentions. However, community group buying seemed to ease panic buying perception. Another way to reduce panic stockpiling is shown in the descriptive statistical analysis of Kim et al. (2020). They found that the perceived threat and stockpiling behavior could be reduced when providing comparative statistics.

Compared to all the aforementioned studies, our study explicitly analyzes external effects by comparing results from survey from pre-COVID-19 and an additional survey from within COVID-19.

D.3 Research Question, Hypotheses and Study Design

D.3.1 Research Question

Considering the ongoing COVID-19 pandemic, the topic of supply chain disruptions and resulting shortages in the availability of certain essential goods is more relevant than ever. Due to the circumstances, we assume that many people reduced their shopping frequency at supermarkets to

follow social contact restrictions. Did, in turn, the stockpiling of essential goods from the population increase? We want to quantify the effects of the current stockpiling of the population and gain knowledge on the effects of the pandemic. A scientifically sound database is indispensable to public authorities for initiating and controlling appropriate measures, specifically towards certain goods that need to be focused on in particular. Our main research question is, therefore:

How intense is the stockpiling behavior of the population in the sense of crisis prevention, and is there an effect in this behavior measurable in terms of heavy disruptions as seen by the COVID-19 pandemic?

D.3.2 Hypotheses

We derived four hypotheses from existing literature based on this overarching research question. In industrialized countries, public authorities are responsible for supporting the population in times of crisis (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2021). The authors also note that private-sector supply structures should be maintained for as long as possible in a crisis. However, public authorities should ensure supply after that. At the same time, the population is encouraged to stockpile essential goods at home for up to 10 days in order to bridge the transition time until a public replacement of supply is established. However, Hess (2011) shows that, on the one hand, private households do not necessarily invest in crisis preparedness because of the increased costs that come with no direct corresponding profits. On the other hand, state institutions are not, or only to a limited extent, able to quickly supply large parts of the population with essential goods in the event of a crisis (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2019a). These (temporal) supply gaps have to be closed by individual stockpiling so that we formulated our first hypothesis:

H1: *Respondents stockpile as a means of crisis management.*

Usually, in western countries, there is no need to worry about supply shortages in supermarkets (Gerhold et al., 2019). The population is used to their constant and unrestricted supply. This has changed with the COVID-19 pandemic. Images of empty supermarket shelves were ubiquitous in the media (Balzter et al., 2020). These shortages had mainly two reasons. At first, minor issues with supply chains led to minor shortages at local places. Secondly, shortages were amplified mainly based on so-called hoarding purchases due to the population's fear of potential supply shortages in the food sector (Holzer, 2020). Many people had to realize for the first time in their lives that supply bottlenecks can occur in western countries. The people were not prepared for this, either physically with enough goods stored at home or mentally, which even increased the panic

buying. The question whether the pandemic experiences have changed the population's stockpiling behavior arises. Behavioral researchers stated that people increase stockpiling to overcome the effects of the pandemic (Rudert and Janke, 2021; Garbe et al., 2020). Based on these findings and considerations, we developed our second hypothesis:

H2: *Stockpiling behavior of the respondents has changed during the COVID-19 pandemic*

Within the following hypothesis, we analyze the relationship between food shortages and stockpiling behavior: The fear of losing the ability to control their food stocks and being restricted to a few nutrition alternatives causes people to increase stockpiles. This crisis-induced stockpiling commonly explains the observed panic buying behavior during crisis events. Relating to the pandemic situation in Germany, media coverage on supply bottlenecks and governmental efforts to reduce the spread of disease imparted people with the feeling of food scarcity, which in turn might have caused them to buy excess food capacities (Lehberger et al., 2021).

Hao et al. (2020) conducted a consumer survey on vegetable and instant noodle stockpiling in major Chinese cities. The authors denote a significant correlation between the panic behavior of people and the willingness to stockpile more. In contrast, the inability of e-commerce suppliers to provide such goods might explain the excessive stockpiling observed in these cities. Ben Hassen et al. (2021) performed an online survey on Serbian citizens during the pandemic's 'second wave' and found fear of food shortages and increasing food prices to be relevant parameters to trigger stockpiling.

Based on preliminary research and stockpiling being an elementary strategy to bypass food shortages, we expect the fear of food shortages to be a major cause to increase stockpiles during COVID-19:

H3: *The primary reason for the increased stockpiling in the first lockdown was fear of food shortages.*

As already stated in section D.2.2, there are mixed results on whether sociodemographic factors influence individual stockpiling behavior (Ben Hassen et al., 2021), or not (Dammeyer, 2020). Amuakwa-Mensah et al. (2022) analyzed a dataset from the beginning of the pandemic in early 2020 via regression/covariance analyses for interrelated variables in stockpiling. They controlled for factors such as age, amount of shopping, fear of COVID-19 infection, and residential location (urban or rural). Before COVID-19, Wagner and Hildt (2019) investigated lowered immune defense at a higher age so that despite complete vaccination protection, there was still a higher probability of infection with contagious viral diseases during shopping. To counter such a situation, some of the elderly either tried to reduce their shopping frequency during a pandemic or have their shopping

done by family members or younger acquaintances who do not belong to a pandemic risk group (Meyer-Aurich et al., 2021).

Following these insights from the literature, we propose the last hypothesis:

H4: *Age, household size, household net income and shopping frequency significantly correlate with stockpiling behavior of participants*

D.3.3 Study Design and Structure of Questionnaire

We conducted a quantitative house-to-house population survey with 29 questions in survey round 1 (S1) before the first COVID-19 lockdown in Germany took place (January/February 2020). When the pandemic hit and changed the demand and supply of essential goods worldwide, we decided to go for survey round 2 (S2). In this second round, performed between July and September 2021, we used an updated questionnaire containing 30 questions (inter-subject comparison). In both survey rounds, the questionnaire included additional six questions about the respondents' demographics. The social research institute GESIS supported us with the wording of the questionnaire and the randomized selection of small municipalities ($< 10,000$ inhabitants) in southern Germany belonging to the federal state of Baden-Württemberg. Within the municipalities, we started from a central place (mainly the marketplace or the town hall). We used a random walk algorithm, asking every third household to participate in our research project. In S1, we performed our survey in 13 municipalities. In S2, we asked people from the same municipalities and added seven additional ones to obtain a more extensive database. The location of all 20 municipalities is shown in the map in Figure D.1.

After a short introduction to the survey (see Appendix), the first block of questions deals with the life situation of the participants, i.e., their household size, kind of property they live in, and distance to the closest supermarket. The second block contains questions about the participants' grocery shopping behavior, i.e., for what purpose respondents generally keep supplies. Accordingly, in S2, the second block of the questionnaire was updated with two additional questions about whether participants stockpiled more since the beginning of the COVID-19 pandemic. We also asked about the reasons participants had for building up stocks. In the third block, participants had to answer eight questions concerning the actual size of their current food stock, and for how many days it would last (inter-subject comparison). This is taking into consideration the size of the households, and these questions were derived from the different food categories public authorities such as the BBK recommend ((Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2019b), compare Table D.2).

In our survey, participants were asked how many days their total household could live on their current stocks for each of the mentioned food categories. The time intervals were measured via
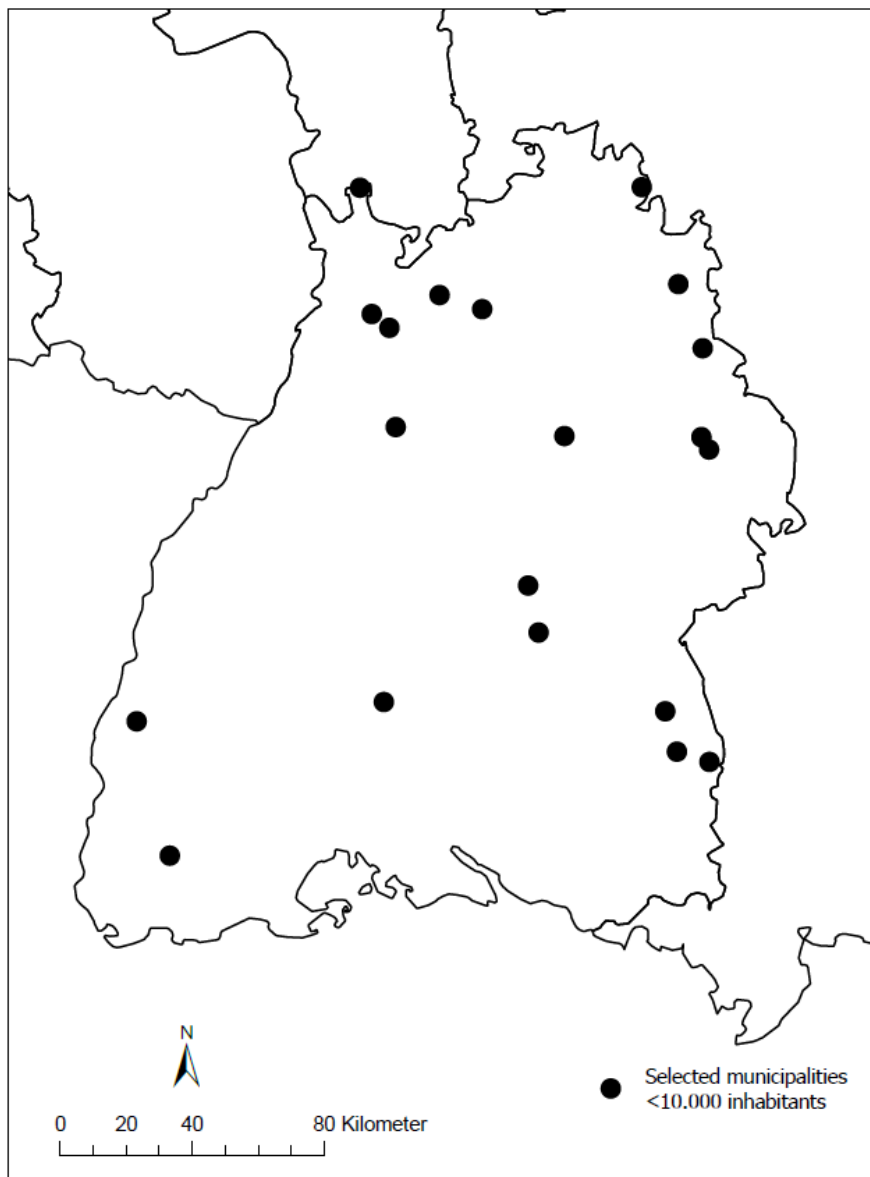
Figure D.1: Map of selected municipalities in the federal state of Baden-Württemberg with its location in Germany and the neighboring European countries

a 5-item Likert scale from *less than a day* up to *more than two weeks*. Since the category *Other* came without further explanation on the exact composition or recommended quantity, we excluded it from our survey. The fourth block addresses risk assessment regarding the possibility of supply shortages. The final question block deals with the respondents' demographics (e.g., household net income, marital status, approximate age).

Stockpile category	Recommended amount per capita and day
Beverages	2 liters
Grain products[1]	350 grams
Vegetables and pulse	400 grams
Fruits and nuts	250 grams
Milk and milk products	260 grams
Meat, fish, egg[2]	150 grams
Fats and oils	36 grams
Other[3]	not defined

[1] including bread, potatoes, noodles and rice

[2] including egg replacement products

[3] including sweets, salt, prepared dishes

Table D.2: Necessary stockpiles per capita and day according to BBK

D.4 Results

D.4.1 Demographic Characteristics of Respondents

Demographics of the sampled respondents are shown in Table D.3. In S1, we contacted 1262 households and received 330 complete answers (response rate: 26.1%). In S2, we contacted 1402 households and received 405 complete answers (response rate: 28.9%). In both survey rounds, more females than males participated. Thereby, the share of females participating turned out to be more assertive in S2 (females = 68.4%) than in S1 (females = 54.8%). Regarding age, most participants were classified under the group of $36 - 67$ *years*. As a result, the participants in S1 appeared to be tendentially younger than those in S2. When asked for their marital status, fewer individuals of S1 claimed to be married (67.9%) than persons of S2 (77.3%). While most people claimed to live in 2- person households in both samples, the corresponding share is lower for S1 (38.8%) than for S2 (54.3%). In contrast, the share of people living in 4-person-households is remarkably higher for S1 (30.6%) than for S2 (15.1%). Performing Mann-Whitney-U test on both samples supports the assumption that household sizes differ significantly between S1 and S2 (Table D.4).

Regarding net income, only 42.2% of all participants in S2 were willing to state their income, of which the highest share was between 3001 and 4000 Euro net household income per month. For S1, 81.8% of the participants answered the income question, with the highest share of them associating themselves with the range between 4001 and 7000 Euro. Excluding all the cases in which respondents did not answer, the income distributions of S1 and S2 appeared to be comparable since the Null-hypothesis of Man-Whitney-U was not rejected (Table D.4). Asking for the kind of health insurance survey participants owned, most claimed to be insured by statutory health insurance. The proportion of privately insured participants is slightly higher in S1 (15.8%) than in S2 (7.9%).

Sample Population	S1 ($n = 330$)		S2 ($n = 405$)	
	Number	Percentage (%)	Number	Percentage (%)
Age				
18 − 35 years	78	23.6	57	14.1
36 − 67 years	197	59.7	262	64.7
> 67 years	53	16.1	86	21.2
No answer	2	0.6	0	0.0
Gender				
Female	181	54.8	277	68.4
Male	148	44.8	128	31.6
Diverse	0	0.0	0	0.0
No answer	1	0.3	0	0.0
Marital status				
Single	61	18.5	45	11.1
Married, registered partnership	224	67.9	313	77.3
Divorced	16	4.8	17	4.2
Widowed	23	7.0	29	7.2
No answer	6	1.8	1	0.2
Number of persons living in household (excluding toddlers)				
1-person household	40	12.1	55	13.6
2-person household	128	38.8	220	54.3
3-person household	61	18.5	48	11.9
4-person household	101	30.6	61	15.1
5-person household	0	0.0	18	4.4
6-person household	0	0.0	3	0.7
Monthly net income available (for total household)				
Up to 1000 Euro	8	2.4	8	2.0
Between 1001 and 2000 Euro	28	8.5	16	4.0
Between 2001 and 2500 Euro	39	11.8	12	3.0
Between 2501 and 3000 Euro	50	15.2	19	4.7
Between 3001 and 4000 Euro	63	19.1	72	17.8
Between 4001 and 7000 Euro	70	21.2	42	10.4
More than 7000 Euro	12	3.6	2	0.5
No answer	60	18.2	234	57.8
Kind of health insurance				
Insured by German law	270	81.8	367	90.6
Privately insured	52	15.8	32	7.9
No answer	8	2.4	6	1.5

Table D.3: Demographic characteristics of the respondents

Stockpile category	Asymptotic significance p	z-Value	r-Value
Gender of participants	$< 0.001^{**}$	-3.719	0.137
Age of participants	$< 0.001^{**}$	-3.249	0.12
Marital Status	0.058	-1.893	0.07
Household size	$< 0.001^{**}$	-3.481	0.128
Net household income	0.491	-0.809	0.039

** $p < 0.01$ (Statistically significant on 1% significance level)

Table D.4: Mann-Whitney-U tests on differences between S1 and S2 for defining sociodemographics

We compared this data with census data from the Statistical State Office of Baden-Württemberg (Statistisches Landesamt Baden-Württemberg, 2020). However, data is only partially comparable with respondents' characteristics, as in our study we focused on the rural area of the federal state. The office reports an average citizen age of 43.8 years, slightly higher than the averages in both S1 and S2. For gender, S1 and S2 appear biased toward female respondents since only about 50.3% of inhabitants turned out to be female according to the census. Moreover, the share of single persons appears to be underrepresented in S1 and S2. About 43% of people in Baden-Württemberg stated to be single in the census survey. For household size, an underrepresentation is found in S1 and S2 for 1-person households (about 40%).

D.4.2 Preventive Crisis Management & Stockpiling Behavior

To evaluate H1, we started with a descriptive analysis of participants' self-estimations. A vast majority of participants in S2 (93.8%) stated not to maintain extraordinary large food stockpiles when comparing their contemporary stockpiling behavior to times before the COVID-19 pandemic. Based on this first impression, we now investigate the detailed results to quantify the stockpiling sizes. Thereby, the question arises whether, in general, respondents stockpile essential goods so that their independence and flexibility are increased in a crisis. Especially when the food supply is interrupted for a certain amount of time, this is of importance. If so, the stockpiles of participants can be seen as a tool to manage crisis-induced risks. In order to compare stockpile sizes of participants with each other, we used in a first step the BBKs' necessary good categories and the advice of keeping 10-day stockpiles for each category as a guideline (see section D.3.3 (compare Table D.2).

Given participants' answers regarding the time their stockpile of each food category may last, we performed Exploratory Factor Analysis (EFA) on the S2 data set as a baseline to find coherent food category factors which can be used as a structure for index creation. According to Table D.5, the usage of EFA can be justified for the given data set (KMO value > 0.5), whereby investigated variables share significant relationships ($p < 0.001$). Unweighted least squares (ULS) was used as a factor extraction method since participants' single food category stockpiles were not normally distributed (Izquierdo et al., 2014).

Likewise, Oblimin was used as a matrix rotation method, assuming that factors created might not be entirely independent of each other due to the generality of mentioned food categories (Brown, 2009). Based on the input data, results of the EFA implied a mono-scale factor containing all food stockpile categories, but *fats and oils* which did not yield a significant loading on our monoscale model. Thus, an improvement in scale coherency (Cronbachs' Alpha) could be achieved by removing the category.

Basic measures of Exploratory Factor Analysis performed

Cronbachs Alpha: $\alpha = 0.812$

KMO and Bartlet Test: $KMO = 0.835, p < 0.001$

Variance explained: $R^2 = 41,265\%$

Stockpile category	Factor loadings	Cronbachs' Alpha if left out
Beverages	0.475	0.806
Grain products	0.755	0.762
Vegetables and pulse	0.835	0.754
Fruits and nuts	0.79	0.761
Milk and milk products	0.554	0.796
Meat, fish, egg	0.648	0.779
Fats and oils	*0.210*	0.834

[1] Factor loadings stated in *italic* are considered as weak (< 0.3)

Table D.5: Results of initial EFA

Content-related explanations, for the exclusion of *fats and oils*, are that a majority (60.5%) of participants in S2 indicated that they have stockpiles of *fats and oils* which last for more than two weeks. No other food category has such large stockpiles. Another aspect could be the circumstance that *fats and oils* differ from other categories in terms of consumption (mainly used for cooking or preparing other meal ingredients rather than contributing nourishment themselves). Hence, we decided to accept the statistical specification and excluded *fats and oils* from the index creation. The reduced model could then explain 47.477% of variance in stockpiling behavior for the remaining food categories.

We then created a **Stockpiling Index (SI)** to compare participants' stockpiling behavior. Participants would barely match their stockpiles with a time interval. If they would not be sure to have at least sufficient stocks for the lowest time duration of the interval, we decided to calculate the index based on the minimum values of the respective answer categories. This was achieved by assigning a point score to the respective time interval resembling its lower bound (Table D.6).

With the point score, we were able to calculate the average stockpile durations for each separated food category for the reduced model found in EFA (Table D.7). As evident, people in S2 had the longest stockpile durations for comestibles falling under the categories of *grain products*, *beverages* as well as *milk and milk products*.

Current stockpile duration per category	Point value
Less than 1 day	0
Up to 3 days	1
Up to 1 week	4
Up to 2 weeks	8
More than 2 weeks	15

Table D.6: Stockpile durations and respective point scores used for statistical analysis

Stockpile category	Average point score
Beverages	5.04
Grain products	6.06
Vegetables and pulse	3.90
Fruits and nuts	3.46
Milk and milk products	4.55
Meat, fish, egg	3.88

Table D.7: Average stockpile durations per food category of participants in S2

In a second step, we calculated the SI as the average value of participants' point scores over all food categories gained from EFA. Given the BBK recommendation of 10-day-stockpiles, we set an average SI score of 10 as a threshold for recognizing crisis-relevant stockpiles. As evident in Figure D.2, the Stockpiling Index confirms the initial impression that respondents barely build crisis-relevant stockpiles: According to our measures, only 8.86% (36 individuals) of all participants in S2 displayed overall sufficient stockpiles. In addition, the total average SI value was relatively low (4.48 points, $\sigma = 3.184$), which is far below the value of 10.00. Likewise, *H1* is rejected since there is no evidence of risk-preventive stockpiling for most people in S2.

D.4.3 COVID-19 & Stockpiling Behavior

Regarding the second hypothesis, we compared the stockpile sizes in S1 and S2 for each food category in terms of an inter-subject comparison (i.e. same question is asked to different participants in the two survey rounds S1 and S2). The average point scores for each food category (Table D.8) reveal that stockpile durations of participants in S2 tended to be higher than those in S1 for most categories. *Milk and milk products* and *Meat, fish, egg* are the only categories where this statement does not hold.

To test whether these differences are also statistically significant, a Mann-Whitney-U test was employed to determine changes in the distribution of stockpile durations for each food category. According to Cohen (1992), $r < 0.3$ constitute a weak, $r < 0.5$ a medium and $r >= 0.5$ a strong effect size. As shown in Table D.9, the differences can be confirmed for all food categories except *Milk and milk products* and *Meat, fish, egg*. However, comparing both samples concerning
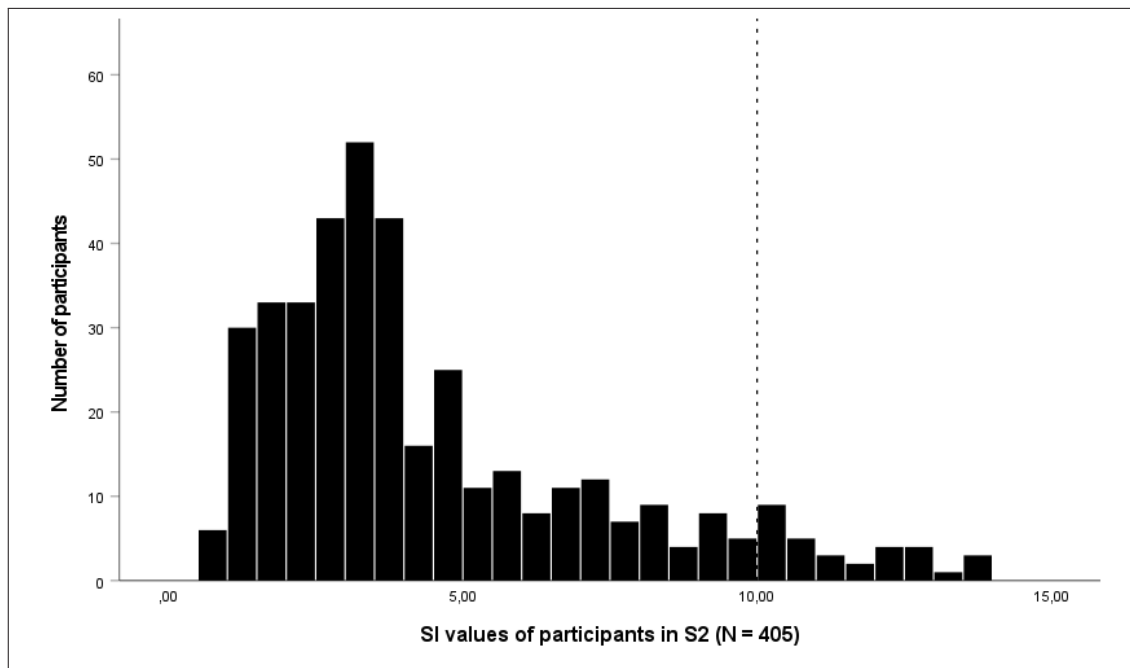
Figure D.2: Distribution of stockpiling index values for participants in S2

Stockpile category	Average point score
Beverages	3.95
Grain products	4.3
Vegetables and pulse	2.84
Fruits and nuts	2.93
Milk and milk products	4.74
Meat, fish, egg	3.97

Table D.8: Average stockpile durations per food category participants in S1 indicated

the stockpiling duration within the significant food categories, the r-value suggests only minor differences ($r < 0.3$ for each food category). The effect size was largest for the change in *Grain products*, which is in line with reports stating higher sales of grain products during the COVID-19 pandemic (King, 2020).

Stockpile category	Asymptotic significance p	z-Value	r-Value
Beverages	$< 0.001^{**}$	-5.345	0.197
Grain products	$< 0.001^{**}$	-5.947	0.219
Vegetables and pulse	$< 0.001^{**}$	-4.795	0.176
Fruits and nuts	0.008^{*}	-2.652	0.097
Milk and milk products	0.602	-	-
Meat, fish, egg	0.299	-	-

* $p < 0.05$ (Statistically significant on 5% significance level)

** $p < 0.01$ (Statistically significant on 1% significance level)

Table D.9: Mann-Whitney-U tests on differences between S1 and S2 regarding stockpile size for different food categories

The SI has also been calculated for participants of S1, as displayed in Figure D.3, to assess the existence of risk-relevant stockpiles in S1. Furthermore, the question remains whether there is an effect expressed via the share of people maintaining risk-relevant stockpiles (i.e., above ten days).
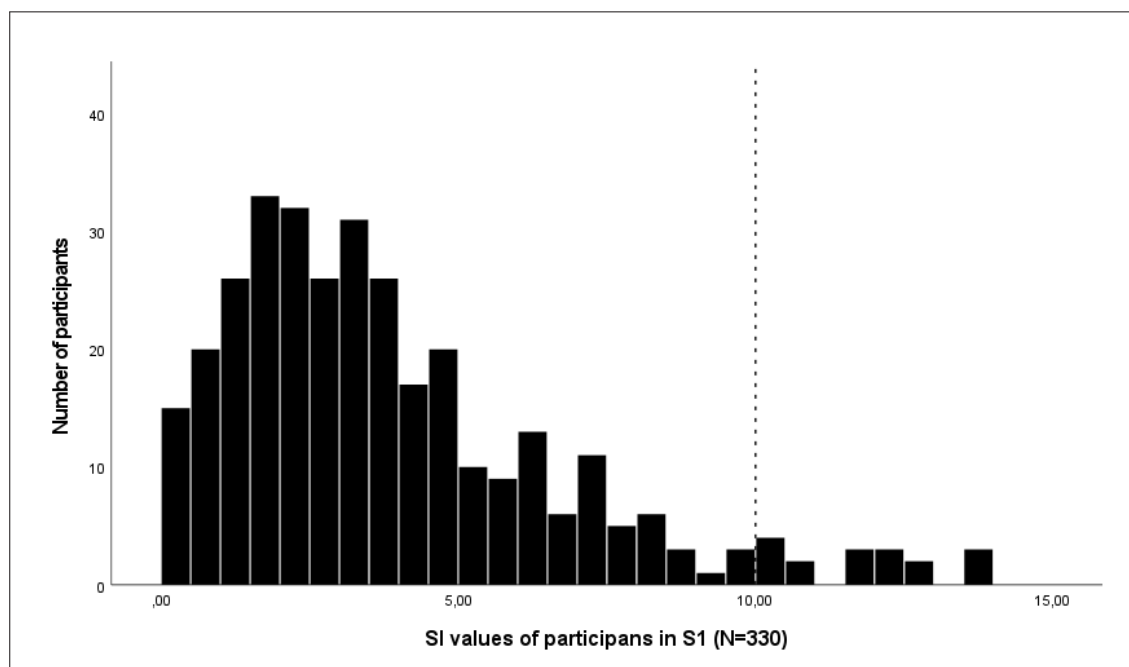
Figure D.3: Distribution of stockpiling index values for participants in S1

In this sample S1, 5.15% (17 individuals) report having a stock of at least ten days as recommended by BBK. Moreover, the mean SI-value constitutes 3.79 points with $\sigma = 2.84$. Again, we employed the Mann-Whitney-U test for evaluating SI differences between S1 and S2 (Table D.10). Accordingly, significant differences between S1 and S2 can be confirmed for the SI (with a minor effect size of $r = .115$). All in all, *H2* is not rejected.

Stockpile category	Asymptotic significance p	z-Value	r-Value
Complete (Stockpiling Index)	0.002*	-3.119	0.115

*: $p < 0.05$ (Statistically significant on 5% significance level)

Table D.10: Mann-Whitney-U tests on differences between S1 and S2 regarding stockpiling index

D.4.4 Fear of Food Shortages & Stockpiling Behavior

In order to assess possible changes in the stockpiling behavior of participants, we additionally performed an intra-subject comparison for the respondents of S2 (i.e., participants of S2 answer the same question related to two different points in time). As mentioned in chapter D.3.3, we asked participants of S2 to self-indicate whether they observed a change in stockpiling when comparing

their stockpiling behavior during the first lockdown with stockpiling behavior before the crisis (Table D.11).

Change of Stockpiling behavior	Absolute value	Percentage (%)
I have stocked significantly less	0	0.0
I have stocked a little less	2	0.5
I have stocked about the same	295	72.8
I have stocked a little more	94	23.2
I have stocked significantly more	14	3.5

Table D.11: Perception of participants in S2 regarding own stockpiling behavior during first lockdown

We asked these 108 participants in S2 who indicated that they built up larger stockpiles when facing the first lockdown for the main reasons that might have caused this increase. Now, participants were offered six different items and had to display their level of agreement with these items on a 5-point Likert scale (1 = complete disagreement, 5 = complete agreement). Results of this analysis can be seen in Table D.12.

Why did you stockpile more?	Mean (μ)	Std. Deviation (σ)
As a countermeasure against rising food prices	1.12	0.468
Due to concerns regarding food shortages at home	3.99	1.249
Due to fear of food shortages at local supermarkets	3.84	1.320
Due to the fear of catching a COVID-19 infection	2.46	1.609
Due to the fear of not being able to buy food anymore caused by strict quarantine restrictions	2.57	1.664
Due to the fear of possible supermarket shutdowns during lockdown	1.99	1.343

Table D.12: Average agreement levels of participants in S2 on statements regarding changes in stockpiling behavior

Accordingly, on average, people who changed their stockpiling behavior during the first lockdown agreed on fearing food shortages. This becomes evident by a mean Likert-value higher than 3 (neutral statement) for the questions regarding fearing food shortages at home or at local supermarkets. Only a few participants feared more severe crisis scenarios like a supermarket shutdown. The fear of quarantine restriction and COVID-19 infection also played a subordinate role. However, one has to keep in mind the relatively high standard deviation of the answers to these options. This might indicate that for some participants (e.g., vulnerable people due to high age or previous illnesses) the aspect of catching COVID-19 still might have been decisive as well for changing stockpiling behavior. All in all, *H3* is not rejected.

D.4.5 Demographic Characteristics & Stockpiling Behavior

Searching for possible factors correlating with participants' stockpiling behavior, we decided to apply a cluster analysis. Hence, we employed a k-Means Clustering algorithm with standard parametrization (max. ten iterations of cluster center changes) on the questions regarding the stockpile duration, which were used for creating the Stockpiling Index. By doing so, we employed the same point value system for formalizing the answer options as with SI (compare Table D.6) to extract a set number of $k = 3$ clusters. Since SI was created based on $c = 6$ different food categories, participants are assigned to 6-dimensional cluster centers. The mean point scores can approximate clustered participants shown for respective food categories (Figure D.4).
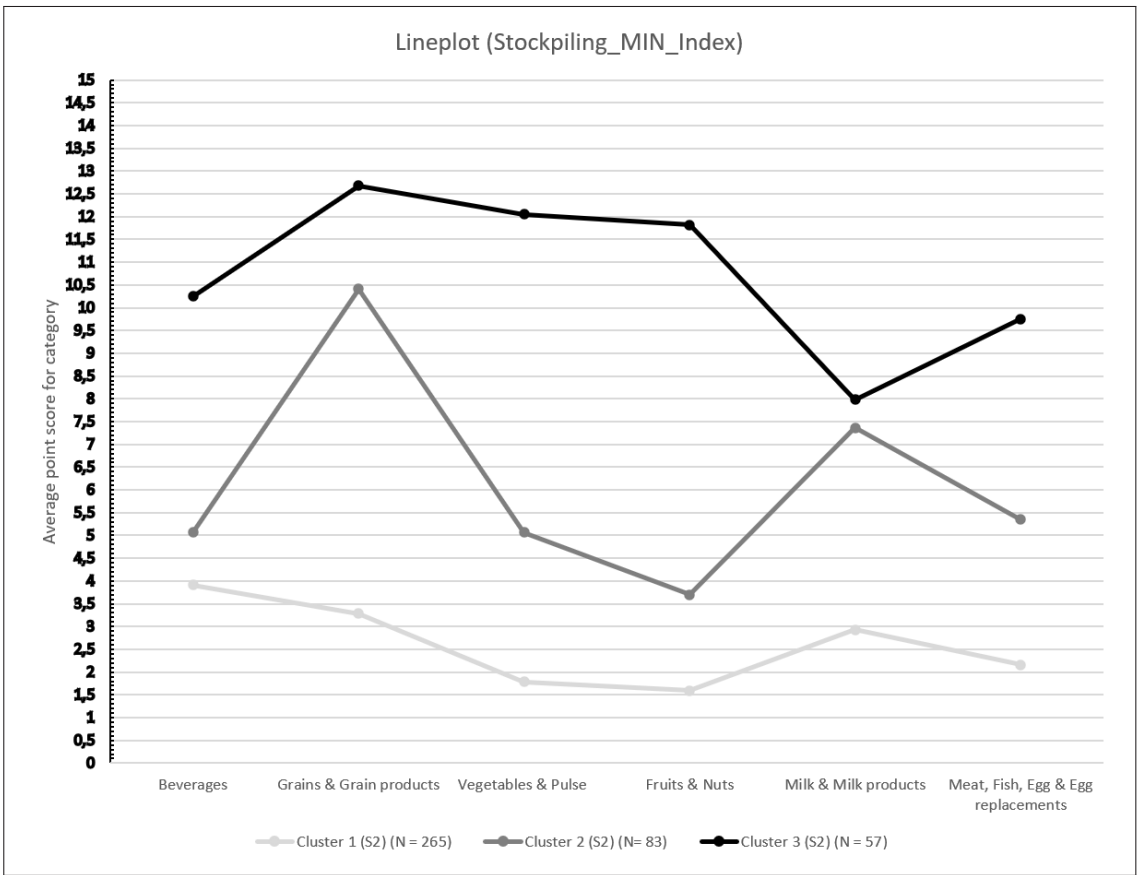
Figure D.4: Lineplots of the mean point scores participants achieved across individual food categories

Clusters represent a different perspective on stockpiling, compatible with the insights provided by the SI but with less strict boundaries between the categories. The first cluster represents *Contemporary Non-Stockpilers*, which do not display meaningful stockpiling behavior for any food category. We describe the second cluster as *Convenience Hoarders* or *Week Planners*, which indicates food stocks that might last around one week. In particular, people assigned to the second cluster appeared to hoard foodstuff which is easy to store (e.g., grain products such as noodles or cereals or UHT milk). The last cluster contains *Actual Hoarders*, which on average display food

stockpiles for more than a week in each food category. Most people indicating preventive crisis stockpiles are also assigned to this cluster.

The division of S2 was then used to assess the cluster-wise mean values of participants' stockpiling behavior (Table D.13). Thereby, major findings are summarized as follows: The cluster denoted as *Actual Hoarders* contained people who (on average) were older than participants in the other clusters. These people were more likely to claim crisis prevention as a practical reason to stockpile (nevertheless, only around 30% of the people belonging to *Actual Hoarders* stated this to be true). They tendentially agreed more often on fearing a COVID-19 infection while agreeing less strictly to having build-up stockpiles during the first lockdown to overcome food shortages at local supermarkets. Meanwhile, their monthly disposable net income turned out to be lower, while they went food shopping less frequently on average.

According to a Kruskal-Wallis test (Table D.14), significant differences between the clusters can be observed in age, net income, and food shopping frequency. In addition, there are significant differences in the following motivational reasons for building up stockpiles: crisis prevention, fear of food shortages (both at home and local supermarkets), fear of COVID-19 infection, and fear of closing supermarkets during lockdowns.

Performing Kendall-Tau correlation analysis on the whole S2 sample for the Stockpiling Index (Table D.15) confirms the results found with cluster analysis and offers additional insights on the directionality of relationships between influence factors and stockpiling. Thereby, a significant positive correlation between age and SI values is found. Moreover, peoples' degree of consent to the statements that crisis prevention and the fear of catching COVID-19 were reasons for them to stockpile more also correlates positively with SI value. Moreover, a slightly positive but significant correlation of SI with food shopping frequency is observed, meaning that people in S2 who bought groceries less frequently tended to have higher SI values. In opposition, net income and SI value correlate negatively. Negative linear correlations with SI can be found for the fears of food shortages and lockdown restrictions which makes sense since people maintaining larger stockpiles of food may feel more prone to the fear of running out of essential goods. All in all, we do not reject H4.

Question	Answer options	Cluster 1	Cluster 2	Cluster 3
How old are you?	**1**[1] 18 - 35 years **2** 36 - 67 years **3** > 67 years	$1.98(265)^2$	2.06(83)	2.51(57)
What is your gender?	**0** male **1** female	0.69(265)	0.64(83)	0.74(57)
What monthly net income is available to your household?	**1**[1] <= 1000 Euro ... **7** > 7000 Euro	4.79(130)	4.15(26)	3.13(15)
How far away from your home is the nearest supermarket located?	**1** < 1 kilometer **2** 1 - 5 kilometers **3** 5 - 15 kilometers **4** > 15 kilometers	1.25(265)	1.32(83)	1.34(57)
How often per week do you buy food?	**1** Daily **2** >= 3 times/week **3** 1 - 2 times/week **4** < 1 time/week	2.85(265)	2.84(83)	3.04(57)
Is crisis prevention a reason why you build up stockpiles?	**0** No **1** Yes	0.03(265)	0.17(83)	0.3(57)
Motivation to increase Stockpile during first lockdown	**1** Complete disagreement ... **5** Complete agreement			
Concerns regarding food shortages at home		4.26(58)	3.58(31)	3.84(19)
Concerns regarding food shortages at local supermarkets		4.03(58)	3.74(31)	3.42(19)
Fear of catching a COVID-19 infection		2.07(58)	2.90(31)	2.95(19)
Fear of not being able to buy food anymore due to quarantine restrictions		2.38(58)	2.94(31)	2.58(19)
Due to the fear of possible supermarket shutdowns during lockdown		2.34(58)	1.65(31)	1.47(19)

[1] Bold values represent the codes of answer options in the questionnaire

[2] Values in brackets represent the number of people in the cluster who answered the respective question

Table D.13: Mean values of selected questions within the respective clusters for participants of S2

Subject	χ^2	Asymptotic significance p
Age	38.812	< 0.001**
Gender	1.535	0.464
Net income	19.897 (171)[1]	< 0.001**
Distance to supermarket	3.478	0.176
Food shopping frequency	7.027	0.03*
Stockpiling for crisis prevention	44.906	< 0.001**
Motivation: Food shortages at home	11.053 (108)	0.004**
Motivation: Food shortages at local supermarkets	9.115 (108)	0.01**
Motivation: Fear of COVID-19 infection	7.066 (108)	0.029*
Motivation: Strict quarantine restrictions	1.745 (108)	0.418
Motivation: Lockdown causing supermarkets to close	10.308 (108)	0.006**

*: $p < 0.05$ (Statistically significant on 5% significance level)
** $p < 0.01$ (Statistically significant on 1% significance level)

[1] Values in brackets represent the number of people who answered the question

Table D.14: Kruskal-Wallis test on differences between the three clusters of S2

Subject	τ	Asymptotic significance p
Age	0.243	< 0.001**
Gender	-0.018	0.659
Net income	$-0.222(171)$[1]	< 0.001**
Distance to supermarket	0.057	0.168
Food shopping frequency	0.082	0.041*
Stockpiling for crisis prevention	0.281	< 0.001**
Motivation: food shortages at home	-0.208 (108)	0.006**
Motivation: food shortages at local supermarkets	-0.203 (108)	0.006**
Motivation: Fear of COVID-19 infection	0.259 (108)	< 0.001**
Motivation: Strict quarantine restrictions	0.181 (108)	0.014*
Motivation: Lockdown causing supermarkets to close	-0.212(108)	0.005**

* $p < 0.05$ (Statistically significant on 5% significance level)
** $p < 0.01$ (Statistically significant on 1% significance level)

[1] Values in brackets represent the number of people who answered the question

Table D.15: Kendall-Tau correlation of potential stockpiling influence factors with the stockpiling index

D.4.6 Further Insights

To get an overview of the stockpiling behavior of participants, we assessed their main reasons for building up food stocks. Table D.16 shows the results of this evaluation. Multiple answers were possible. As mentioned with *H4*, only a few participants in both S1 and S2 indicated that they generally build up safety food stocks to prepare for disasters. At the same time, most people named convenience reasons as major causalities of food stockpiles.

Main reasons to build up stocks of food - several answers possible	S1 ($n = 330$)		S2 ($n = 405$)	
	Agreements	Rate (%)	Agreements	Rate (%)
Meeting of spontaneous demand (e.g. surprise guests)	309	93.6	395	97.5
Usage of temporary discounts on foodstuff	143	43.3	241	59.5
Preparing for crisis scenarios	27	8.2	39	9.6
Other reasons	39	11.2	3	0.7

Table D.16: Results of binary questions on general stockpiling motivation

Furthermore, as specified in subsection D.3.3, the questionnaire was also designed to measure people's risk perceptions regarding severe crisis scenarios. Since participants in S2 had experienced the COVID-19 pandemic already, their estimations regarding crisis scenarios were deemed valuable: The participants were requested to imagine a situation where Germany was affected by a massive breakdown of supermarket and pharmacy supply chains leading to the closing of stores. When asked for rating the risk of experiencing such a crisis (1 = low risk, 5 = high risk), around 84% of people in S2 estimated a low or rather low risk ($\mu = 1, 51, \sigma = 0.886$). Likewise, they had to state whether they trust in the ability of supermarkets and pharmacies to deal with such a crisis scenario (1 = absolutely not, 5 = with certainty). Hereby, it turned out that participants on average put slightly higher trust in pharmacies ($\mu = 2.17, \sigma = 1.377$) than in supermarkets ($\mu = 1.95, \sigma = 1.426$). Thereby, a strong correlation between the trust in supermarkets and the trust in pharmacies was observed (Spearman correlation, $\rho = 0.69, p < 0.001^{**}$). Moreover, a weak positive correlation between participant age and trust in supermarkets (Kendall correlation, $\tau = 0.159, p < 0.001^{**}$) as well as pharmacies (Kendall correlation, $\tau = 0.142, p < 0.001^{**}$) was found. Likewise, monthly net income showed a weakly negative correlation with trust in supermarkets (Kendall correlation, $\tau = -0.132, p < 0.047^{*}$) and pharmacies (Kendall correlation, $\tau = -0.158, p < 0.015^{*}$). Interestingly, the severe crisis risk perceptions of participants in S1, which had not experienced the COVID-19 pandemic crisis yet, were higher than for people in S2, with only 68.6% believing in a low or rather low risk of occurrence($\mu = 2.02, \sigma = 1.083$). A possible explanation for this finding might be that respondents did not suffer severe food shortages during COVID-19 and, considering future crises, are more optimistic about the availability of essential goods. Meanwhile, trust in supermarkets ($\mu = 2.34, \sigma = 1.016$) was on average higher than in S1 and even higher compared to the trust level in pharmacies ($\mu = 2.28, \sigma = 1.036$). In comparison with S2, both institutions tendentially received slightly higher trust levels. In S1, the significant correlation between trust in supermarkets and the trust in pharmacies is confirmed (Spearman correlation, $\rho = 0.464, p < 0.001^{**}$). A negative correlation between net income an trust in pharmacies is found as well (Kendall correlation, $\tau = -0.193, p < 0.001^{**}$)

D.5 Discussion

This study contributes to a better understanding of the population's stockpiling behavior. We have pointed out various implications and critical aspects based on our survey and the related hypothesis tests. For public authorities, we can derive several implications based on our findings.

D.5.1 Managerial Implications

First, stockpiling of the population is considered an integral preventive measure by the authorities since people are first dependent on themselves in the first days after a complete breakdown of private infrastructures. Our study's results show that the population's stockpiling should be increased. During the pandemic, however, the authorities recommended that people should not stockpile too much. So as a second outcome, authorities should improve their communication in this regard. This also applies to improved handling of fake news, i.e., news containing intentionally false information. The effects of media communication were investigated by (Jones, 2020). Incessant media coverage increased the subjectively perceived risk and eventually led consumers to change their behavior immediately. According to Donthu and Gustafsson (2020), the further dissemination of certain 'fake news' did little to calm people's concerns and fears. Public authorities need to help to clarify wrong information. Third, concerning the COVID-19 pandemic, the fear of food shortages in supermarkets did not increase compared to pre-COVID-19. While these results are reassuring in the sense of a lingering emerging panic in the population, they also make clear that the supply of supermarkets during the COVID-19 pandemic functioned smoothly with few exceptions. For future crises, this condition may not be maintained. Once again, the authorities need to sensitize the population accordingly. Finally, based on our cluster analysis, we could show apparent differences in the stockpiling behavior of people belonging to different sociodemographic groups. Public authorities should prioritize support within a crisis according to vulnerability and need for essential goods. With this study, we helped to identify person groups that do not stockpile enough as well as the properties describing them: public authorities need to specifically address and motivate these person groups to increase stockpiles.

D.5.2 Limitations and Future Research

While the survey revealed several insights on behavioral changes in stockpiles, some aspects can be discussed controversially. Some of the following limitations of our research design may serve as starting points for further research in this area. First, the number of participants could have been increased and conducted in other federal states of Germany in future works to assess whether the current findings might hold for most German households and also to account for the long-time changes with the experiences of the COVID-19 pandemic. Likewise, the study subject could have been extended to larger cities to control differences in stockpiling behavior when comparing rural

and urban areas. Second, data protection guidelines did not allow storing personal information during the surveys. Keeping in mind that S1 and S2 constitute independent participant samples, this study does not reveal the stockpiling changes of participating households. However, by the inter/intra-subject comparison and due to the relatively high sample sizes of S1 and S2, it can be assumed that the general stockpiling behavior in the rural areas where the participants were recruited, underwent small but significant changes. To overcome this problem, a panel study with a longitudinal design could be implemented in future research. Third, using Likert scales as an answer-coding was limited to some questions, especially regarding stockpile duration for food categories. Since time intervals turned out to be non-equidistant, the Likert scales made it challenging to interpret mean values produced by the Stockpiling Index. However, directly using minimal values of these time intervals for constructing the SI was assumed to be a valuable alternative to creating a conservative estimate of stockpile duration. Fourth, regarding the type of questions, it could be interesting to investigate the stocking of hygiene items such as soap and disinfectant, especially during a pandemic. Accordingly, it could be helpful to survey whether participants have consumed other foods (such as fresh fruit or supplements) that ought to boost the immune system since the start of the pandemic. Fifth, we observed that age, as well as other demographic factors, influenced stockpiling behavior. For example, age led to more frequent stockpiling out of concern for COVID-19 infection. Among other things, this suggests a relationship between personal risk perception and stockpiling behavior. It would therefore be of interest for further research to investigate the stockpiling behavior of other risk groups and to analyze the reasons for a particular stockpiling behavior in more detail. Finally, stockpiling distributions for the different household sizes are significantly different for some food categories (according to the Kruskal-Wallis test). It could be analyzed to what extent the stockpiling behavior also depends on household size.

D.6 Conclusion

Within this study, we investigated the stockpiling behavior of the population to examine if people stockpile according to the BBK's recommendations. Furthermore, we wanted to analyze possible changes in this behavior due to the COVID-19 pandemic. To summarize our main results: most households do not hold a recommended ten-day supply in most categories (they do only for fats and oils) and therefore do not stockpile enough in terms of disaster preparedness. Large households (4 persons or more) have lower stockpiling per person than households with a smaller number of persons. Regarding our main contribution, we quantified participants' stockpiling sizes regarding the eight categories the BBK has stated as essential goods for disaster preparedness. We received inter-subject comparison results, as responses to stockpiling sizes in survey rounds S1 and S2 on the same questions are comparable. Furthermore, we obtained information based on intra-subject results (some questions we asked respondents in S2 on current stockpiling behavior, for spring 2020 and before the pandemic). In summary, only slight differences in participants' stockpiling behavior

in S1 compared to S2 on average could be detected. COVID-19 has shown short-term effects in stockpiling behavior but not much during the pandemic. Future studies should focus on different sociodemographic influences and the long-term effects of the COVID-19 pandemic on stockpiling behavior.

D.7 Appendix

The following expression was used to introduce our research topic to selected inhabitants, which were asked to participate in our stockpiling investigations (translated and anonymized):

We are currently conducting a Baden-Württemberg-wide survey on food and drug stocks in private households. Your household was selected at random. If you would like to support our research project, you would greatly help us if you participated in the following survey, which takes about 10 minutes. By participating in the survey, you would be contributing significantly to the success of our research project. If you have any questions, please feel free to contact us.

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E Supply Chain Disruptions, Firm Reputation and Customer Loyalty — An Experimental Study

Abstract[1]

In this experimental study we analyze the threat of customer churn as an incentive for a firm to take precautions against disruptions of supply and to establish a reputation for product availability. The design makes it possible to directly measure the strength of reputational incentives (firm reliability and customer loyalty) by isolating the effect of indirect losses due to customer churn from the direct loss caused by a disruption. Based on a repeated-game setting firms can invest in different levels of safety-stock, which reduces the duration of disruptions. We compare the effects of two different settings for reputation building on customer response and firm performance. Within this framework, the study analyzes the customers' tolerance vis-à-vis disruptions and the scope for relational contracting between customer and firm. The results show that it is worthwhile for companies to invest in costly safety stocks, not just for self-protection motives. Preventive Stockpiling can pay off in the form of a double dividend of higher firm reliability on the one hand and, on the other, reduced customer churn in the long run.

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[1] This chapter includes the preprint of the article "Supply Chain Disruptions, Firm Reputation and Customer Loyalty — An Experimental Study". This article was written in collaboration with Marcus Wiens, Milad Baghersad, Christopher Zobel, and Frank Schultmann. It was submitted to a scientific journal as Wiens, Lüttenberg et al. (2022).

E.1 Introduction

The occurrence of natural disasters, criminal or terrorist acts and critical infrastructure breakdown due to human error and high technological vulnerabilities are prevalent on a world-wide level with an increasing impact on supply chains. During the worldwide Covid-19 pandemic, supply chain disruptions have caused large economic damage and most studies identify a growing trend. In general, the economic loss of supply chain disruptions can be divided into the two categories direct and indirect loss (Wei et al., 2009; Kleindorfer and Saad, 2005). Direct losses of supply chain disruptions represent the immediate loss of a company due to foregone sales or the capital loss due to damaged installations. In contrast to direct losses, indirect losses result out of second round effects of the primary impact, which are mainly based on market reactions such as increased input prices, labor shortage or shortage of critical parts. As indirect losses frequently result out of complex cause-consequence effects and often materialize just after a significant time lag, it is difficult to identify and measure them and hence to mitigate these losses.

One commonly underestimated source of indirect losses lies in customer churn, the reluctance of dissatisfied customers to continue buying at their preferred shop if they repeatedly stand in front of empty shelves (Cai and Jiang, 2020). As the Ponemon Institute (2011) states, "the cost associated with business disruption, which includes reputation damages and customer churn, represents the most expensive cost category". Customer churn implies a double loss: a direct and immediate one, which is due to foregone sales and an indirect one, which represents a persistent follow-up effect, which affects future customer behavior. The first one can be measured by comparing the number of sales in normal times with the sales in periods of supply shortage.

However, the second effect is more difficult to measure. In the eyes of the disappointed customers, the firm has the reputation of being unreliable. As reputational effects are belief-driven and customer churn is a second-order reaction to experienced unreliability of a firm, it is empirically difficult to disentangle the firm's losses, which are due to the pure churn-effect from losses, which result out of the disruption as a direct effect. Even if the firm realizes a noticeable long-term-decrease of sales of a disruption-prone product variant, it is plausible but an empirically difficult task to ascribe most of this effect to historic stock-outs (Lariviere and Vandenpoel, 2005). Customer surveys can be ruled out as an option because dissatisfied customers are lost permanently. Therefore, research must rely upon approaches like scenario experiments, which simulate these effects in a hypothetical setting. An alternative approach is the use of laboratory experiments, which makes it possible to analyze incentivized decisions in a controlled environment and to suppress undesired effects by design.

In this contribution, we experimentally analyze customers' willingness to abandon a firm as a reaction to a stock-out on the one hand and the reputational incentives of firms to prevent customer churn on the other hand. We consider a repeated-game setting over five sequences of 10 periods, which simulates a simple 2-player market interaction between a customer (C-player) and a firm (F-player). Stock-outs ("disruptions") are simulated by a random procedure and can have a duration of either one, two or three periods (each disruption length is equally probable). Except during

disrupted periods, the F-player can invest in safety-stock of one, two or three items, which reduces the number of stock-outs. As the cost for safety stock is set sufficiently high in a sense outlined in section 3, the F-players do not have an incentive to increase safety stock just to reduce direct losses. This makes it possible to isolate the pure *reputation effect*: If firm-players decide to invest in safety stock, this is unambiguously motivated by the desire to prevent customer churn and to provide for a stable demand in future periods.

The buyers, in turn, can decide to acquire the item at the F-player or they can turn away and receive a similar but lower valued item at a dummy-firm (Bot), which is simulated by the computer. The Bot is not affected by disruptions and hence the item is always available (which is known by both, F-player and C-player). C-players must make their choice between F-player and Bot before they learn of a disruption. They can switch to the Bot at no cost but switching back to the F-player is costly. Due to this asymmetry in switching cost, the customer could have an incentive to "remain stuck" at the Bot if she does not expect the F-player to provide reliable supply in future periods to compensate for the switching cost. Hence, we take the *customer return rate* as a measure of *customer loyalty*.

As the buyers know that the historic duration of experienced stock-outs is influenced by the firm's safety-stock decision, they gradually build a belief about the safety stock-level and hence the firm's reliability. To control for this reputation effect, we play this game in two different treatments, a short-run (SR) and a long-run (LR)-treatment. In the SR-treatment, the C-player is matched to a different F-player at the beginning of each block. Estimating the safety stock based on only 10 periods is relatively difficult, but even if the customer makes this estimation correctly, this guess is not relevant for the next block, because here she is going to play a fresh F-player. Hence, the SR-treatment provides limited scope for learning and reputation building. By contrast, in the LR-treatment, the buyer is matched with the same F-player over the whole sequence of five blocks. This treatment should provide enough opportunity to learn about the (average) safety stock of the firm and to build an expectation on its future reliability accordingly.

To the best of our knowledge, this is the first study which investigates firm reputation for product availability in an experimental setting. The insights of this study are relevant for managerial decisions in the areas of risk management, business continuity management and corporate social responsibility.

The remainder of the paper is organized as follows. In section 2, we present the relevant literature on customer loyalty, customer churn and firm reputation from both a marketing and an experimental economics perspective. In addition, this section provides the theoretical underpinning regarding the sequence of disruptions (reliability analysis) and with respect to the reputation mechanism (game theory). In section 3, we explain the details of the experimental design and derive the hypotheses. Section 4 presents the results and section 5 provides a critical discussion and concluding remarks.

E.2 State of the Art

E.2.1 Dealing with Supply Chain Disruptions, Stock-Outs and Customer Churn

Various authors have looked at issues related to SC disruptions, stock-outs, and associated customer churn rates in the corporate world. These first articles are concerned with network optimizations to make SC more reliable and resilient. Garcia-Herreros et al. (2014) state that disruptions are often neglected from the supply chain analysis because of their unpredictable and infrequent nature. Their goal is to demonstrate that significant increases in network reliability can be obtained with moderate increases in investment cost through appropriate capacity selection and allocation of inventories. Salam et al. (2016) consider the relationship between inventory and service levels. They assume that poor service levels can result in the loss of customers and sales. They use an inventory system utilizing a simulation model based on company data obtained from Thailand's retail fast-moving-consumer goods chain. An and Ouyang (2016) considered a market entry problem and how to gain market share with existing companies through inventory management and pricing. This is based on a three-tier supply chain network of farmers, storage location providers, and the export market.

In the disaster context, Campbell and Jones (2011) analyze the location decision of supplies in preparation for a disaster and how much to store in one location. They establish equations to determine the optimal amount of stockpiling and the expected cost of supplying a demand point from a delivery point. Coskun et al. (2019), in turn, presents a study of optimizing the stockpiling decisions of two aid organizations that collaborate and share their inventories when needed and calculate associated Nash equilibria.

Other articles focused more deeply on the interaction of SC disruptions and the consequences in terms of customer loyalty and the churn rate. Buckinx and van den Poel (2005) are principally interested in the predictability of customer churn. They argue that lost profits from (partially) churned customers can be substantial, so increasing the customer retention rate can be very profitable. They build a model to predict the partial churn of behaviorally loyal customers using logistic regression, among other techniques. They show that future partial churn rates can be successfully predicted using actual data from an FMCG retailer. They find (similar to applications in direct marketing) that frequency, frequency, and monetary value are the best predictors of partial customer churn. Hopp et al. (2008) model the impact of supply disruptions on competing companies. Considering a variable to quantify the lost profit due to reduced inventory, the authors find that hazardous products are characterized by high market share, low customer loyalty, and reduced inventory. Their analysis works out both tactical consequences (in terms of short-term sales loss) and strategic consequences (in terms of market share shifts).

Regarding the own Supply Chain, Sarkar and Kumar (2015) investigate the impact of communicating interruption information in real-time with a focus on the different SC stages involved in the process

of production. They find that supply chain interruptions can lead to higher-order variation than the base case (no interruption). They advocate that manufacturers share information about supply interruptions in real-time to benefit from a lower bullwhip effect and associated costs. They are looking more into the price and stock competition Cai and Jiang (2020) model a market situation with two retailers who need to decide on stock and price level without knowing the actual customer demand. In addition, customer switching may lead to unpleasant outcomes for the firms, leading to not optimal pricing and stocking levels. In the absence of customer switching, retailers always adopt asymmetric profile to stock and price high (low) when market conditions are optimistic (pessimistic).

Khmelnitsky and Singer (2015) set up a problem incorporating reputation of the retailer as a key factor influencing its policy. Like our approach, the retailer's reputation depends on the degree to which past demand was satisfied. The authors argue that reputation impacts the distribution of future demand and works out optimality conditions for an optimal base-stock policy. The current level of base stock depends on the retailer's current reputation.

Another study examines customers' purchasing decisions based on different levels of quality (Gans, 2002). The study examines suppliers who are stocked with goods of varying quality. Borle et al. (2016) analyze customers, using models of lifetime purchase behavior in order to gain a bigger picture of customer decisions. They use a Bayesian data augmentation scheme and observe strings of inter-purchase times of customers, which firms can relax to restrict memory-less property of exponential inter-purchase times and enhance lifetime purchases of customers by increasing flexibility.

E.2.2 Reputational Incentives for Firms and Business Reputation Strategies

The reputation of companies as perceived by their stakeholders is an important factor for their long-term success and is becoming increasingly important in the light of Corporate Social Responsibility (CSR). Corporate reputation comprises directly or indirectly observable firm characteristics and business practices, such as product quality, working conditions or mission statements, and their public perception conveyed by the media. Stakeholders like customers, professional buyers and investors have an expectation on trustworthy and responsible firm behavior, which is also dependent on the socio-cultural environment.

In principle, a negative corporate reputation results from discrepancies between expectations and observables and eventually leads to a loss of credibility and reliability of the firm. With regard to social and environmental criteria, high standards of behavior are expected from companies today, and misconduct, such as use of child labor or pollution, is sanctioned with negative press, a boycott of purchases, and low attractiveness of the company among potential applicants. Studies like Cho

et al. (2019); Madsen and Rodgers (2015); Dahlsrud (2008) show that differences in corporate reputation also affect the market valuation of companies.

While theoretical and empirical studies on CSR-related firm reputation increasingly gain in momentum, the aspect of delivery reliability, i.e. the stable availability of the commodities in the store, is rarely considered.

From a game-theoretical and behavioral economics perspective, reputation is best understood as an intertemporal and self-enforcing incentive structure based on certain information requirements (Fudenberg and Tirole, 1991). The economic concept of reputation is thus a special variant of a relational contract and is often formally analyzed in terms of game theory, namely as a repeated game with incomplete information (Milgrom and Roberts, 1992). Relational contracts and reputation are closely related. Relational contracts are self-enforcing and based on the reciprocity-principle of Conditional Contract Renewal (Gintis, 2000). According to this theory, players are willing to play cooperatively as long as the opponent does so, too. The repeated game structure provides the opportunity to each player to establish a reputation for a "cooperative intention" in the first rounds of the game (reputation building process). Once each player establishes these beliefs, a cooperative equilibrium can evolve. However, in the absence of specific reciprocal preferences, such an equilibrium can just be supported in a supergame of infinite duration. In a game with a fixed number of rounds, rational players would never cooperate because they apply backward induction: There will be no cooperation in the last round, which makes the next-to-last round the last round and so forth until cooperation collapses already in the first round.

These theories are empirically tested in economic lab experiments. In particular, two variants of reputation experiments are established: The product quality problem and the worker productivity problem. The latter is an empirical test of the efficiency wage theory and shows how a relational contract can be implemented in the combination of "higher productivity against higher wage (and vice versa)". While there is no reputational incentive in the short-run treatment (one-shot interaction), employer and employee develop a reciprocal pattern of increased wage and productivity levels under repeated gameplay (long-run treatment). The product quality set focuses on the potential for reputation in the context of experience goods. Here, a firm is matched with a potential buyer. Also here the short-run interaction is characterized by low levels of quality and willingness to pay (WTP). At the same time, in the long-run treatment firms provide higher quality, and customers are willing to pay a quality premium. In these experiments, the long-run treatment usually corresponds to a sequence of 10 rounds. Contrary to the theory of repeated games, real players in the lab do not apply backward induction for most periods and stop cooperation only in the last rounds of the game (endgame-effect). Our experiment is similar in structure to these reputation games but differs from them in several ways. To the best of our knowledge, there is no reputation experiment on the topic of supply disruptions, availability reputation, and customer churn.

E.3 Design & Hypotheses

Subjects are randomly assigned their role in the experiment, either the role of a firm or a customer. Both groups are equally informed about the general procedure.

General procedure

Firms and Customers are randomly and pairwise matched. Each player does not know the identity of her/his co-player, and communication between the players, other than implicit communication inherently resulting from their strategy choice, is neither possible nor allowed. The matched pairs can realize together five consecutive blocks of 10 transactions concerning a fantasy fitness drink, which is produced by the firm and can be bought by the customer. If the customer purchases this drink, she receives a net valuation (utility of consumption minus price) equivalent to $V_F = 7$ monetary values (MU). The firm receives a net profit (revenue minus price) of $\pi = 20$ MUs for each transaction. As we are not interested in analyzing the choice of diverse pricing strategies (e.g., bargaining, signaling, etc.) and instead focus on the issue of product availability, we suppress these effects and assume constant net values for the surplus of both customer and firm.

All subjects learned in the description of the experiment that the unique feature of the fitness drink is the special taste due to the addition of vanilla. However, vanilla can be purchased almost only on Madagascar, an island where violent natural disasters are regularly expected. Natural disasters cause supply chain disruptions with a duration of either one, two, or three periods with the consequence that the product cannot be delivered during the duration of a disruption. Each type of disruption occurs four times over the 50 rounds; the participants know this frequency but do not know when the disruptions materialize. We decided for an a priori fixed distribution of disruptions to expose the participants to the same risk environment to control for risk aversion. Figure E.1 shows the sequence of disrupted and non-disrupted periods over five blocks.
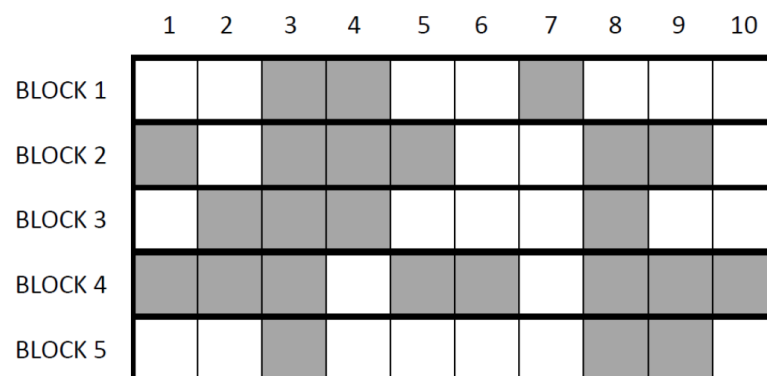

Figure E.1: Fixed distribution of disruptions

Target safety stock-level s	No. unaffected rounds H (h%)
0	26 (52%)
1	38 (76%)
2	46 (92%)
3	50 (100%)

Table E.1: Safety-stock and number of unaffected rounds

The risk of a supply disruption can be mitigated if the firm takes additional precautions by investing in safety stock $s \in \{0, 1, 2, 3\}$ of one, two or three units. The cost for holding one unit safety stock per round is c=6 MU. Depending on the type of disruption and the safety stock-level s, the firm can thus reduce the duration of a disruption according to Table E.1.

For example, by permanently keeping one unit safety stock over the total of 50 rounds, the firm can increase the absolute number of "healthy" rounds from $H = 26$ to $H = 38$, which corresponds to a relative share of unaffected rounds of $h = 52\%$ and $h = 76\%$ respectively. In unaffected rounds, the firm can order safety stock at any time and the ordered units arrive in the next period. Safety stock orders, which are placed during disrupted periods, just arrive after the disruption. Thus, it is of no use to the company to wait for a disruption, but instead it must plan its emergency stock in calm times in order to deploy it in "stormy" times. Both, firms and customers, are informed about the average effects of safety stock on the firm profit as well as on the relative share and absolute number of disrupted periods. The firms' investment decision is not directly observable but can be read out of the experienced duration of a disruption. Contrary to the firm-player, the customers do not know the duration of the disruptions at the moment of occurrence.

Firm decision

The expected firm period profit $E\Pi$ is given by expression (1).

$$E\Pi(s) = h(s)\rho(s)\pi - c \cdot s \qquad \text{(Exp. E.1)}$$

The firm expects the net transaction profit π with a probability of $h(s) \cdot \rho(s)\%$. $h(s)$ is the share of unaffected periods and the variable $\rho(s)\epsilon[0, 1]$ represents the purchase probability. As all other cost elements are already "factored in" in the net profit, the only cost relevant to the firm decision refers to the target safety stock-level and is given by the product $c \cdot s$. We ignore discounting of future values to keep the exposition simple.

From expression (1), it can be seen that safety stock is an investment: Any number of units s the firm plans to hold increases the direct cost term while the return can just be realized in future periods. Note that the future return has two components: First, higher safety stock increases the proportion of unaffected rounds $dh/ds > 0$ (supply-side effect by increased product availability)

and second, higher safety stock should also increase the purchase probability $d\rho/ds > 0$ (demand-side effect due to higher firm reputation and resulting customer loyalty). As this study wants to find out whether and to what extent an investment in safety stock pays off in terms of customer loyalty, we are just interested in the second effect. For this reason, we need to control for the first effect in order to rule out that pure product availability drives the safety stock investment. To this end, we need to ensure two requirements, which can be expressed as two series of inequalities. For the ease of exposition, we use the shorter notations h_s and ρ_s, where the index s indicates the target level of safety stock. Expressions (2) and (4) together imply that an investment in safety stock up to the level $s = 2$ is profitable for the firm if customer loyalty increases. While (2) makes sure that the investment pays off, expression (4) rules out that the investment is profitable just due to product availability alone. If customer loyalty remains unaltered by the investment (fixed value $\overline{\rho}$ corresponds to $d\rho/ds = 0$), increased product availability cannot compensate the cost for safety stock.

$$h_2\rho_2\pi - 2c > h_1\rho_1\pi - c > h_0\rho_0\pi \qquad \text{(Exp. E.2)}$$

$$h_2\rho_2\pi - 2c > h_1\rho_1\pi - c > h_3\rho_3\pi - 3c \qquad \text{(Exp. E.3)}$$

$$h_3\overline{\rho}\pi - 3c < h_2\overline{\rho}\pi - 2c < h_1\overline{\rho}\pi - c < h_0\overline{\rho}\pi \qquad \text{(Exp. E.4)}$$

Inequalities (3) impose an efficiency bound on the safety stock investment. While $s=2$ maximizes firm profit if customers are availability-sensitive, $s = 3$ represents an over-investment: For $s=3$, product availability is maximal ($h_3 = 1$). However, even if customer loyalty was also maximal ($\rho_3 = 1$), the stocking cost of 3c per period are simply too high. We allowed over-investment in order to check whether F-players understood the profitability (the investment $s = 3$ is just a rational choice in the case of extreme risk aversion) and to avoid an odd number of investment-levels, which bears the risk that subjects show the tendency to pick the "prominent middle point". In addition, overinvestment in precaution makes it a much more realistic setting. For the experiment, we set the parameters of this decision problem in a way that the conditions (2) – (4) are fulfilled. Any observable investment in safety stock must then inevitably be motivated by the company's assumption that customers will look favorably on its higher level of precaution and reward it with a greater willingness to buy. In other words: The firm's investment is unambiguously based on reputational concerns.

Customer decision

The customers know that the firm has the option to invest but they do not directly observe the firms' decisions. However, they can indirectly infer the level of a firm's investment just by comparing the number of experienced and expected disruptions according to Figure E.1. Although this could imply a cognitive difficulty for the participants in the role of customers, we decided against the possibility to directly observe the investment decision because this appears unrealistically simple

and would "design away" the uncertainty about firm behavior, which is an important and challenging factor for reputation building in practice.

The customers have the choice between buying at the assigned F-player, which is another participant in the experiment, or switching to the Bot-firm (dummy player). As already explained, the Bot-firm delivers undisrupted supply because it does not use vanilla for the drink. For the same reason, the customer has a lower net valuation of this fitness drink $V_B = 6$ MU. Although this product is less attractive for the customers, the mere existence of the Bot creates competitive pressure for the F-player and provides consumers with a risk-limiting alternative if the main company is unable to deliver.

In the short-run treatment, the C-players always start with a fresh F-player at the beginning of each block, and they never play against the same F-player twice. In the long-run treatment, they are assigned to "their" F-player at the beginning of each block, regardless whether they had the last transaction with this player or with the Bot. Apart from these initializing assignments, the C-players can switch between F-player and Bot at any time. While switching to the Bot is free of charge (switching cost in this direction are hence $k_{FB} = 0$ MU), returning to the F-player is costly (switching cost from Bot to F-player is k_{BF}=6 MU). The reason for this asymmetry in switching cost is the difficulty to draw clear conclusions from churn behavior with respect to firm reputation. Customer churn as a reaction to manifest product unavailability is predominantly an act of self-protection and this act allows at best weak conclusions about the customers' attitude towards the firm. However, if the same customers are ready to return and to bear the switching cost, this "switching-back" move is based on an expectation regarding future product availability. Thus, this move can be interpreted as a sign of customer loyalty, plausibly based on firm reputation.

Similarly to the firm decision, there are formal requirements for the C-players which have to be taken into account for the design in order to induce the required preference relations.

$$EV(s) = h(s) \cdot n \cdot V_F + f(s)[\overline{d}(s) \cdot V_D - k_{FB} - k_{BF}] \qquad \text{(Exp. E.5)}$$

$$\overline{d}(s) \cdot V_D > k_{FB} + k_{BF} \qquad \text{(Exp. E.6)}$$

$$EV(s = 3) > EV(s = 2) > V_D \cdot n - k_{FB} > EV(s = 1) > EV(s = 0) \qquad \text{(Exp. E.7)}$$

Let f_d be the frequency of a disruption of duration d and $f = f_1 + f_2 + f_3$ the overall frequency of disruptions (regardless of length). The variable $\overline{d}$ is the average duration of a disruption. For the chosen distribution of Figure E.1, we have $f_1 = f_2 = f_3 = 4$ and hence f=12 occurring disruptions in total; the average duration is $\overline{d} = 2$ rounds. Note that both variables, disruption frequency f and average disruption duration $\overline{d}$, depend on the safety stock level.

Expression (5) represents the customer's expected (net) valuation EV for a given safety stock level s. Depending on s, the C-player can expect the consumption value V_F for $h(s) \cdot n$ unaffected rounds (over the entire time horizon of n periods). During affected rounds, the customer has the

chance to leave the firm. The expected payoff for this "sidestep to the Bot" is given by the second summand: The customer can expect $f(s)$ disruptions. At each disruption, the customer churns (at cost $k_{FB} = 0$ MU), receives the slightly lower, alternative consumption value V_D for $\overline{d}(s)$ rounds and finally switches back (at cost $k_{BF} = 6$ MU). Note that EV increases monotonically in s. Inequality (6) ensures that the advantage from buying at the Bot more than compensates for the switching cost (otherwise the consumer would be stuck with their own company just because the switching costs are too high which can easily be misinterpreted as loyalty).

If the firm foregoes any protection and chooses a zero or low safety stock level ($s = 0$ or $s = 1$), the customer should prefer a once-and-for-all switch to the Bot. In this case, she receives the (deterministic) payoff $V_D \cdot n - k_{FB}$.

Inequalities (7) determine the required incentives for the C-player: For high safety stock levels, i.e. $s \in \{2, 3\}$, the customer should strictly prefer the purchase at the F-player, including a temporary switch to the Bot during disrupted rounds and the subsequent return. For zero safety stock levels ($s = 0$), the C-player should strictly prefer the permanent switch to the Bot and for a low safety stock level ($s = 1$) the C-player should at least slightly prefer a permanent switch to the Bot.

Game calibration and equilibria

In addition to the distributions of disruptions (Figure E.1), we apply the parameter values $\pi = 20$ MU, $V_F = 7$ MU, $V_D = 6$ MU, $c = 6$ MU, $k_{FB} = 0$ MU and $k_{BF} = 6$ MU to ensure the conditions (2) – (4), (6) and (7). Table E.2 represents the strategic form of the game between C-player and F-player, which shows the cumulated payoffs over the total 50 rounds, assuming that the customer just plays one of the two pure strategies "F: purchase at F-player in unaffected rounds" and "B: purchase at Bot in unaffected rounds".

↓ C-player F-player →	$s = 0$	$s = 1$	$s = 2$	$s = 3$
Buy at F-player	254 , 520	290 , 460	322 , 368	350 , 172
Buy at Bot	**300 , 0**	300 , - 300	300 , - 552	300 , - 828

Table E.2: Strategic form of the game between C-player (first payoff) and F-player (second payoff)

As can be seen, the strategy-combination (Bot, $s = 0$) is the Nash-Equilibrium (NE) of the game (highlighted in Table E.2 by bold letters). Hence, in the static equilibrium, the F-player foregoes any investment and the C-player permanently switches to the Bot. However, in the dynamic setting of a repeated game, there is scope for implicit communication and cooperative strategies, which allow both players to improve their position. Compared to the static NE, the strategy combinations (F-player, $s = 2$) and (F-player, $s = 3$) represent Pareto-improvements. From these two alternatives, the first is more efficient and appears as the fairest outcome as the players' payoffs are close (322 , 368). In a repeated game setting, F-player and C-player can reach this outcome by establishing a relational contract, which is based on reciprocity. As long as they both observe that the co-player

chooses the cooperative strategy, each player is reluctant to deviate to the static NE-strategy. The F-player has the highest incentive for opportunistic behavior but at the same time he incurs the highest loss if the C-player switches to the Bot. Hence, the F-player should have a strong incentive to stick to the relational contract. Therefore, in order to convince the C-player of his cooperative intention, he needs to establish a reputation for a high level of precautions and product availability.

Hypotheses

H1 (irrelevance of the static NE): *In both, the SR and LR-treatment, the safety stock level is significantly different from zero and customers predominantly choose the F-firm instead of the Bot.*

We expect a moderate reputation effect even in the SR-treatment, which will be just enough to overcome the static NE. This stands in stark contrast to other experiments on reputation and relational contracting. However, the identification of reputation-effects is more complicated in a risk-context compared to a classic product quality-problem or labor-productivity-context for at least two reasons. First, it is impossible to unfold frequency-based risk scenarios in a one shot game. The short-run scenario requires more than one or two rounds to make it possible for C-players to learn about precaution-measures. As a result, reputation effects of smaller magnitude can in principle also occur in the short-run treatment. Second, in a risk context, the root cause of the problem is not the firm (as it is the case for product quality) but exogenous shocks, such as natural hazards, etc. This can lead to customers holding the company only partially responsible for low availability and thus being more tolerant of a lower safety stock.

H2a (firm investment): *The average safety stock level in the LR-treatment should be systematically higher than in the SR-treatment.*

H2b (customer retention): *The customers' adherence to the F-players as well as their loyalty-level after disrupted periods should be systematically higher in the LR-treatment compared to the SR-treatment.*

Hypotheses H2a and H2b are in line with established reputation experiments like Brown et al. (2004) or Falk et al. (1999). The LR-treatment offers the best opportunity for learning and for reciprocal, cooperative play. Therefore, the F-player should have the strongest incentive to establish a reputation for product availability in this treatment. As a response, the customers should positively respond to this higher level of availability by an increased willingness to stay with the F-player, both during unaffected periods and directly after affected periods. The second part of hypothesis H2b goes a little further and assumes that in the LR-treatment also customer loyalty is higher in turbulent phases of the game, i.e., phases characterized by a longer sequence of disrupted periods,

compared to the SR-treatment. The long disruption sequences (three outages of three periods duration and two outages of two periods duration) occur in the last three blocks of the game. In these crisis-periods, it is to be expected that several F-players cannot deliver, which leads to the departure of their customers. To a certain extent, this customer-churn is forced by the design and deliberately generated. What is of interest here is whether these customers return to their company in the immediate, unaffected rounds thereafter. If they do, then this would be an indication of customer loyalty.

Hence, in the context of availability reputation, customer loyalty can be measured by whether the C-player still buys or buys again from the F-player (and not from the Bot) after experiencing a disruption in blocks 3-5. As can be seen in Figure E.2, there are seven such loyalty-critical rounds in total.
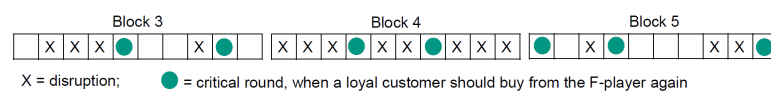

Figure E.2: Loyalty-critical rounds over the blocks $3 - 5$

To generate a loyalty-measure, we built an index as follows: If the customer did not switch at all during the critical phase in question (regardless of whether her own company was able to deliver or not), she received one point. If the customer switched to the bot due to the inability of her own company to deliver, but switched back at the next unimpaired round thereby incurring the switching costs, she receives 2 points. If the customer left the own company although this one was able to deliver then she receives 0 points. Finally, she also receives 0 points for leaving but not returning back to a company which was unable to deliver. The points are added up for each of the critical phases to a loyalty score $L \in \{0 - 14\}$.

H3 (reputation building and reciprocity): *In the LR-treatment, firms which choose a higher average safety stock-level over the initial two blocks, achieve higher sales, both in unaffected periods and affected periods.*

Since the LR-treatment provides companies with the opportunity to build up a reputation, it is to be expected that they will invest in safety stock especially during the first two blocks (20 rounds) following two objectives: Firstly to strengthen customer loyalty during the unaffected rounds and secondly to be able to count on their regular customers even in crisis phases, when they can bridge disruptions longer because of the higher safety stock. The customer, in turn, has no prior experience regarding her firm and should thus use the observations over the first 20 rounds to draw conclusions about the firm's current and future safety stock level. If the customer shows some responsiveness to the firm's reliability, she should buy at her firm during unaffected rounds and return to her firm

after stock-out periods, which is both measurable by higher sales. The expected interaction as formulated in hypothesis H3 corresponds to the classic reciprocal pattern of relational contracts.

However, even though the tendency towards reciprocally cooperative behavior is generally strong in experiments and therefore justifies the expectation of a relational contract, there are always other conceivable reasons that can explain a high safety stock and a low churn rate and that cannot be ruled out by the experimental design. For example, it is possible that C-players develop a certain solidarity simply because of the assignment to "their F-player" and, given the higher payoff risk of the firm, they want to protect it from larger losses. This would be in line with the phenomenon of "other regarding-preferences" or the widespread tendency for solidarity and willingness to help. To have at least one indicator of whether loyalty is due to the expectation of high product availability, we always asked subjects what they think which strategy their co-player chose in the last block and what they expect for the next block. To avoid further complexity for the participants, we did not incentivize these queries.

E.4 Results

We conducted the experimental sessions using the infrastructure of the Karlsruhe Decision & Design Lab (KD²Lab) at the Karlsruhe Institute of Technology. Due to COVID-19 restrictions, the experimental sessions themselves were conducted remotely. Participants were recruited through a pool of the KD2LAB. We recruited 262 participants (in 13 sessions ranging from 12 to 30 participants) across two treatments at the Karlsruhe Institute of Technology in May 2021. For each session, one of the two treatments was chosen. Participants were randomly assigned to either the company's or the customer's role. In the second step, participants were randomly assigned to each other. Irrespective of their role, each participant received the same full set of instructions. These were shown on the participants' screens and then read aloud by the experimenter to achieve transparency and common knowledge. The average session duration, which included some familiarization with the game, the game itself, and a post-experiment questionnaire, was 60 min. The average hourly compensation was 12.97 Euro, which included a 5.00 Euro show-up fee. The programming of the experiment took place in Python and was afterward implemented in oTree. Across all treatments, the average age of the participants was 23.7 years old, and 60.7% of the participants were female.

H1 (irrelevance of the static NE): *In both, the SR and LR-treatment, the safety stock level is significantly different from zero and customers predominantly choose the F-firm instead of the Bot.*

Regarding the first part of the hypothesis, Table E.3 gives an descriptive overview of the distribution of current safety stock levels of all firms over the 50 periods. The table shows the safety stock-levels for SR- and LR-treatment as well as the aggregate level.

Current s-level per Period	Overall % $(n = 6550)$		SR % $(n = 3200)$		LR % $(n = 3350)$	
0	24.5	(1602)	25.8	(824)	23.2	(778)
1	23.1	(1515)	24.00	(768)	22.3	(747)
2	28.7	(1882)	30.4	(973)	27.1	(909)
3	11.8	(776)	10.2	(326)	13.4	(450)
4	5.3	(346)	4.3	(137)	6.2	(209)
$>= 5$	11.83	(775)	5.4	(172)	7.6	(256)

Table E.3: Firms' current safety stock-level per period

The second part of the hypothesis, which is related to the choice of the customer (again for overall results and separated for SR- and LR-treatment), is summarized in Table E.4.

Current status	Overall % $(n = 6550)$		SR % $(n = 3200)$		LR % $(n = 3350)$	
Firm	74.0	(4844)	73.0	(2336)	74.9	(2508)
Bot	26.0	(1706)	27.00	(864)	25.1	(842)

Table E.4: Customers' overall choice of firm or bot

Obviously, the descriptive data from tables E.3 and E.4 for both variables show that we cannot reject hypothesis 1. Additional tests substantiate the obvious: The safety stock chosen by the F-players is significantly different from zero (Wilcoxon-test: $p < 0.001$***) and the C-players mostly choose the F-company instead of the bot (Chi-Square-test: $p < 0.001$***).

H2a (firm investment): *The average safety stock level in the LR-treatment should be systematically higher than in the SR-treatment.*

A first insight into the evaluation of H2a was given in Table E.3. Figure E.3 shows the moving average of the safety stock-level over the entire 50 periods for the LR-treatment and SR-treatment (after removing three outliers). The average safety stock-level for the LR-treatment (s-LR = 1.77) clearly exceeds the SR-level (s-SR = 1.62). A Mann-Whitney-U-test reveals a highly significant effect (U = 411.00; $p < 0.001$***) and also a high effect size (Cohen's d = 0.977). Hence, we can clearly reject the null hypothesis that the average safety stocks for SR and LR do not differ systematically.
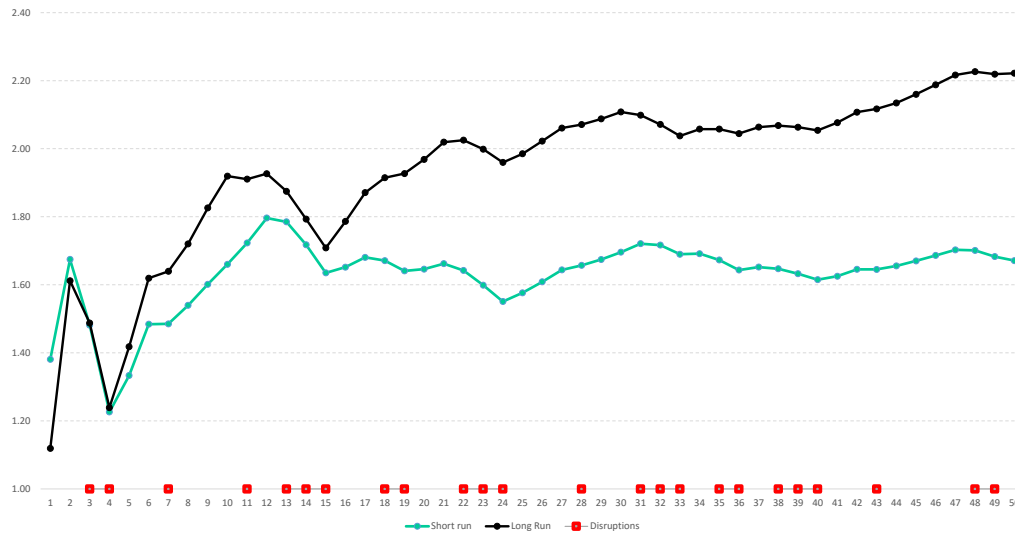
Figure E.3: Moving average of safety stock

H2b (customer retention): *The customers' adherence to the F-players as well as their loyalty-level after disrupted periods should be systematically higher in the LR-treatment compared to the SR-treatment.*

With hypothesis H2b we first postulated that - as an implied consequence of the result of H2a - consumers should be systematically more frequent with their F-player in the LR-treatment than in the SR-treatment. However, as Table E.5 shows, this is not the case.

treatment	# periods with F-player: mean (SD)	% of all undisrupted periods	N	T	p-value (one-sided)
LR	21.47 (6.058)	82.6%	67	0.982	0.082
SR	20.46 (5.668)	78.7%	64	0.982	0.082

Table E.5: LR- vs. SR-Treatment

Albeit the cumulated number of rounds which the customers stay with their F-player is larger than the number of rounds they stay with the Bot, this number is just very slightly larger than in the SR-treatment. For this comparison, we looked at the share of the 26 unaffected rounds because we do not expect customer retention during disrupted periods.

In the LR-treatment, the F-player can retain the customer only one more round compared to the SR-treatment. A t-test shows that this difference is not significant. Seemingly, the firms' investments in the LR-treatment did not pay off, at least with respect to the unaffected rounds.

Now we look at the second part of H2b and want to find out whether there is a difference between LR and SR with respect to the customer loyalty index. Figure E.4 illustrates how the index-values of the customers of the SR and LR-treatment are distributed over the whole range of the loyalty index. The picture shows that customers in the LR-treatment on average have a larger loyalty index than those in the SR-treatment. This difference is also significant (Mann-Whitney-U: $U = 2622.00$; $p = 0.013*$). As a Cohen's d of 0.382 indicates, the effect size is low to medium.
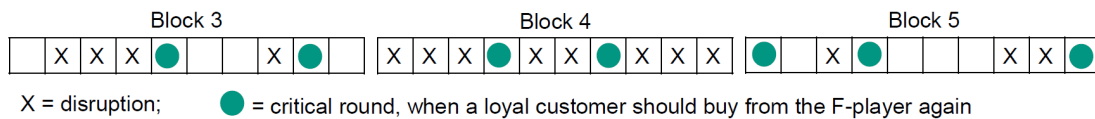

Figure E.4: Loyalty index

Hence, although there is no customer retention-effect measurable over all 26 unaffected periods (possibly because the customer retention is already quite high in both treatments), the loyalty-index of customers in the LR-treatment is significantly larger compared to the customers in the SR-treatment. This means that customers in the LR-treatment show a stronger commitment to their firm right after an affected period. In this sense, the reciprocal effect of relational contracting is at work with respect to higher precautions on the side of the firms and higher unavailability-tolerance on the side of the customers.

H3 (reputation building and reciprocity): *In the LR-treatment, firms which choose a higher average safety stock-level over the initial two blocks, achieve higher sales, both in unaffected periods and affected periods.*

To analyze hypothesis H3, we carried out a correlation analysis. In a first step we looked at the interaction of the average safety stock-level over all 50 periods of the entire game (variable AvStock50) with the total sales of the firms over all 50 periods (variable Sales50). The upper right diagram of Figure E.5 shows the correlation and the first line of Table E.6 reports the statistical details.

As can be inferred from the scatter-plot and the table, the two variables are positively correlated in a nearly identical way for both treatments and the correlation is statistically significant. This result is plausible as it reflects the simple purpose of a safety stock, namely to bridge interrupted periods: The more safety stock is available over the entire game, the more sales can be realized. We thus oberve the direct compensation-effect of safety stock, which is not related to reputation and thus occurs in a comparable manner in both treatments.

treatment	interaction variables	Spearman-Rho	p-value (one-sided)
LR	AvStock50 – Sales50	+0.265	0.018*
SR		+0.252	0.024*
LR	AvStock20 – Sales50	+0.384	0.001***
SR		+0.151	0.121
LR	AvStock50 – Sales26	+0.009	0.473
SR		+0.035	0.394
LR	AvStock20 – Sales26	+0.132	0.151
SR		-0.075	0.281

* $p < 0.05$ (Statistically significant on 5% significance level)

*** $p < 0.01$ (Statistically significant on 1% significance level)

Table E.6: Correlations of safety-stocks in LR- and SR-Treatments

In the diagram below (bottom right in Figure E.5), we find the relationship between AvStock50 with the sales in the non-disrupted 26 periods of the game (variable Sales26). As expected, the correlation vanishes in parallel for both treatments, which confirms that the variable AvStock50 indeed captures the direct effect of safety stock: In undisrupted rounds, there is nothing to bridge and as safety stock does not serve any further purpose (AvStock50 does not trigger any reputational effect), sales are not affected. This can be seen in detail in the third row of table E.6, where the correlations are lowest (or even non-existent) for both treatments.
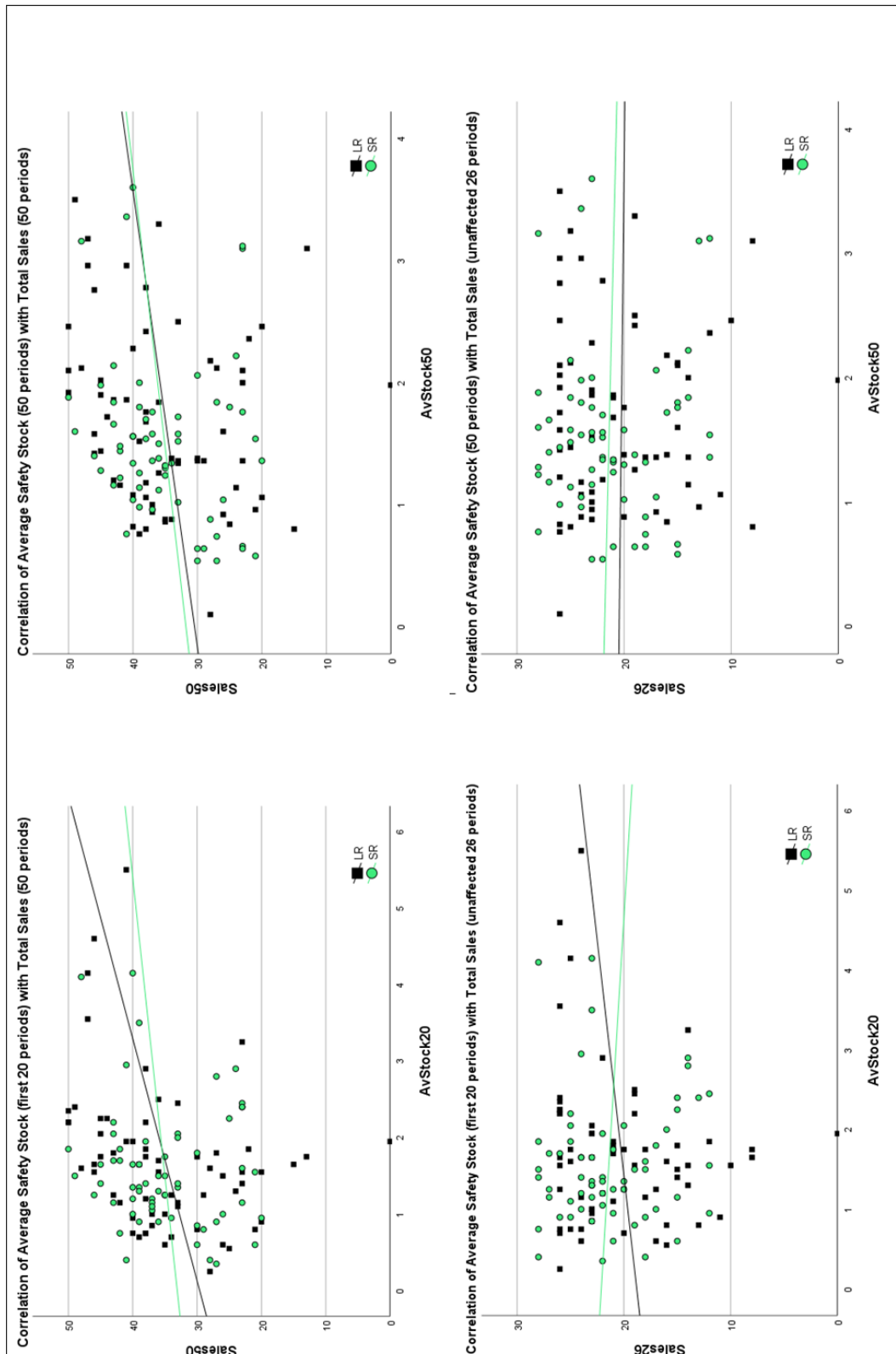
Figure E.5: Correlation of average safety stocks with total sales

The actual test of hypothesis 3 is now done by considering only the first 20 rounds for building up safety stock (variable AvStock20), since these initial periods can be used by the firms to specifically form a reputation and build up a relationship with their customer. However, the first 20 rounds are too short to cushion interruptions over the entire game, which is why the focus here should be on the indirect reputation effect rather than the direct compensation effect. Note that there is just limited scope for a reputation effect in the SR-treatment because the duration of the interaction is too short.

The scatter-plot in the upper left corner of Figure E.5 as well as the second line in Table E.6 confirm the expectation. The correlation in the SR-treatment is clearly reduced and no longer significant while the correlation in the LR-treatments becomes substantial. The strong and highly significant correlation in the LR-treatment provides strong evidence for a reputation-effect and confirms that sales are also stabilized by an indirect effect, which is based on a relational contract between seller and buyer.

To complete the analysis, we also look at the interaction between AvStock20 and Sales26 as the remaining constellation. Apparently, the correlations diverge because the correlation in the SR-treatment even becomes slightly negative while the correlation in the LR-treatment is still positive. However, this correlation is too weak (and not significant) in order to draw conclusions on the scope for reputational effects to even stabilize sales in undisrupted periods.

E.5 Summary & Discussion

In this study, we experimentally investigated whether key properties of relational contracts, such as reputation building, reciprocity, and loyalty, can also be transferred to a risk context. In this experiment, players in the firm role were able to protect themselves against supply failures by building up a safety stock, while players in the customer role were able to switch to a dummy player as the firm's "competitor" for free, but only by incurring switching cost if they move back to their F-player. The game was played in a SR and LR variant, with the latter designed to allow players to build a higher safety stock as well as customer loyalty.

First, it was found that the opportunity to build a reputation as well as a customer relationship that existed in the LR treatment was indeed used by the firms by building a higher safety stock over the entire 50-round period. However, this only marginally increased customer retention over the 26 unaffected rounds. On the one hand, this low responsiveness "on aggregate" is due to the fact that customer loyalty is already very high (even in the SR-treatment at just under 79%) and, in addition, customers occasionally switch to the bot in the LR-treatment as well. The advantage of customer loyalty initiated by the LR-treatment thus lies primarily with the customers. The companies do not experience any noticeable revenue gain at the aggregate level, but they bear the higher costs for the safety stock.

Nevertheless, companies have an advantage from precautionary behavior in one important respect: Customer loyalty immediately after supply interruptions is significantly higher in the L treatment than in the short run and also has a noticeably positive effect on the companies' sales. So especially in the immediate aftermath of more frequent or larger crises, supply arrangements are not only the means of choice for protecting one's own market share or - in extreme cases - also for protecting one's own existence. Such indirect effects through customer loyalty are to be expected, especially in times of crisis, which can certainly be worthwhile, since the aim after crisis events is to get one's own processes up and running again as quickly as possible. A loyal customer base can then support this critical moment of "resurrection"

The development of reputation and customer loyalty was finally demonstrated by the correlation analysis for hypothesis 3. If one filters out the effect of the first 20 rounds, which a company can use to specifically build customer loyalty, then the effect can be neatly isolated. Moreover, the correlation analysis reveals that the heterogeneity of the firms in the LR scenario is the main reason why customer retention cannot be detected on an aggregate level: Only those LR-firms that use the first 20 rounds to build a reputation as a reliable supplier can thus effectively address customers' responsiveness to be more loyal and thus generate the reciprocal pattern of efficient cooperation typical of relational contracts. However, this correlation also implies the downside of relational contracts: The other LR-firms that leave this opportunity unexploited experience an all the more significant drop in their sales. This is most likely because they fail to meet the higher expectations of LR-customers.

To the best of our knowledge, this study is the first which shows that relational contracts can also unfold in a risk context. In this regard, the most important managerial implication of our study is the message that it is worthwhile for companies to invest in costly safety stocks not just for motives of self-protection. Precautionary risk management strategies can pay off in the form of a double dividend of reduced supply shortages on the one hand and a more stable and crisis-proven customer relationship on the other hand. In highly uncertain and crisis-ridden times due to pandemics, war, climate change and eyber attacks, loyal customer basis acts like an insurance, in particular if the companies have multiple customer contacts.

As already outlined in the introduction, it is more difficult to measure reputation effects and the features of relational contracting in a context of frequency-based risks (compared to, e.g. product quality issues in a stable and deterministic market environment (Gans, 2019)). For this reason, there are further possible explanations why we were not able to measure customer retention on an aggregate level. First, the block length of 10 rounds could be too long for the SR-treatment (10 rounds might be already enough to create a bond between company and customer). And second, the disruptions are exogenous disturbances to the transaction ("noise") that make it hard for the customer to differentiate between particularly reliable and particularly unreliable behavior of the company. Against the backdrop of these challenges our study can be seen as an important first step into the interesting and relevant research agenda of risk-related relational contracting.

The results of this study have to be evaluated in the light of the upcoming trend of increasingly demanding customers and decreasing customer loyalty. All this will make it difficult to "play the reputation mechanism" for firms. The same is true for informational issues. Reputation is highly dependent on the available information flows and the availability of a "memory" on the side of the customers and hence their willingness to memorize and honor positive purchase experience.

However, this study can provide some guidance which elements of the reputation mechanism will still be effective and which are not. In other respects, it could even be easier for firms to develop such a reputation in the real world than in an experimental setting. On real markets, customers (predominantly) decide for themselves which companies they want to buy from permanently. This means that customer loyalty in reality is usually "underpinned" by a stronger preference, which was deliberately kept low in our experiment with the valuation difference of 1 MU so as not to generate a bias in the direction of the long run. With respect to real markets, it would be exciting to see how top managers, strategic planners, risk managers and marketing experts would play the company role.

E.6 Conflict of Interest Statement

E.7 Acknowledgements

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