Lisbon School of Economics & Management
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Masters Final Work

Dissertation

Supply Chain Resilience: A Portuguese Pharmaceutical Case Study

Diogo André Jesus Portas

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Supervisor:
PhD Professor Graça Silva

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Abstract

In recent times with the globalization of the economy, companies' supply chains have been under increasing pressure and more prone to disruptions. The risks that supply chains face have exponentially increased due to this added complexity. As such, understanding what risks affect supply chain and how supply chain resilience can be potentialized is of high importance.

This study focusses on identifying the risks present in the Portuguese pharmaceutical sector and the supply chain resilience practices adopted by supply chain linked professionals in this same sector. This study focusses on the risks and supply chain practices present in the pharmaceutical sector. Seven interviews were conducted with supply chain professionals from six companies with presence in Portugal. An analysis is made in order to understand what those professionals and companies identified as supply chains risks and what supply chain resilience practices they have adopted.

The result revealed a total of twenty-one identified supply chain risks with a primary focus on environmental, supply and process risks. Key risks include overextension of the supply chain due to globalization and supplier concentration.

Furthermore, results also indicated that interviewed professionals and their companies focused more on the readiness and responsiveness phases of supply chain resilience, often neglecting the recovery and growth phases as shown by the type of supply chain resilience practices they adopt. The major consequence of supply chain disruptions was identified as stockouts, which in the pharmaceutical sector has not only financial but also public health consequences.

Finally, there were twenty-one supply chain resilience practices identified within the visibility, flexibility, redundancy and collaboration dimensions. Results point out that companies do understand supply chain resilience but often limit its application in informal programs and with limited top management support. Regulation in this sector was also found to be detrimental to supply chain resilience.

Resumo

Nos últimos tempos, com a globalização da economia, as cadeias de abastecimento das empresas têm estado sob crescente pressão e mais propensas a perturbações. Os riscos que as cadeias de abastecimento enfrentam têm aumentado exponencialmente devido a esta complexidade adicional. Devido a isso, é muito importante compreender os riscos que afetam a cadeia de abastecimento e como potencializar a resiliência da cadeia de abastecimento.

Este estudo centra-se na identificação dos riscos presentes no setor farmacêutico português e nas práticas de resiliência da cadeia de abastecimento adotadas pelos profissionais ligados à cadeia de abastecimento neste mesmo setor. Este estudo centra-se nos riscos e nas práticas da cadeia de abastecimento presentes no setor farmacêutico. Foram realizadas sete entrevistas com profissionais da cadeia de abastecimento de seis empresas com presença em Portugal. Foi realizada uma análise de modo a compreender o que estes profissionais e empresas identificam como riscos da cadeia de abastecimento e quais as práticas de resiliência da cadeia de abastecimento que adotam.

No total, o estudo identificou um total de vinte e um riscos na cadeia de abastecimento, com principal foco nos riscos ambientais, de abastecimento e de processo. Os principais riscos incluem a sobre extensão da cadeia de abastecimento devido à globalização e à concentração de fornecedores. Adicionalmente, os resultados também indicaram que os profissionais entrevistados e as suas empresas se concentraram mais nas fases de preparação e resposta da resiliência da cadeia de abastecimento, muitas vezes negligenciando as fases de recuperação e crescimento, conforme demonstrado pelo tipo de práticas de resiliência da cadeia de abastecimento que adotam. A principal consequência das perturbações na cadeia de abastecimento foi identificada como a falta de stock, o que no setor farmacêutico tem consequências não só financeiras, mas também para a saúde pública.

Por fim, foram identificadas vinte e uma práticas de resiliência da cadeia de abastecimento nas dimensões de visibilidade, flexibilidade, redundância e colaboração. Os resultados apontam que as empresas compreendem a resiliência da cadeia de

abastecimento, mas muitas vezes limitam a sua aplicação a programas informais e com apoio limitado da alta administração. A regulamentação neste setor também foi considerada prejudicial à resiliência da cadeia de abastecimento.

Contents

1. Introduction

During several decades, supply chains across the world experience a period of relative stability but a new era of turbulence has ushered in (Christopher & Holweg; 2011; Durach et al., 2015). Additionally, supply chains have followed a trend of globalization with increasing complexity which in consequence also makes them more costly and exposed to risk of disruption (Pettit et al., 2010; Zhao et al., 2020).

Several studies have reported that a disruption can reduce a firm ability to gain competitive advantage as well as having a negative effect on a company financial result (Pettit et al., 2013; Pu et al., 2023; Zhao et al., 2019).

Recent events like the 2011 Japan earthquake and Thailand floods, 2012 hurricane Sandy, 2019 Covid-19 pandemic and the 2022 Ukraine-Russian war (Carvalho et al., 2021; Chopra & Sodhi, 2014; Cotta et al., 2022; Dyson et al., 2023; Kashiwagi et al., 2021) have brought increased public and academic attention to ways to mitigate the negative impacts that these events cause in supply chains.

Supply Chain Resilience (SCR) is recognized as a key capability to operational excellence, by enabling a company to give a quick and timely response to rapidly changing business environments (Mishra et al., 2022). SCR has recently attracted academic interest, with several studies attempting to deepen knowledge of the subject (Christopher & Peck, 2004; Han et al., 2020; Ponomarov & Holcomb, 2009; Tukamuhabwa et al, 2015).

Nevertheless, the main research is still focused on theoretical, macro-level aspects. SCR literature shows that empirical research on supply chain resilience practices remains underdeveloped (e.g., Cotta et al., 2022). Furthermore, most case studies conducted on this topic tend to be cross-sectional rather than focused on one industry (Aigbogun et al., 2014).

This study intends to answer the following research question: How do pharmaceutical companies develop supply chain resilience? The specific research objectives are:

- Understand the main supply chain risks that affect pharmaceutical companies,
- Understand how pharmaceutical companies build and develop SC resilience.

To answer this question, a case study approach was adopted and primary data was collected through semi-structured interviews with managers in supply chain management positions in the Portuguese pharmaceutical industry.

This work structure is divided into five main chapters. The first chapter contextualizes the study and presents its research questions and objectives. In the second chapter it's presented a literature review about the main topics of this work: disruptions and risk, supply chain resilience and its dimensions and phases. The following chapter describes the applied methodology, and the characterization of the companies included in this study. In the fourth chapter, the study findings are presented and discussed. In the final chapter, the conclusions of this work are presented as well as its limitations and contributions.

2. Literature Review

2.1 Disruptions and Risk

The increasing market globalization has, in consequence, created a growing pressure in supply chains to adopt lean practices, reduce costs and Just-in-Time methodologies (Blackhurst et al. 2005; Katsaliaki, Galetsi, & Kumar, 2021**;** Tang, 2006). Keeping with this, supply chains have also become more and more interconnected and subjected to more uncertainties (Bret et al., 2021).

These mentioned drivers have potentialized the occurrence of disruptive events along the supply chain, which have a negative impact on companies as well on the entire network (Ponomarov & Holcomb 2009; Shuai, Wang, and Zhao, 2011).

These events cause disruption in the flow of goods (Tukamuhabwa et al, 2015) making firms exposed to financial and operational risks (Craighead et al., 2007; Wakolbinger & Cruz 2011). These impacts are exorbitated by the multiple connections along the global network (Pereira et al., 2014). With increasing turbulence, the likelihood of these disrupting events happening also grows (Stadtfeld & Gruchmann, 2022). Major examples of these events are the 9/11 terrorist attack, SARS, Avian Influenza, COVID-19, the Fukuoka Earthquake, (Ivanov, 2020; Shuai et al., 2011) and the impact of these disruptions in supply chains has been studied (Ivanov et al., 2017).

The ability to deal with these events in an effective way and being able to mitigate them, assumes an ever-increasing importance for a company to ensure survival (Pereira & Da Silva, 2015). For this reason, supply chain resilience, or in other words creating conditions in organizations that make it possible to avoid, prevent or react to the after mentioned disruptions have received increased attention in recent times (Ali & Gölgeci, 2019; Christopher and Peck, 2004; Pettit et all, 2019).

In every activity in the supply chain, there is an inherent risk associated with it (Ponomarov & Holcomb, 2009). Risk taking is generally perceived as an inevitable part of management (March & Shapira, 1987). These risks represent the possibility of a disruption or event happening that causes an interruption in the flow of information, materials or products between suppliers and clients (Peck, 2006).

A risk results in a sudden or gradual divergence between market demand and supply (Jüttner et al., 2003). Other definition put forward puts risk as the probability of an event versus its negative impacts on a business (Christopher & Peck, 2004). Manuj and Mentzer (2008) describes risk as an expected outcome of an event with some degree of uncertainty. Hence, risk can be defined as possible consequence of a more or less probable event that results in a mismatch of the markets demand and the ability of the supply chain to meet them (Bret et al., 2021).

Faisal et al. (2006) characterized risk in two main dimensions: impact (as the level of the repercussions) and likelihood (as the probability of occurrence). These dimensions are important because not all risk actually manifest in the supply chain (Jüttner & Maklan, 2011). Manuj and Mentzer (2008) add two other dimensions to characterized risk: speed (the pace of with a risk can occur) and frequency (the rate of recurrence of an event). The speed of risk can be divided into three main categories: the speed of the event that results in losses, the quickness of the loss occurring and the rate the risk is discovered (Manuj & Mentzer, 2008).

Risks with low probability to occur but with high impact are more tolerated as they have too high of a cost/effectiveness rate and companies have low capacity to control them (Jüttner & Maklan, 2011). Nevertheless, these same risks are the ones that threaten more severely the continuity of a business (Pournader et al., 2016). Chopra and Sodhi (2014) echoes this notion by affirming that disruptive risks (less frequent,

independent of supply chain processes) have more impact on supply chain activities than recurrent risks (more frequent, dependent on practices).

Supply chain vulnerability is a concept closely related to risk (Christopher & Peck 2004). Svensson (2000) defined it as the existence of deviation leading disturbances in the supply chain in the normal sequence of activities while Jüttner and Maklan (2011) argue that vulnerability is associated to the susceptibility of the supply chains to likely disruptions. Complexity, long lead-times and plant location are some of the factors that influence vulnerability in a supply chain. The more vulnerable the supply chain is the more likelihood there is of a disruption occurring (Sheffi & Rice, 2005). Problems can also arise from organizations' cultural patterns and perceptions of risk (DuHadway et al. 2018).

Thus, risk management can be defined as the recognition of potential sources of risk and consequent enactment of corresponding strategies in order to prevent or mitigate the supply chain's vulnerability to them (Jüttner et al., 2003). This definition is one of the more referenced in literature (Kamalahmadi and Parast, 2016), but there is not an overwhelming acceptance of a single definition (Ponomarov & Holcomb, 2009). One other definition puts risk management as the measures taken with the purpose of identifying and mitigate risks (Tang, 2006).

Bandyopadhyay et al. (1999) and later Jüttner et al. (2003) identified four main areas of risk management: 1) risk identification; 2) risk analysis; 3) risk reduction, transfer, acceptance; 4) risk monitoring. Risk identification is the process of finding risk along the supply chain, while risk analysis assesses the probability and impact of said risks. Risk treatment consists in developing action and strategies to avoid, mitigate or deal with risk and risk monitoring compromises of observing developments in the supply chain that might influence and affect present risks (Manuj & Mentzer, 2008; Zsidisin et al., 2005).

Risk sources are the environmental, organizational or supply chain-related variables that have influence on the supply chain outcome variables (Jüttner et al., 2003). There are a wide variety of sources of risk which results in an ever-increasing complexity to manage them all (Hägele et al., 2023). Risk drivers can be grouped into environmental sources (risks arising from interactions between the supply chain and environment), network-related sources (present within the range of the supply chain)

and organizational sources (arising from interactions between organization within the supply chain) (Jüttner et al., 2003).

Later, Kong & Li (2008) categorized risk sources in 3 main areas: 1) Environmental Complexity: This category relates to the exposure to risk due to macroeconomic, political and natural environments; 2) Internal Complexity: Resulting from the interactions between members of the supply chain and it's dynamism; 3) Insufficient Information and Knowledge: Arising from the lack of full information about the environment, partners, other players and firms itself.

In order to understand risk management and further expand the knowledge in the subject, it's important to segment and categorize various kinds of risks (Habermann, 2009; Schlegel & Trent 2012) so that companies can become more prepared to manage and deal with disruptions (Pereira & Da Silva, 2015). Although a variety of studies have been done on this matter there is not a consensus (Katsaliaki et al., 2021; Shekarian & Mellat Parast, 2020; Sodhi, Son, & Tang, 2012).

Risks can be divided due to their nature and source in five main areas: process risk, control risk, demand risk, supply risk and environmental risk (Christopher & Peck, 2004). This categorization is also suggested by Shekarian and Mellat Parast (2020): 1) Demand risk which entails risks from a) demand forecasting deviations and b) disturbances on the flow of products to markets, (e.g. volatile demand, market changes, client payment delays, etc); 2) Supply risk which relates to a) deviations in flow of materials and b) deviation in information from upstream, (e.g. materials delivery lead time failure, supplier quality problems, outsourcing issues, etc); 3) Process risk involving a) failure to meet outlined lead time and quantities deliveries, for inbound, outbound or in-house reasons and b) disruption in internal owned assets and infrastructures, (e.g. factory shutdowns, labor disputes, breakdown of IT infrastructure, etc); 4) Control risk is associated with the control organizations exert over their processes and systems, (e.g. lack of collaboration, asymmetric power relations); 5) Environmental risk are risk external to the organization, (e.g. political or economic instability, epidemics, natural disasters, etc). Similar categories are suggested by Safari et al. (2022): demand risks, supply risks, organizational risk (related to changes within the organization), operational risk (related to processes within the supply chain) and environmental risks. Some research suggests that supply risks have a more severe effect on a firm than demand

risks (Chen et al., 2013). Supply chain risk undermines its performance (Chen et al., 2013) so it's imperative understand risk, it's sources and develop adequate strategies to mitigate, avoid or deal with it in order to be able to design more resilient supply chain (Colicchia et al., 2010) and assure the continuity of core supply chain processes (Pettit et al., 2010; Pettit et al., 2013).Tang and Tomlin (2008) divided risk into six categories: supply risks, process risks, demand risks, intellectual property risks, behavioral risks, and political/ social risks. Supply, operational, demand and security risk are the categories suggested by Manuj and Mentzer (2008).

Chopra and Sodhi (2004) provide another categorization of risk based on cause: a) disruptions – natural disasters, supplier bankruptcy; b) delays – hindrances in supply; c)systems – information structure breakdown; d) forecast – bullwhip effect, inaccuracy forecasting; e) intellectual property – global outsourcing and markets duplication; f)procurement – single sourcing, industry capacity; g) receivables – client financial capacity; h) inventory – obsolescence, demand variations; i) capacity – capacity cost and flexibility.

Another way to categorize risks is by whom they affect: a) environmental – affecting the overall context across industries, b) industry – affecting specific industry segments, c) organizational – affecting specific firms, d) problem-specific – specific to how the organization solves problems and e) decision-maker – related to how a decision-maker individual or group operates (Rao & Goldsby, 2009).

Risks can also be divided into operational risk and disruption risk (Kleindorfer & Saad, 2005). Operational risks usually rise from coordinating supply and demand and are more frequent while disruption risk comes from disturbances to normal activities and are less frequent but more impacting. With effective risk management, organizations can gain visibility, be more proactive and prepared to deal with disruptions (Kong & Li, 2008).

2.2 Supply chain resilience

The word resilience comes from the word *resiliere* which means *bounce back* (Shishodia et al., 2021) and until a recent time the term was not well-known in business (Pereira & Da Silva, 2015). Supply chain resilience started to receive special attention in the early 2000's with the work of Christopher and Peck in 2004 and Sheffi in 2005.

Although resilience was initially a very underdeveloped topic, the apparent ability of some supply chains to recover from unavoidable risk events more effectively than others has prompted recent research to gain further knowledge on the subject (Nikookar et all, 2024). Even so, resilience is still a somewhat unexplored subject with varying different approaches. Various authors have tried to define supply chain resilience but there still isn't a unified, comprehensive definition (Kamalahmadi & Parast, 2016).

One of the earliest definitions of supply chain resilience was that proposed by Rice et al. (2003), which is the ability to respond to an unexpected disruption and restore normal operations. Christopher and Peck (2004) maintain the concept of resilience as the ability of a system of returning to its original state but add that moving on to a new, improved state after some level of disturbance is also an important part of that concept.

Subsequent studies expand on these definitions and frame them on a supply chain level. Ponomarov and Holcomb (2009) expand the definition by describing resilience as the capability of an organization to prepare, respond and recover from unexpected disruption while maintaining its operations at a desired level and maintaining control over its structure and inter-connectedness. Hohenstein et al. (2015) refers that ensuring better financial performance, market share or customer service is the final objective of being able to recover from disruptive events.

A more complete definition is brought forward by Tukamuhabwa et al. (2015) which claims that resilience is the ability to prepare for a disruption and/or respond to it but should be done in a cost-effective way while progressing to a better state of operations than prior to the disruption.

More recent definitions proposed that resilience is the capacity of a supply chain to persist, adapt or transform not in the face of a disruption but change in general (Wieland & Durach, 2021). Similarly, Stadtfeld and Gruchmann (2022) defines supply chain resilience as an organization capability to prepare, respond and recover from unexpected and expected disruption in a quick and efficient way to return to a better state than pre-disruption in order to gain competitive advantage.

Most definitions of SCR in the literature present supply chain resilience as the ability to react, cope, adapt and withstand disruptions (Hohenstein et al., 2015). This

definition is reflected in the various phases of resilience: readiness, responsiveness and recovery (Jüttner & Maklan, 2011; Ponomarov & Holcomb, 2009; Sheffi & Rice, 2005).

The most explored phases are responsiveness and recovery phases (Hosseini et al., 2019; Jüttner & Maklan, 2011; Shuai et al., 2011), which are viewed as central to the notion of resilience (Hohenstein et al., 2015). The response phase is very referenced in the literature as the phase where an organization reacts to an expected or unexpected disruption (Han et al., 2020). The recovery phase refers to the ability to bounce back after from the post description state (Christopher & Peck, 2004; Ponomarov & Holcomb, 2009). The importance of recovery to resilience has been discussed in the literature (e.g., Hägele et al., 2023). Compared to the two previously mentioned phases, readiness is not as mentioned (Han et al., 2020; Hohenstein et al., 2015; Ponomarov & Holcomb, 2009). However, readiness is an important phase of resilience (Hohenstein et al., 2015) as it is the phase where companies make efforts to detect, anticipate and prevent disruptions (Chowdhury & Quaddus 2016; Ivanov & Dolgui, 2020). The more a firm invests in this phase, the less impact a disruption will have in subsequent phases (Bret et al., 2021). Some studies have shifted the focus from simply responding and recovering to a more comprehensive view of how to deal with disruptions (Ali et al., 2017). Several studies (e.g., Tukamuhabwa et al, 2015; Wieland et al., 2023) recognize the need of an additional phase. This perspective defends that although it is important to prepare, respond and recover from disruptions it is also important to develop the supply chain after the disruption in order to move to a better state (Nikookar et all., 2024). This phase is still the one that receives less attention (Ali et al., 2017).

A systematic literature review developed by Hohenstein et al. (2015) supports this perspective by dividing resilience into four phases: 1) readiness, 2) response, 3) recovery, 4) growth. This division implies that the resilience of the supply chain should be assessed through the preparation for a disruption, the response to an event, the recovery from the event and the resulting growth after the event (Hohenstein et al., 2015; Tukamuhabwa et al., 2015). In line with this perspective, Kamalahmadi and Parast (2016) propose three main phases: 1) Anticipation - predicting and preparing for disruptions, based on proactive though and plans; 2) Resistance - to be able to withstand and deactivate the disruption before it expands by maintaining control over structure

and functions; 3) Recovery and response - respond to the disruption and minimize future impacts using rapid and effective reactive actions.

Identifying and developing the dimensions that make up supply chain resilience is an essential part of establishing an organization that can deal with disruptions (Pettit et al., 2013). Ponomarov and Holcomb (2009) emphasized the need for different dimensions and their relationships in order to improve resilience.

The dimensions that compose supply chain resilience aren't still well defined and neither are their boundaries (Hägele et al., 2023; Pettit et al., 2013). This divergence results in inconsistent use of terminology to describe what does creates and develops resilience (Hohenstein et al., 2015).

Some authors describe it as capabilities (Jüttner & Maklan, 2011; Pettit et al., 2010; Pettit et al., 2013), enablers (Agarwal et al., 2020) ; elements (Christopher & Peck, 2004 ; Harrison; 2018; Hosseini et al., 2019; Peck, 2005), strategies (Bayramova et al., 2021); antecedents (Ponomarov & Holcomb 2009; Spieske & Birkel, 2021) competencies (Wieland and Wallenburg 2013), enhancers (Blackhurst et al., 2011), drivers (Agrawal and Jain 2021), dimensions (Chowdhury & Quaddus 2017) and dynamic capabilities (Stadtfeld & Gruchmann, 2022). In this study, the term dimension is used. These dimensions that make up supply chain resilience aren't static. They are to some extent interlinked and there is also some overlap between them, which promotes both synergies and trade-offs between them (Tukamuhabwa et al., 2015). They can also be proactive, reactive or both dimensions of resilience (Ali et al, 2017; Wieland & Wallenburg, 2013).

2.3 *Supply chain resilience dimensions and practices*

A common recognized dimension that organizations require in order to develop supply chain resilience is visibility (Kong & Li, 2008; Pettit et al., 2010). Through visibility, companies can increase their supply chain resilience by better understanding the sources of risk (Colicchia et al., 2010).

Supply chain visibility can be described as the ability to see through the supply chain (Christopher & Peck, 2004). It can also be translated as the ability for a company to know the identity, location and status of the events along the supply chain both in the present

or in the future (Francis, 2008). Its main objective is to enable information transparency along the supply chain on orders, transportation and distribution (Fiksel et al., 2015; Jüttner and Maklan, 2011; Melnyk et al., 2010; Sheffi, 2001; Smith, 2004; Pettit, Fiksel, & Croxton 2010; Wei & Wang, 2010). It's also important to the readiness phase, enabling to perceive possible disruptions (Van der Vorst & Beulens, 2002) but also to the response phase by making it feasible to perceive changes and react to them in a timely manner (Wullenburg, 2012).

By increasing visibility, companies are also increasing their confidence on the certainty of events along the supply chain and their ability to react appropriately (Christopher & Lee, 2004). The use of technological tools (Pereira & Da Silva, 2015) as well as a focus on collaboration and sharing with other supply chain members (Christopher & Lee, 2004) increases visibility.

Several studies present visibility not as a stand-alone but as an antecedent of agility (Christopher & Peck, 2004; Chopra & Sodhi, 2004; Faisal et al., 2006; Li et al., 2009; Tang & Tomlin, 2008). Jüttner and Maklan (2011) found that visibility was an important factor in the timely intervention of risk events and had helped to mitigate the negative impact of these events. Blackhurst et al. (2005) also recognize that visibility was an important factor in perceiving a disruption.

Christopher and Peck (2004) introduces another dimension, velocity. This dimension refers to the pace of adaptations (Stevenson & Spring, 2007) and the response and recovery speed to disruptions in the supply chain (Johnson et al., 2013; Jüttner & Maklan, 2011; Tukamuhabwa et al., 2015). Agrawal and Jain (2021) describe velocity as the speed of response to changes.

Velocity enables organizations to mitigate disruptions due to the application of rapid corrective actions (Stadtfeld & Gruchmann, 2022). Jüttner and Maklan (2011) found that velocity has a positive impact in companies revenue target.

Nevertheless, velocity is a less referred dimension in the literature (Hohenstein et al., 2015). A significant part of studies view velocity as an antecedent of agility (Adobor & McMullen, 2018; Christopher & Peck, 2004; Jüttner & Maklan, 2011). Others consider velocity as an antecedent of flexibility (Fiksel, 2006). Stadtfeld and Gruchmann (2022) state that velocity is enhanced by visibility.

One of the most frequently mentioned dimensions in literature is agility. It is the most dominant dimension to have in order to achieve supply chain resilience (Christopher & Lee, 2004). Agility can be defined as the ability of an organization to respond in a quick manner to unexpected changes both upstream or downstream in the supply chain (Carvalho, 2011; Christopher & Peck, 2004; Wieland & Wallenburg, 2012), the ability of a company to change operating states from its initial stable state in response to uncertainty and volatility (Parast & Shekarian, 2019; Wieland & Wallenburg, 2012), the ability to adjust supply chain resources rapidly in order to shorten the response time disruption and recovery (Hohenstein et al., 2015). Wieland and Wallenburg (2012) refer to agility as a reactive dimension.

Agility can help to reduce the negative impact of a disruption (Cabral, Grilo, and Cruz-Machado, 2012) since it reduces the time of response to disruptions (Christopher et al., 2011). Christopher and Lee (2004) states that a firm with high agility can recover faster. Similarly, Stadtfeld and Gruchmann (2022) also state that agility directly increases responsiveness and recovery, enabling companies to cope with disruption.

Some studies show agility as one of the top dimensions identified, which increases supply chain resilience and has good perception from decision makers in business (Soni et al., 2014; Taylor & Branicki, 2011).

Several authors see agility supported by velocity and visibility (e.g., Christopher & Peck, 2004; Kochan & Nowicki, 2018).

Flexibility is another widely recognized dimension that enhances supply chain resilience (Ali et al., 2017; Christopher & Peck 2004; Sheffi, 2005; Tang & Tomlin 2008).

Flexibility can be described as the ability of a company to adapt to changing requirements (Erol, Sauser, and Mansouri, 2010). Parast and Shekarian (2019) describe flexibility as the ability of a firm to respond to changes by reconfiguring its supply chain. An important aspect of flexibility is that it enables companies to not only withstand disruption but also to adapt and adjust accordingly (Han et al., 2020; Wallace & Choi, 2011).

Through flexibility companies can create supply chain resilience (Christopher & Holweg, 2011), reduce their risk exposure (Skipper & Hanna, 2009) and gain competitive advantage (Sheffi & Rice, 2005). Flexibility can help to contain costs by enabling redeployment of capacity or to shift suppliers (Jüttner & Maklan, 2011). Tang and Tomlin

(2008) found that flexibility contributes to the reduction of disruption in the supply chain.

There are several ways to improve flexibility like: flexibility through backup or multiple suppliers (Bode et al., 2011; Jüttner & Maklan, 2011), flexible production systems or flexibility in distribution channels (Pettit et al., 2013; Sheffi and Rice, 2005; Tomlin, 2006), strong relationships (Sheffi, 2005), flexible product design (Blackhurst et al., 2011; Tachizawa and Gimenez, 2010; Yi et al., 2011); flexible labor force (Tukamuhabwa et al, 2015).

An important topic in the literature is the analysis of the mismatch between flexibility and redundancy (Kamalahmadi & Parast, 2016).

Redundancy is the use of spare capacity and/or inventory during a disruption in order to cope with it (Christopher & Peck, 2004; Parast & Shekarian, 2019). Rice and Caniato (2003) describe redundancy as the duplication of capacity to maintain operations during a failure, and Lakhal (2017) as excess capacity to respond to change.

Redundancy helps to create supply chain resilience (Christopher & Rutherford, 2004; Kamalahmadi & Parast, 2016) by avoiding delays and disruptions but it can also be costly (Carvalho et al., 2012; Tukamuhabwa et al, 2015) as it requires pre-disruption investments (Aliet al., 2017). It also only gains time to respond to the disruption, not to address the disruption in itself (Zsidisin et al., 2000). Chowdhury and Quaddus (2017) see redundancy as a must to mitigate uncertainty.

Some strategies to achieve redundancy are safety stock (Blackhurst et al., 2011; Kleindorfer & Saad, 2005; Wu et al., 2013; Zsidisin & Wagner, 2010), excess production capacity (Bode et al., 2011; Craighead et al., 2007; Zsidisin & Wagner, 2010), backup transportation and warehouses (Ivanov et al., 2017), slack labor force (Johnson et al., 2013).

Some authors see redundancy as a means to flexibility (Kristianto et al. 2014; Rice & Caniato, 2003), as its spare resources allow the organization to respond flexibly to disruptions (Jüttner & Maklan, 2011).

Since supply chain is a complex network, another important supply chain resilience dimension is collaboration (Jüttner & Maklan, 2011). Collaboration refers to the exchange of information and shared knowledge across the supply chain in order to reduce uncertainty (Christopher & Peck, 2004; Faisal et al., 2007). Pettit et al. (2010)

describe collaboration as the ability to work with other entities in the supply chain to gain mutual benefits. Scholten and Schilder (2015) describe it as the process of a company working together with one or more companies to implement strategies with common aims.

To achieve high levels of supply chain resilience and reduce uncertainty, companies must collaborate between them, by sharing information across the supply chain (Li et al., 2017; Mandal, 2012).

Collaboration increases supply chain resilience by providing a coordinated response across partners (Tukamuhabwa et al., 2015), enables cost sharing (Bakshi & Kleindorfer, 2009), reduces uncertainty and increases transparency (Christopher & Peck, 2004) and reduces risk exposure (Christopher et al., 2011). Bakhshi and Kleindorfer (2009) demonstrated in their study that cooperative relations between entities lead to better supply chain resilience. Collaboration is also identified as a major enabler of supply chain resilience (Soni et al.,2014).

Simatupang and Sridharan (2008) identified five main elements of supply chain collaboration: 1) collaborative performance system, 2) information sharing, 3) decision synchronization, 4) incentive alignment and 5) innovative supply chain processes.

Collaboration is a dimension close related to visibility since both enhance each other (Faisal et al., 2006) but also can cause some implication with flexibility (Stevenson & Spring, 2007).

Robustness describes the ability for a company to resist disruption and meanwhile maintain normal operations, absorbing shocks (Ali et al., 2017; Kochan & Nowicki, 2018).

Most literature view robustness as a consequence of other dimensions like redundancy and flexibility (Stadtfeld & Gruchmann, 2022).

Leadership and culture are also important to achieve supply chain resilience. Christopher and Peck (2004) highlighted the need for firms to embrace a culture of resilience alongside its organization. Through a culture of resilience, organizations enhance flexibility (Stadtfeld & Gruchmann, 2022) and its potential is enhanced through collaboration (Tukamuhabwa et al., 2015).

In order to maximize the resilience of the supply chain, the supply chain itself should be designed in a way that maximizes the resilience potential (Christopher & Peck,

2004). Although the supply chain is usually designed to achieve low cost and customer satisfaction (Kamalahmadi & Parast, 2016), resilience should also be a factor in the design options to mitigate risk (Pereira & Da Silva, 2015). Pettit et al. (2013) state that a balance should be achieved between cost and strategic objectives and the resilience objective in the supply chain. Supply chain design is key to achieving resilience (Chowdhury & Quaddus, 2017; Ponis & Koronis, 2012). One less explored dimension is security. Security describes the ability to resist outside disruption like theft and infiltrations (Tukamuhabwa et al., 2015).

The general consensus in the literature is that research on measuring supply chain resilience is still limited (Shuai et al., 2011) and there is still very little research on measurement methods (Hohenstein et al., 2015). Nevertheless, although it is a challenging task, some progress has been made from different perspectives (Bret et al., 2021; Wagner & Neshat, 2012).

Some authors suggest customer service levels as a resilience measure (Datta et al., 2007; Hohenstein et al., 2015) and state that maintaining a high service level during disruptions is a sign of supply chain resilience (Kinra et al., 2019; Rajesh, 2016; Sawik, 2016).

Another measure is the lead time for specific operations in the supply chain that can give us variations due to disruptions (Azevedo et al., 2016). It's also possible to measure resilience by analyzing the time it takes for firms to recover to a normal pre-disruption state, or the gap between the pre-disruption state and the post-disruption state (Ambulkar et al., 2015; Datta et al., 2007; Shuai et al., 2011; Tan et al., 2019).

In addition, by looking at indicators such as reserve capacity or inventory position, a company can better understand how resilient it is, i.e. the more reserve capacity available and the better the inventory position, the more resilient a company is (Pettit et al., 2013; Wicher et al., 2016). Financial indicators that measure recovery costs post disruption are also recognized as good measures of resilience (Ivanov et al., 2017; Vugrin et al., 2011). By using indicators such as incurred post disruption costs and financial performance during the disruption, resilience can be better measured (Hohenstein et al., 2015). In addition, measuring the impact of a disruption on an organization is another possible measure of resilience (Ambulkar et al., 2015; Chowdhury & Quaddus, 2017).

Lastly, the ability to measure how good an organization can predict disruption can be a good measure of supply chain resilience (Chen et al., 2017). Being able to have good forecast accuracy is a possible indicator of resilience (Rajesh, 2016). Pettit et al. (2013) developed a tool to identify various measures that could be used to guide the resilience improvement process.

2.4 Pharmaceutical supply chain

The pharmaceutical industry can be described as "a combination of processes, organizations and operations involved in the development, design and manufacture of useful pharmaceutical drugs" (Singh et al., 2016). Over the last two decades there has been a considerable growth in the pharmaceutical industry (Foster et al., 2021; Mikulic, 2021).

The pharmaceutical sector distinguishes from other sectors due to its impact on society (Brown et al., 2013) since it has a key role in assuring the health and wellbeing of the population (Sabouhi et al., 2018). As such, the possibility of failure within the sector is not acceptable (Papalexi et al., 2020). The United Nations Millennium Development Goals recognizes the pharmaceutical industry as a key driver of the whole health sector and it's one of the more profitable sectors in the world (Narayana et al.,2014; Sabouhi et al., 2018). These characteristics make the industry highly dependent on public opinion (Eyinda, 2009) and very pressured by society to be able to deliver high quality, safe products (Dobrzykowski, 2014).

Key players in the pharmaceutical sector are: 1) large multinationals with own-brand products, 2) generic producing multinationals, 3) local or national manufacturing companies with generic or own-brand products, 4) contract manufacturers that produce key intermediaries, active ingredients or even final products to other companies and 5) drug developing focused companies (Shah, 2004).

The pharmaceutical supply chain is defined by a complex web of organization, information, activities, resources, and people (Yaroson et al., 2021) with the objective of delivering the right quantity of materials and finished product at the right time at the correct place (Kochan et al., 2018). It consists of a range of processes and operations that enable medicine's discovery, development, manufacture and distribution of pharmaceutical products (Narayana et al., 2014). It's usually composed of the following

actors: raw materials manufacturing, pharmaceutical production, market warehouses/distribution centers, wholesalers, retailers/hospitals/ pharmacies and patients/consumers (Shah, 2004; Zighan et al., 2023).

The pharmaceutical supply chain differs from other supply chains due to being more complex (Chen et al., 2013; Zahiriet al., 2017), as it includes many partners and stakeholders with multiple relationships between them (Bhakoo and Chan, 2011). Additionally, the pharmaceutical supply chain has a critical impact on human life and consequential high standards of urgency and regulations as well as distribution importance (Moktadir et al., 2018). As an important contributor to the healthcare system (Narayana et al., 2014), a small disruption in the pharmaceutical supply chain can have negative effects on the health of the population (Sabouhi et al., 2018).

Previously seen as a secondary segment of the pharmaceutical industry, the pharmaceutical supply chain is now given more attention, as companies try to extract more advantages from them (Shah, 2004). In tandem, globalization has increased the length and complexity of the pharmaceutical supply chain creating more uncertainty and complexity that, consequently, lead to more vulnerabilities (Aigbogun et al., 2014). These vulnerabilities can often result in medicine shortages which have a negative effect on healthcare operations (Chen et al., 2020).

The main objective of the pharmaceutical supply chain is to ensure the flow of pharmaceutical products from the start of the sourcing and production process all the way to consumer delivery points, all the while maintaining the quality and safety of the products (Papalexi et al., 2020; Zighan et al., 2023).

Due to the nature of these products, which have potential for adverse health effects, the supply chain is restricted in its activity by several strict regulation (Shah, 2004; Taddesse et al., 2015). These regulations make it harder to implement supply chain improvement measures (Sieckmann et al., 2018), as all pharmaceutical supply chains must adhere to current GMP (Good Manufacturing Processes) (Sharabati et al., 2022) and this results in many challenges (Khlat et al., 2014). In addition to this, most suppliers' selection processes must be approved by the regulatory entities beforehand (Zighan et al., 2023). Finally, it is also common for countries to impose some form of price control on pharmaceutical products (Alkalha et al., 2019).

Other factors that cause challenges to the pharmaceutical supply chain is longer lead times, rising costs, unstable demand and increasing processes complexity (Emilia Vann Yaroson et al., 2023; Kochan et al., 2018; Mehralian et al., 2015; Narayanamurthy et al., 2018).

Regardless of the importance of the pharmaceutical supply chain, there are few industry benchmarking studies (Alkhalidi & Abdallah, 2018) as most studies focus on specific subjects within the pharmaceutical supply chain. For example, Rossetti et al. (2011) studied the overall shifts in the pharmaceutical supply chain in order to understand major strategic trends in it while Chowdary and George (2012) observed the impact that lean manufacturing can have in the pharmaceutical supply chain. Nicholson et al. (2004) analyzed the impacts in inventory management between in-house and outsourcing distribution networks whereas Jarrett (2006) explored the benefits a just-in-time system can have in the pharmaceutical supply chain. Dixit et al. (2019) indicates that risk management is a critical issue for a well-functioning health supply chain.

Although resilience in the pharmaceutical supply chain has been the subject of recent interest (Sabouhiet al., 2018; Tucker & Daskin, 2022), studies focusing on this topic are still sparse (Yaroson et al., 2023). Due to increasing disruption, there is a need to understand how to implement resilience in the pharmaceutical supply chain (Yaroson et al., 2021) especially since the complexity of the pharmaceutical supply chain can hinder resilience implementation (Karmaker & Ahmed, 2020).

3. Methodology

A qualitative exploratory multiple-case approach was used for this study. Following the recommendations given by Karlsson (2016) this study follows three main methodological steps: 1) case study design; 2) case selection; 3) data collection and analysis.

3.1 Case study design

This study aims to understand how pharmaceutical manufacturing companies identify and manage risks in their supply chain and also aims to gain a better understanding of the supply chain resilience practices they use to prevent and/or

respond to disruptions. Resilience in the pharmaceutical supply chain is still a under researched topic (Yaroson et al., 2023), so applying an exploratory nature qualitative multiple case study methodology is suitable (Hohenstein et al., 2015).

A multiple case study is a methodology indicated to understand a complex issue and add strength to what is already known due to previous research (Eisenhardt & Graebner, 2007). In addition, a multiple case study is also suitable to understand a topic in a contextual setting by using various sources of information (Lindgreen et al., 2020; Yin, 2009).

Moreover, case study methodology has been used in several studies about supply chain resilience (Leat & Revoredo-Giha, 2013; Tukamuhabwa et al., 2017; Urciuoli et al., 2014) since it can develop, confirm or contradict existing theory (Michel et al., 2023).

3.2 Case selection

For this study the Portuguese pharmaceutical sector was chosen. In this sector, supply chain resilience has increased importance, since failure of operations means negative impacts for the population (Moktadir et al., 2018). The pharmaceutical sector is responsible for the wellbeing of the population and so failure to deliver high quality products to consumers can't be accepted (Papalexi et al., 2020). Additionally, the pharmaceutical supply chain is highly complex which makes it difficult to adopt supply chain resilience practices (Emilia Vann Yaroson et al., 2023). As such, supply chain resilience has a great impact on the sustainability of this sector to prevent negative impacts of disruptions and guarantees business continuity.

After choosing the Portuguese pharmaceutical sector, the process of selecting the companies and their respective interviewees adhered to the following rules:

1. Companies must have pharmaceutical manufacturing plant in Portugal,
2. Companies must be of relevant dimension: more than 50 employees and above 10 M€ of annual turnover,
3. Interviewees must be in a management position linked to the supply chain.

These rules were taken in order to ensure that companies selected for this study had a supply chain with complexity and dimension enough to draw relevant data from

it. Additionally, interviewees linked to managerial roles in the supply chain can provide better insights relevant to this study topic.

In total nine companies were selected and contacted to participate in this study. Of those nine companies, six agreed to participate in this study. The characterization of the companies is presented in Annex I.

3.3 Data collection

Data was collected through semi-structured, face-to-face interviews. A semi-structured interview is a good tool for qualitative studies as it permits researchers to gather detailed information from those interviewed (Ruslin et al., 2022).

An interview guide was created with the literature review as a base, but nevertheless, deviation from the questions were permitted to give the possibility for interviewees to expand and contextualize the topics discussed. The interview guide can be seen in Annex II.

In total, seven interviews were conducted, as in company E it was possible to interview two employees. All interviews were recorded and transcribed in order to facilitate data analysis. The characterization of the interview and interviews can be seen in Annex III.

4. Findings

4.1 Supply chain structure and organization

All companies in this study position themselves in the middle of the pharmaceutical supply chain, meaning they acquire raw materials from suppliers and own the manufacturing and warehousing phases after which they sell the finished product to wholesalers or retailers that consequently sell to the end consumer. Every company has their own factory where they produce pharmaceutical products and pharmaceutical industry approved, specific warehouses for storing products and raw materials. This position on the supply chain exposes the companies to risks and disruptions both upstream and downstream.

Additionally, every company is part of an international supply chain, with suppliers and clients across the globe. Five of the six companies have clients spread out worldwide and, although with different geographical focuses, are simultaneously present in countries in at least three continents in addition to the national market. The only exception was company B, which focused on the national market and Europe only.

On the supplier side, a large geographical dispersion is noted, although suppliers tend to be located depending on what raw material they provide. Active ingredients, being the costliest component for pharmaceuticals products, makes cost one of the key aspects considered while procuring. Consequently, the large majority of these component's suppliers are located in lower costs producing countries in Asia, especially in China and India. On the other hand, excipient and primary packaging's suppliers tend to be located in Europe but with some in other continents, since cost isn't as important and service level gains relevance. When it comes to secondary packaging materials all companies have national suppliers, due to being one of the cheapest materials and flexibility of supply being more valued. When buying finished products companies stick to European suppliers.

Five out of six companies manufactured both own brand products and provided CMO (Contract Manufacturing Organization) services in parallel, while only one company focused just on CMO services. Additionally, all companies that produce their own brand products also export them, with three companies stating that exportation represents a significant share of sales. These business segmentations are important as all companies adapt their production strategy based on this product distinction, using a make-to-order strategy if the product is for exportation or CMO and a make-to-stock strategy to own brand products. This dichotomy exists due to the companies' effort to reduce risk of idle stock. Additionally, this segmentation also influences the supply chain resilience practices adopted since factors as supply risks, demand variation and idle stock can highly vary.

The typology of finished products manufactured also varies. Four of the six companies have a clear and major focus on producing prescription products while the two others also substantially produce a range of over the counter and cosmetics products. This adds to the complexity not only in sourcing materials but also manufacturing and warehousing, increasing risk and opportunity for disruption.

Even though the study companies have very similar positions on the supply chain and produce similar products, the way they organize their supply chain structure varies. Only half the companies have a holistic view of the supply chain reflected in their organization, with the main departments responsible for the supply chain (purchasing and sourcing, planning, production, warehousing, logistics, quality) aggregated under a main area of supply chain management.

4.2 Risk management

During the interviews, several risks were identified by the interviewed managers, in total, twenty-one risks were identified which can be viewed in Annex IV. In order to outline in a concise manner all these risks, this study followed Christopher and Peck (2004) matrix for risk categorization, dividing all the risks into five main categories: supply risks, demand risks, process risk, control risk and environmental risks. Examples of quotes referencing the identified risks are also shown in Annex IV.

The categories with the most risk types identified were supply risks, environmental risks and process risks with five types of risk each, followed by control risks and demand risks, both with three types.

- Environmental risks

Across the interviews, the most referenced environmental risk was geo-political risk relating to armed conflicts, political instability and pandemics, in a total of four in seven interviews. Both the Ukraine-Russia and Israel-Palestine wars were referenced as well as the COVID-19 pandemic as factors that had significant impact on the company supply chain and represented risks as exemplified by the following quote: "On top of this we have geopolitical factors. Very marked. In the aftermath of the pandemic (...) there was the war in Europe, with all the consequences, and then the most recent war in Israel." (Interview I4). All the study's companies supply chains are on a global level and as such, they are very exposed to this type of risk.

One other important risk type referenced in the environmental category was related to regulation. The pharmaceutical sector is a heavy regulated sector: "the second most regulated industry in the world" (Interview I3). This regulatory burden focus both on price control: "the focus of the authorites is price or cost" (Interview I3) and on

quality regulatory issues: “due to the regulations themselves we have legal obligations in terms of qualification (of suppliers)” (Interview I4).

Both these dimensions of regulation create risks for the supply chain as exemplified by these quotes: "We have an economic risk. In particular, with prescription medicines, we don't generally control the price of medicines. The price is set by the regulator, the state." (Interview I4) and "We have clients who come up with issues like from now on, we have six months to change (product formulas) because regulations mean we can't have them on the market." (Interview I7).

Still in the environmental risk category, another risk listed by interviewees was companies’ presence in emerging markets. The instability of emerging markets where companies maintain presence both with clients and suppliers creates instability to the supply chain by being more volatile and offering less visibility: "(...) we work with some markets, they are, let's say, emerging markets and some of them are more complicated. There are some external situations in these markets themselves (...) but they interfere a lot with the supply chain." (Interview I1).

Increasing energy costs are also considered a risk, with two interviewees (Interview I3 and I5) stating that suppliers could close their factories at any moment due to costs not being affordable to the business: "We had several suppliers whose factories in Germany were at risk of not being able to produce because they had to ration energy there." (Interview I5).

Lastly, economical risk was also mentioned by one interviewee as it can be seen in the following quote: “We always have some instability when it comes to policies to encourage investment. When we look ahead there's always some difficulty in understanding what the strategic bets are for the country." (Interview I4).

- Supply risks

Supply risks were referenced by six interviewees (Interview I1, I2, I3, I4, I5 and I7). Globalizing their supply chain also entails overexposing it to risk. The concentration of suppliers, which creates a big geographic dependency, was mentioned by four interviewees (Interview I2, I3, I5 and I7) as a risk, exemplified by the following quote: "When there was the OPA (laminated foil) crisis last year, it was clear that there were two or three players in the world controlling the market." (Interview I3).

Additionally, some materials only have one existing worldwide supplier meaning companies are total dependent on a sole company for their supply which brings a great risk to operation continuity in case of disruption, a fact mentioned by three interviewees (Interview I1, I3 and I4) and exemplified by following quote: "Because 20 years ago we hypothetically had 10 suppliers with the same substance. Now we have 2, and sometimes only 1." (Interview I4). This risk is especially worrying to the companies as it is very hard to deal with it as exemplified by the quote “I think the big problem is when we talk about suppliers, which are single suppliers. And then it's really a problem that we can't get around” (Interview 1).

The suppliers quality was also recognized as a risk by two interviewees (Interview I2 and I4) that creates instability in the supply chain and it’s hard to perceive, as the following quote states: "In some cases, some weaknesses and degradations of some suppliers (...), which are difficult for the companies themselves to perceive, unless they are always inside the supplier's doors doing constant audits, to realize if they are sources of risk." (Interview I2).

Another supply risk mentioned was increasing lead times by suppliers as exemplified by the quote: “Our contracts were mostly between 4 and 5 months and right now, new contracts, everything is over 6 months” (Interview I3). This is a pertinent risk since lead time was referenced in six out of the seven interviews (Interview I1, I2, I3, I4 and I7) as an important aspect for the companies: “lead time is our number one priority” (Interview 7).

- Process risks

Regarding process risks, six interviewees stated that they identify lack of human resources availability as a major risk. Lack of available manpower and a high turnover create difficulties in assuring a full-functioning and efficient plant and production plan, which can cause delays in deliveries and/or quality problems as exemplified by the following quotes: "There's a lack of availability of people to do certain jobs, and it's becoming noticeable" (Interview I2) and "You have a very important risk, which is the turnover of people." (Interview I7).

Two interviews mentioned the risk of equipment failure (Interview I1 and I6) and the risk of lack of production capacity (Interview I2 and I3). For example, Interviewee

6 states "Internally, I think that the lack of, for example, a part for a machine (...) can stop everything".

In a similar line, another identified risk in two interviews (Interview I2 and I3) was a lack of production capacity, as demonstrated by the following quote: "We don't have extra production capacity at the moment." (Interview I2). Lack of capacity causes difficulties in fulfilling lead times to clients.

Over storage in warehouses, a process risk, was also mentioned by the interviewees. This is illustrated by the following quote: "The increase in stocks has also led to a need to tighten up storage more and more, because warehouses aren't infinite, and this has started to cause serious problems, and we're seeing a lack of space here in Portugal." (Interview I3).

Finally, Interviewee I7 mentioned production quality problems as a risk: "What gives us more instability will eventually be the (formula quality) instability of the products we produced" (interview I7). Although this risk wasn't frequently mentioned, for a sector that highly values quality as the pharmaceutical sector this could be an important risk. In Interview I3 it was mentioned that: "the focus of the pharmaceutical industry has always been on quality".

- Control risks

In what concerns control risks, four interviewees (I3, I4, I5 and I7) identified risk related to transport: "We also realize that an increasing risk is related to transport. Speaking of transport, the cost of transport, especially for imports from Asia, has risen dramatically." (interview I3). Due to the globalization of the supply chain, as well as events occurring across the globe like wars, transports have become a risk both in terms of variability of lead time but also in rising costs: "the conflict between Palestine and Israel, has further increased the problems of the Suez Canal, there's more problems because the boats aren't getting through easily." (Interview I5).

Other risks identified in this category were lack of information and lack of internal communication. Incorrect information relates to system information that has not been updated.: "We have something in the system, but it doesn't correspond to reality" (Interview I1). Lack of internal communication is also pointed as a risk: "It's

always a challenge to be able to work with commercial areas, (...) but it does put a lot of pressure on us from a risk point of view." (Interview I4).

- Demand risks

Finally, in demand risk category a risk mentioned by four interviewees (Interview I2, I3, I4 and I7) was demand variability: "Then you also realize that post-Covid there was a clear deregulation of what demand was." (Interview I3). Demand variability in a sector with such responsibilities towards the population represents a big risk: “a sector such as the pharmaceutical industry that has a huge social responsibility dimension here. If there is a shortage of medicines, (...) it becomes a strategic problem for the independence and autonomy of nations” (Interview I4).

Other identified risk is the risk of hoarding by clients which is a common occurrence in this sector: “the hoarding effect, for example, is very characteristic of this sector” (Interview I4). This also can cause stockouts to companies.

Finally, the emergence of parallel markets was also mentioned as a risk, closely linked to demand fluctuations and hoarding, where customers buy large quantities of stock in one country in order to sell it in other countries.: "Because, especially the rationing of stocks in the domestic market, you've clearly started to see parallel exports." (Interview I3).

4.3 Disruptions consequences

When talking about disruptions, it was possible to gather a number of direct consequences that were caused to the companies to which the interviewees belonged. One consequence of disruptions mentioned by all interviewees was stockout. Since the pharmaceutical sector is highly regulated, a stockout causes additional consequences on itself like activating the regulation authorities’ action, which exert enormous pressure to replace stock and guarantee market supply. This is illustrated by the following quotes: ‘Then there's the other side of the authority that says you have to guarantee the supply (of finished product)’ (Interview I2); ‘the authorities seem to forget that these problems are worldwide, they seem to forget completely and say that you have to guarantee four months’ supply (of stock), it’s your problem' (Interview I3).

Furthermore, stockout in the pharmaceutical sector often means not only the momentary sale opportunity is lost but also, future sales are also compromised, since the consumer will stay with a competitor product for the whole treatment. This is supported by the quote: “The loss of sales of certain products (...) leads consumers to look for alternatives. So, in addition to this direct impact, which is a loss of sales that month, there is an effect which is the loss of future sales which may not be recoverable” (Interview I4). Other consequences of stockout are serious health impacts on a patient or fines applied by authorities as said by Interviewee I7: “(referring consequences) losing a client (...) or having to pay fines for delays”.

One other consequence of disruption mentioned is the need to halt production which has considerable financial impact: “And when that client had a problem, (...) we had to stop production, (...) and there were financial problems” (Interview 1).

Lastly, examples of new projects and products needed to be abandoned or discontinued due to disruptions were also mentioned: “I can also say that there have been some projects for new products that have been put on hold for a while (...) because you start to see that I can't respond to what I already have here” (Interview I3).

The opposite is also said, where a disruption can end up having a good impact if a company has the supply chain resilience to withstand or adapt to it, gaining a competitive advantage towards competitors as exemplified by the quote: “having stock during a disruption is a business opportunity, and you'll make sales that weren't even planned, weren't even projected (...) in some cases we've done a lot of business precisely because we have stock” (Interview I3). Nevertheless, in most cases interviewees said that companies end up in a more difficult situation after a disruption occurred: “It gets worse because many of these measures, which at first end up being transitory, become definitive. I haven't had any suppliers who have increased their lead times say that have now reduced their lead times, for example” (Interview I3).

When it comes to the frequency of disruptions, the responses vary. Four out of seven interviewees said that major disruptions were rare. For instance, Interviewee I2 state “nowadays the trend since 2019 is perhaps two a year”. Most of the interviewees suggest that smaller disruptions are very frequent. The following quote supports this situation “(referring to smaller disruptions) but now, practically every day, on a daily or weekly basis, we have disruptions that affect one product or another” (Interview I4). It’s

also mentioned by interviewee I3 that more frequently smaller disruptions can evolve to much bigger consequences, as illustrated in the following quote: “I'm starting to say that it's becoming more frequent, because it's already small things that have big impacts (referring to disruptions)”.

4.4 Supply chain resilience

In response to the question of what constitutes a resilient supply chain, the respondents gave a variety of answers, which can be seen in Annex V. Most definitions highlight the need to resist disruptions and maintain operations in order to have stock available to sell.

All companies that participated in this study have an informal supply chain resilience strategy. In interview I2 it was said: “I can’t say that there is a rule or an established practice or established strategies to instill resilience”. Overwhelmingly, each disruption or risk is dealt with in a case-by-case fashion without an overreaching company guideline. Also, four interviewees (Interview I1, I2, I5 and I6) stated that most resilience enhancing actions were taken individually by each department, while three interviewees (I3, I4 and I7) stated that in their companies, all departments came together and worked jointly in order to tackle the risk or disruption on a more overreaching way as show by the quote: “The resilience of the supply chain is less formal, but we do have a series of forums with the teams responsible, with the players who have key roles in the supply chain and we do this on a week-to-week basis where all these elements are constantly monitored” (Interview I4).

This less than formal strategy and case-by-case approach results in a more reactive focus on disruption, a fact shared by three interviewees, as exemplified by the following quote: “you manage by reaction, you don't manage by prevention” (Interview I3). Additionally, only three companies stated that they had a business continuity plan (Interview I3, I4 and I7).

In terms of top management support for supply chain resilience, initiatives and resources allocated, the responses indicate a lack of concern about the issue. While all interviewees said that there was some support and concern from top management, six interviewees felt that there wasn't enough support. A common theme in the responses

is that concern or input from senior management only occurs when disruptions are already impacting the supply chain. An example that supports these ideas is the statement of interviewee I5: “It's something they worry about, but sometimes they only worry when things are really bad, which means that the problem is already there”.

It’s noted that concern relates to immediate problems and resilience measures approval are dependent of visible consequences as mentioned by Interviewee I3 “when we're talking about situations where the measurement of the result is not so much in the short term but more in the medium or long term, then it's very difficult (referring to resilience measures approval)”.

Three respondents described their company's supply chain resilience as average (interviews I1, I5 and I6), three others as above average (interviews I2, I4 and I7) and one as below average (interview I3). The main factors explaining the rating were a lack of demand visibility and a supply chain over-exposed to risk and uncertainty. The two following quotes illustrate these factors: “we control a small part of the process, our direct control, is only of a small part of the process” (Interviewee I3) and “a lot because the demand from our suppliers and our customers is very unstable” (Interview I7).

4.5 Resilience Dimensions and Practices

During the interviews, several dimensions and practices for managing supply chain resilience were identified. Examples of these practices and the quotes supporting them are shown in Annex VI.

When it comes to the visibility dimensions all interviewees stated that they consider it important to increase supply chain resilience. In interview I4 it was said that: “In order for any supply chain to work well, it needs information. The more information we have over longer periods of time, the better”. The interviewees referred to a variety of practices related to visibility used by their companies; in particular, seven specific practices were identified in the interviews. These practices can be found in Annex VI. With the highest number of practices identified, this dimension is a focus for companies trying to bring the most transparency to their supply chains, as exemplified by the quote: “clarity and transparency with both customers and suppliers I think this is probably one of the most important solutions” (Interview I3).

Due to the companies' position on the supply chain it's important to enhance visibility both downstream and upstream and that's a concern of the companies as shown by the following quote: "(speaking on client visibility) the closer we are to our customers, the better" (Interview I4). Nevertheless, interviewees also stated that the companies' visibility is still somewhat lacking due to the pharmaceutical sector being very conservative as stated by interviewee I4 "the sector as a whole continues to believe that the secret linked to the supply chain is relevant to a business".

Various interviewees referenced that their companies used demand forecasting (Interview I3, I4, I5 and I7). They use forecasting to reduce the risk of buying materials without confirmed orders, mitigating risks of stockout and/or idle stock. Forecasting is considered by the interviewees as an important tool as shown in the following quote: "to buy an active ingredient that is for a customer's product and I don't buy anything else from them, it is very important to have that forecast" (Interview I1). Forecasting the company's own demand is also a prevalent action used in order to give visibility to their suppliers (Interview I2, I3 and I4). Forecasting their demand helps and streamlines their supplier production planning and reduces the possibility of delays which is stated in interview I4 "And giving suppliers visibility for a longer period of time to be able to give them predictability and visibility".

Interviewees I1, I4 and I5 also stated that they resort to schedule orders to suppliers in order to clearly give visibility to them. In interview I5, the interviewee stated that: "one thing that we being trying to do is to try and place orders further in advance". Two other identified practices in interviews I1, I2 and I3 used by companies are sharing information on identified opportunities and disruptions. In interview I1, it was stated that: "That's why I say that our approach has to be one of great transparency: when we know something is going to happen, they (suppliers) have to be informed as soon as possible". These practices can also be considered in the collaboration dimension of supply chain resilience as companies share vital information to better prepare themselves for disruptions or opportunities.

The last two practices identified were transparent communication and maintaining communication channels (Interview I1, I2, I3 and I4). Focus on keeping communication transparent is highly referenced across the interviews as a way to

counter the culture of secrecy of the sector as stated in Interview I2 "we try to maintain open-door communication as much as possible, this applies in both directions".

Flexibility is also considered as important by the interviewees. Four in seven interviewees referred flexibility as very important to their supply chain resilience. In total four specific practices related to flexibility were mentioned. These practices can be found in Annex VI.

The practice most often mentioned by the interviewees from the companies represented was the qualifications of alternative suppliers. Although only one company stated that it didn't use alternative suppliers, all companies described it as a difficult process. This is exemplified by the following statement of interviewee I4: “due to the regulations themselves we have legal obligations in terms of qualification and even certain changes (...), these changes have to be approved in advance by the regulatory authority and the health authority before they can be implemented. In some cases, this can take several months, and internal work has to be done before these changes are submitted” (Interview I4). Due to this difficult process, costs of having approved alternatives can have a big financial impact and the process is very time consuming, something that is echoed in the following quotes: “when you make a product with a new active ingredients, you go through a process of validation, stabilization, stability and everything else that costs hundreds of thousands of euros in some cases” (Interview 4) and “the process takes a few months in addition to internal work has to be done prior to submitting these changes” (Interview 4). This makes companies very conservative of using this practice, even though it gives clear benefits, so interviewees stated the companies usually just have one alternative supplier on key materials for their products, adding other alternatives only during crisis in a reactive way. Interviewee I2, said that: “we keep both sources of supply alive, because this also incurs costs in terms of keeping records with the regulator”. Overall, companies use this practice in a more restrictive and reactive manner that they would prefer to use. One practice identified by interviewee I7 refers to trying to qualify various manufacturing locations. The interviewee stated: "we have suppliers who have factories in India but then they also have factories in Croatia which are the same factories with exactly the same manufacturing processes with the same raw materials if it's all the same, let's validate their factory."

One other practice mentioned is using adaptable plant configurations in order to be able to adapt production capacity to various scenarios. By adapting their plant configuration, companies can switch products through different machines in case one malfunctions. This was mentioned in interview I7: “we have the installed capacity so that if anything happens, we can transfer production from here to another factory”.

Lastly, using alternatives in transport is also a practice that companies use in order to avoid disruptions like conflicts and natural disaster to have a negative impact in their supply chain. In one of the interviews is stated that: "So, when it comes to transport, whether by road in Europe or by sea in India, or by air in India and China, we always try to have more than one alternative" (Interview I3). Nevertheless, some cases companies admit that it’s difficult to have alternatives specially in specific transport methods like maritime transport as referenced in: “(referring to alternatives in maritime transport) we always used to work on the basis of various alternatives (...) but we also realized that (...) the question of availability is what sometimes makes it more complicated, because there's only one boat, there's a lot of concentration” (Interview I3).

The redundancy dimension was also mentioned, with all interviewees stating the companies they represent use some practices that can be included in this dimension. These practices can be found in Annex VI. Nevertheless, only two in seven interviewees consider redundancy an important dimension for supply chain resilience. This contradiction is explained as interviewees categorized redundancy as a dimension to be used to mitigate disruptions when disruptions couldn’t be prevented in other ways (for example with more collaboration or flexibility). In interview I7, the interviewee reflects this when he states that: “redundancy for us is a solution to achieving flexibility, I don't see it at the same level of importance as flexibility”.

In total five different practices related to redundancy were identified from the interviews. All interviewees stated that they made use of materials safety stock, although with varying levels of focus. Some companies used safety stock in a more targeted way like presented in interview I4: “we try to balance this (stock management) but reinforcing with specific touches in what we have identified as additional risks”. Other companies use safety stock as a general response to disruptions or risk like

mentioned in interview I3: “as soon as these (risk) patterns are detected, we clearly move on to a stocking procedure.

In parallel, using safety stock for the finished product is a practice used by all but one company. This practice gives a direct response to varying demand, but also represents an increased cost to the business, a fact that various interviewees recognized as a disadvantage, for example Interviewee I4 states: “We have the other side in terms of stocks, and this is always an extremely difficult exercise because we have to counterbalance high interest rates, for example, with safety stocks”.

Additionally, another practice used is having an alternative finished product manufacturer. This practice is not used by most of the companies because it’s extremely costly, so utilization is sparse. Interviewee I4 said that: “it's extremely cumbersome, extremely costly and has to be done surgically”.

Two interviewees (Interview I1 and I7) also say their companies are able to have some spare production capacity, although the other companies don’t have any spare production capacity left, working at full capacity. Most interviewees had similar realities as the one presented in interview I2: “when faced with the reality, at least that we have, we are at a capacity threshold and in some situations even exceed it”.

Lastly in interview I4, it was stated that the company used the practice of diversifying its portfolio in order to be able to maintain at least some part of their business in action (Interview I4).

Another dimension mentioned by the interviewees was collaboration, with five interviewees considering it very important (Interview I1, I3, I4, I6 and I7), while other interviewees considered it of moderate importance.

The pharmaceutical sector is more conservative and averse to sharing information as stated in interview I1: “the pharmaceutical industry being a very conservative industry” Paradoxically, although recognised as important, collaboration practices are met with resistance. It’s possible to identify five specific practices related to collaboration.

One practice used by all companies is the integration in a sector wide group of Portuguese pharmaceutical companies, Group ISO, where companies trade insights and cooperate with spare stocks when one of them has the need. In one interview this was said about group ISO: “the relationships that were built and that are still privileged with

some companies have lasted, where we help each other because we have common ground and common materials that we buy and can share" (Interview I4) while in other interview it was stated that "a third hypothesis that arose, and which was greatly increased here, was to be able to ask other Portuguese pharmaceutical companies for help" (Interview I6).

Similar to this type of collaboration, two interviewees (Interview I1 and I6) also state that their companies develop some collaboration with other competitors. Collaboration with suppliers and customers were also mentioned. Several interviewees (Interview I1, I3, I4, I6 and I7) stated that their companies promoted collaboration with their supplier in order to solidify their relationship, reduce risks and find collaborative solutions where both parties are satisfied. One example of the importance of this practice was given in interview I1: "the partnership relationship with both the supplier and the customer is really important" (Interview I1).

Lastly, one other identified practice used is stock risk sharing, which consists in having suppliers hold reserved material stock for the company based on a compromise to buy it after a period of time. About this practice one interviewee said: "we have suppliers who basically end up doing the stocking (...). They end up doing the stocking in their warehouse, because they know more or less what our consumption is, (…) then we order to them" (Interview I5).

The interviewees didn't mention the agility dimension as an important one and neither did they mention any supply chain resilience practices that could be categorized in the agility dimension. The main reasons presented across the interviewees for a lack of agility were the heavy regulation this sector faces. The three main factors were:

1) constrains in changing materials suppliers and sources as said in interview I3: "An approval process for a new active ingredient takes two or three years. The authorities sometimes take a year, a year and a half, two years to respond".

2) restrictions in manufacturing methods explained in interview I4: "due to the regulations themselves we have legal obligations in terms of qualification and even in certain changes of typologies, these changes have to be previously approved by the regulatory authority".

3) product price restrictions mentioned in interview I2 “we end up with an authority (...) that wants low prices, and in order to have low prices you have to have low costs, otherwise you're out of the market”.

All these factors create a very restrictive landscape to creates agility practices a fact stated by various interviewees, for instance: “the problem is that this industry isn't very agile due to all the constraints it faces” (Interview I3). This is reflected on the importance given to this dimension, where although two interviewees (Interview I1 and I6) described it as important, the rest of the interviewees described it as of medium or less importance.

There is not a lot of consideration given to resilience culture, with most interviewees stating that they considered it a less relevant dimension to achieve supply chain resilience. Main reasons for this are that supply chain resilience culture is still not ingrained in the companies and still very restricted to key departments. When asked about this dimension one interviewee (Interview I1) said: “resilience culture is still not very deep-rooted (…) and initiatives are only is used in a few specific departments”. Nevertheless, most interviewees recognize the importance of resilience culture dimension as exemplified by the following quote: “the most important thing (...) is for everyone to realize what risk is and for everyone to be sensitive to the problem and the consequences of a problem in the chain, wherever it may be” (Interview I7).

The design of the supply chain is of smaller importance to all interviewees. This is due to the focus while making decisions concerning the supply chain design is costs, while supply chain resilience is in the background. The following quotes are what interviewees though top management considered while making supply chain design decisions: “but in the end, it's the cost that's most important” (Interview I6) and “I think they are more concerned with costs” (Interview I7). As such most interviewees consider that supply chain design is an undeveloped dimension, as exemplified in interview I1: “it's an issue that still has a lot to be worked on” (Interview I1).

5. Conclusion

5.1 Main conclusions

This study tried to understand how companies develop supply chain resilience by understanding what risks affected the supply chain and what dimension of resilience and their respective practices were used and valued by managers, specifically in the pharmaceutical sector context. The study was able to gather various risks and supply chain practices used in the pharmaceutical sector as well as provide some context on the causes and limitations of those risks and practices.

Regarding risk to the supply chain, it was possible to gather and identify twenty-one specific risks. When organized and categorized, results indicate that managers in this sector identify more risks to the supply chain towards the supply, environmental and process categories while control and demand risks aren't as mentioned. Prakash et al. (2017) systematic literature review also found a bigger focus and incidences on studies on risks related to the supply and environmental categories. The spread of risks identified suggest that managers are alert that risk can come both from external and internal sources.

One of the main sources of risk identified was the overextension of the supply chain framed in the globalization context, which is also stated by Tukamuhabwa et al. (2015). This overextension caused various types of risk identified such as increasing lead time (Safari et al., 2022), risks related to geopolitical instability (Shekarian & Mellat Parast, 2020), risk associated with presence in emerging markets and parallel markets. In parallel another source of risk is the progressive concentration and reduction of available suppliers for raw materials, which was also stated by Safari et al. (2022). In the present days, where talks about re-industrialization of Europe are happening these factors gain especial importance.

Main consequence of disruptions indicated in this study was stockout, which in the pharmaceutical sector is a critical occurrence that has not only financial and business continuity consequences but also legal and public health impacts. In the pharmaceutical sector it was possible to understand the financial impacts but also the public health consequences that a stockout can create. Supply chain resilience importance increases in this sector as well since disruptions and/or stockouts result in decreased patient care which is a highly negative societal consequence. This was also stated by Senna et al. (2020). It was also possible to observe that resilience can be a tool to not only withstand

and/or recover from disruptions but improve the company competitiveness (Hohenstein et al., 2015).

Results also showed that companies focused more on the readiness and responsiveness phase of supply chain resilience and overlooked the recovery phase as well as the growth phase. This is further shown by the companies' adopted practices focus on anticipating, preparing and responding to disturbances in a effective way. This result aligns with the literature which identifies a lack of studies focusing on the recovery and growth phase (Christopher & Peck, 2004; Jüttner & Maklan, 2011; Pettit et al., 2013; Wieland & Wallenburg, 2013). Although the latter two phases are an important part of supply chain resilience, companies in this study report that they end up in a worst position than before a disruption.

When it comes to supply chain resilience results showed that companies understand the concept but use it in an informal and case by case context. Support from top management is sparse and often occurs after disruptions occur. The main reason for this is that top management don't prioritize as supply chain resilience doesn't bring immediate measurable results as also stated by Tukamuhabwa et al. (2015) and Pettit et all. (2019).

It was possible to identify twenty-one supply chain resilience practices. After being categorized it was possible to access an evenly distribution of practices across four main dimensions largely referenced in the literature: visibility (Christopher and Peck, 2004)., flexibility (Han et al., 2020), redundancy (Jüttner & Maklan, 2011) and collaboration (Hohenstein et al., 2015). Visibility is the dimension more favored with more practices adopted by companies, which try to increase their ability to respond to disruption in the supply chain by predicting them or react earlier as possible similar to what was found by Stadtfeld and Gruchmann (2022).

One major takeaway was that regulation does have a negative impact in supply chain resilience. The pharmaceutical sector being heavily regulated creates difficulties in adopting practices that promote the flexibility and agility dimensions in supply chain resilience. Regulation is also identified as a top reported risk source by Jaberidoost et al. (2013).

5.2 Contributions to management

The study offers managers an overview of the risk landscape, with twenty-one specific risks, particularly concentrated in the supply, environmental, and process categories. This sector-specific insight allows for a more targeted approach to risk management. Additionally, it provides a categorized framework of twenty-one supply chain resilience practices across visibility, flexibility, redundancy, and collaboration dimension. It also highlights the negative impact of regulation on resilience, particularly in limiting flexibility. These findings support managers in developing more balanced, proactive, and structured resilience strategies.

The research identifies a gap in the implementation of resilience strategies, with companies favoring readiness and responsiveness while neglecting recovery and growth phases. It also shows that SCR is often applied informally and only gains attention from top management after disruptions occur. Managers should formalize and complement their strategies across the different SCR phases and embed key supply chain resilience objective into strategic objectives in order to gain more top-level leadership support.

Lastly, a key insight is the added negative impact of stockout in the pharmaceutical industry is due to its importance to society's wellbeing. Avoiding stockouts should be a number one priority in this sector.

5.3 Limitations and future recommendations

Although the multiple case study approach used in this research gives context-specific insights, it is limited by its focus on a particular sector of the pharmaceutical industry within a single country. This narrow scope limits the generalizability of the findings to other sectors or geographical contexts. In addition, the study adopts a cross-sectional design which limits the understanding of the long-term impact of supply chain resilience disruptions and the sustainable effectiveness of the practices implemented by companies. A longitudinal research approach is required in order to capture the complexity of how resilience is developed, maintained or eroded over time.

In addition, the study relies on subjective data collected through semi-structured interviews. This allows for the collection of qualitative information, but it is susceptible

to biases. Future research should consider incorporating objective measures of supply chain resilience - such as lead times, service levels or inventory turnover.

Additionally, all the companies in this study were small to medium companies. Future studies could focus on multinational companies with a bigger and broader geographical presence in order to understand what changes related to supply chain resilience would be present.

Future studies could try to identify and measure the positive and negative financial impacts that supply chain resilience practices have on companies in order to contextualize the benefits that supply chain resilience can bring to a company.

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Annexes

Annex I – Companies characterization

Interview Code	Company	Number of Employees	Anual Turnover
I1	A	250-500	25-50 M€
I2	B	250-500	100-200 M€
I3	C	>1000	>200 M€
I4	D	250-500	100-200 M€
I5	E	500-1000	50-100 M€
I6	E		
I7	F	250-500	50-100 M€

Source: Elaborated by the author

Annex II – Interview Guide

Guião de Entrevista

O meu nome é Diogo Portas e estou neste momento a desenvolver um projeto no âmbito do meu trabalho final de mestrado em Gestão e Estratégia Industrial do ISEG. O projeto tem como objetivo perceber como as empresas do sector farmacêutico português trabalham a resiliência na cadeia de abastecimento e as estratégias usadas.

Começo por agradecer desde já a sua disponibilidade para participar nesta entrevista, que sem dúvida é fundamental para o sucesso do meu projeto.

Esta entrevista terá várias questões de resposta aberta, às quais peço que responda de acordo com a sua opinião. Não existem respostas certas ou erradas, apenas nos interessa a sua opinião baseada na sua experiência na empresa.

Gostaria de lhe pedir para gravar a entrevista com o único propósito de mais tarde poder ouvir a gravação e retirar mais informação da mesma. Asseguro desde já a confidencialidade e anonimato das respostas dadas por si.

Pode confirmar que entendeu a informação acabada de transmitir e tenho o seu consentimento para prosseguir com a gravação da entrevista?

Questões Introdutórias

1. Qual a seu cargo na empresa?
2. Pode fazer uma breve descrição das suas funções e responsabilidades no âmbito das atividades da empresa?
3. Há quantos anos trabalha para esta empresa?
4. Quantos anos de experiência profissional no mesmo cargo? Quais os cargos que teve nas empresas onde trabalhou anteriormente?

Questões Empresa

1. A empresa é multinacional?
2. Quantos trabalhadores, em tempo integral, trabalham para a empresa atualmente?
3. Qual foi o volume de negócios de 2023?
4. Gostaria de lhe pedir se pode fazer uma breve descrição da estrutura da empresa e das suas atividades? (departamento de compras, logística, gestão de stocks, etc)
    a. Existe na empresa um gestor da cadeia de abastecimento? Se não, quem desempenha as atividades relacionadas com a GCA?
5. Quais são os principais produtos ou serviços que a sua empresa fornece? Os produtos são standard, customizados, etc?
6. Em que mercado a empresa se insere (genéricos, marca, diversos, suplementos, dispositivos médicos, cosméticos)?
7. Qual a estratégia de produção adotada pela sua empresa (e.g., MTS, MTO, misto)?
8. Quais são os principais fornecedores da empresa (principais países/regiões)?
9. Quais são os principais clientes da empresa (principais países/regiões)?
10. A empresa tem atividade de exportação? Se sim, para que mercados e quais os produtos exportados?
11. Qual a estratégia para seleção de fornecedores? O que valorizam mais: relações fortes com 1 fornecedor ou multi-sourcing? Porque é que a empresa definiu esta estratégia?

Riscos da Cadeia de Abastecimento

1. Que ameaças relacionadas com os fornecedores a empresa identifica?
2. Que ameaças internas existem ao nível da empresa?
3. Que ameaças relacionadas com os clientes a empresa identifica?
4. Que ameaças provenientes do exterior da cadeia de abastecimento a empresa identifica?
5. Quais as estratégias adotadas pela sua empresa, para responder às ameaças que mencionou?
    a. Estratégias de gestão da procura.
    b. Estratégias de gestão da oferta.
    c. Estratégias de gestão das relações.
    d. Estratégias de gestão e partilha da informação
    e. Adoção de novas tecnologias
6. Com que frequência ocorrem disrupções na cadeia de abastecimento? Qual a criticidade desses eventos?
7. Pode dar alguns exemplos de disrupções ocorridas na cadeia de abastecimento da sua empresa?

a. Quais as consequências destas disrupções na empresa?
b. Na sua opinião, considera que estas disrupções contribuíram para melhorar a resiliência da cadeia de abastecimento? Como? Porquê?
c. Quais as medidas adotadas para prevenir estas disrupções da cadeia de abastecimento? Quais as respostas dadas às disrupções?

Resiliência da Cadeia de Abastecimento

1. Na sua opinião, o que é uma cadeia de abastecimento resiliente?
2. Como avalia a resiliência da cadeia de abastecimento da sua empresa? Existem diferenças relacionadas com o tipo de produto, mercado, etc?
3. Existe uma estratégia formal para a SCR? Se sim, em que consiste a mesma?
4. Quais os departamentos envolvidos na definição da estratégia de SCR?
5. Em que medida, a gestão de topo faz uma boa alocação de recursos para implementar práticas que melhoram a resiliência?
6. Existe uma periodicidade definida para a revisão da estratégia de SCR? Qual? Como foi definida?
7. Que indicadores são utilizados para avaliar a resiliência da cadeia de abastecimento?
8. Na sua opinião, como é que a colaboração com os diferentes clientes, fornecedores, associações podem afetar a resiliência da CA?
9. Na sua opinião considera que os recursos atribuídos pela empresa à melhoria da SCR são adequados/fazem parte dos objetivos estratégicos?
10. Na sua opinião, como é que as novas tecnologias podem melhorar a resiliência das cadeias de abastecimentos do sector?
11. Quais são as tecnologias digitais (Industry 4.0) utilizadas pela sua empresa e parceiros? Como é que estas afetam a vossa SCR?

Dimensões da Resiliência

1. Na sua opinião, a seguinte dimensão é considerada um fator importante para a resiliência? Como avalia cada uma na cadeia de abastecimento da sua empresa? Que estratégias adota para melhor a performance das mesmas?
    a. Flexibilidade
    b. Redundância
    c. Visibilidade
    d. Colaboração
    e. Agilidade
    f. Robustez
    g. Cultura de Gestão de Risco
    h. Design Cadeia de Abastecimento
    i. Segurança

Annex III – Interviews and Interviewees characterization

Interview Code	Interview Duration	Interviewee's position
I1	1h32m	Purchasing Manager
I2	1h12m	Planning and Purchasing Manager
I3	1h17m	Director of Operations
I4	56m	Chief Operating Officer
I5	58m	Purchasing Manager
I6	46m	Purchasing Manager
I7	1h52m	Supply Chain Director

Source: Elaborated by the author

Annex IIIV –Identified risks and quotes

Risk Type	Risk	Quotes	Interview
Demand Risk	Demand Variability	"The company that is the main player, which has, for example, an 80 per cent market share that goes into stockout and the competitor that only has a 20 per cent market share has to supply, in reality it's not like that, because it's not going to be the other company that's suddenly going to be able to change."	I2
		"Then you also realize that post-Covid there was a clear deregulation of what demand was."	I3
		"Few clients have a stable forecast."	I7
		“A few years ago, this sector was extremely stable (releating to sales), but today there is no such stability”	I4
	Parallel Markets	"Because, especially the rationing of stocks to the domestic market, you've clearly started to see parallel exports."	I3
	Demand Hoarding	"You begin to realize that customers are starting to behave like hoarders."	I3
		“the hoarding effect, for example, is very characteristic of this sector”	I4
Supply Risk	Supply Quality	"In some cases, some weaknesses and degradations of some suppliers (...), which are difficult for the companies themselves to perceive, unless they are always inside the supplier's doors doing constant audits, to realize if they are sources of risk."	I2
		"Because a large part of the source, as has been mentioned, of materials is in countries that we don't control. That have different regulations."	I4
	Product/ Materials Discontinuity	"We've seen in the last two years, and I think this is going to be more and more frequent, suppliers simply abandoning projects."	I3

		"And so many of these manufacturers are reorganizing themselves (...) and are neglecting and removing from their portfolio substances that are, in fact, 30, 40 years old. "	I4
	Sole Supplier	"In some cases, there is no possible choice. There is only one supplier."	I3
		"Because 20 years ago we hypothetically had 10 suppliers with the same substance. Now we have 2, and sometimes only 1."	I4
		“I think the big problem is when we talk about suppliers, which are single suppliers. And then it's really a problem that we can't get around”	I1
	Leadtime Increase	"Our contracts were mostly between 4 and 5 months and right now, new contracts, everything is over 6 months, and even the old contracts, there was an announcement at the beginning of last year saying that lead times were going to increase."	I3
	Supplier Geographical Concentration	"There's always be some kind of material where are few suppliers available."	I2
		"Ever since Covid, we realized that there was a huge dependence on materials coming from China, regardless of whether they were produced in Europe."	I3
		"It's undeniable, we have to get them (referencing materials) from China or India, they're the biggest suppliers. There's not much we can do."	I5
		“we can even have four or five API suppliers on the market, but they use a common starting material that is eventually controlled by two companies in the world”	I7
Process Risk	Lack of Manpower	"I think one of the biggest risks is always, I say, equipment and human resources."	I1
		"There's a lack of availability of people to do certain jobs, and it's becoming noticeable."	I2
		"There has been some difficulty in finding human resources to come in and stay."	I5
		"Nowadays the hardest part is retaining people in the company".	I6
		"You have a very important risk, which is the turnover of people."	I7
		"a risk would be that perhaps today we have a human resources structure (...) that is not adapted properly."	I4
	Equipment Failure	"We have some equipment that is already very old and that doesn't correspond, that gives some problems, that stops."	I1
		"Internally, I think that the lack of, for example, a part for a machine (...) can stop everything."	I6
		"We don't have extra production capacity at the moment."	I2

	Lack of production capacity	"This increase in demand as a whole is leading to a bottleneck in production capacity"	I3
	Storage	"The increase in stocks has also led to a need to tighten up storage more and more, because warehouses aren't infinite, and this has started to cause serious problems, and we're seeing a lack of space here in Portugal."	I3
		"It's happened that we've had more than 100 per cent utilization in the warehouse."	I7
	Production Quality	"What gives us more instability will eventually be the instability of the products we produced"	I7
Control Risk	Lack of information	"We have something in the system but it doesnt correspond it reality"	I1
		"I can't have the product circulating in a certain flow or in a certain geographical location (...) and the information system tells me it's somewhere else"	I7
	Transport	"We also realize that an increasing risk is related to transport. Speaking of transport, the cost of transport, especially for imports from Asia, has risen dramatically."	I3
		"Which has made transport routes, for example, much more demanding. Much more complex. This has led to rising transport costs and longer transport times."	I4
		"For example, the conflict between Palestine and Israel, has further increased the problems of the Suez Canal, there's more problems because the boats aren't getting through easily."	I5
		"The supplier doesn't take responsibility: I don't know what's going on, the boat is crossing the Suez Canal, I don't know what's happening there."	I7
	Lack of internal communication	"It's always a challenge to be able to work with commercial areas, (...) but it does put a lot of pressure on us from a risk point of view."	I4
Environmental Risk	Emerging markets	"(...) we work with some markets, they are, let's say, emerging markets and some of them are more complicated. There are some external situations in these markets themselves (...) but they interfere a lot with the supply chain."	I1
		"The threats here are more related to the tendency to go abroad. Mainly to Asian areas. That then causes instability here. Lack of visibility, lack of regulation."	I4
		"we export there, to the Middle East, Brazil, (...) Russia (...) to those more complicated countries in terms of (...) regulatory bodies"	I7

	Geo-political	"Nowadays, due to various factors, being geopolitical, potential pandemics or environmental catastrophes, I think that many factors are emerging that may be external to the companies themselves and that are completely beyond their control."	I2
		"On top of this we have geopolitical factors. Very marked. In the aftermath of the pandemic (...) there was the war in Europe, with all the consequences, and then the most recent war in Israel. "	I4
		"Conflicts between countries, for example, started with the conflict between Ukraine and Russia, and there were direct and indirect supply problems right away."	I5
		"Then there are political, geopolitical and economic issues such as wars that affect the whole chain."	I7
	Regulation	"We have an economic risk. In particular, with prescription medicines, we don't generally control the price of medicines. The price is set by the regulator, the state."	I4
		"We have clients who come up with themes that from now on we have six months to change because regulations mean we can't have them on the market."	I7
	Economical	We always have some instability when it comes to policies to encourage investment. When we look ahead there's always some difficulty in Understanding what strategic bets are for the country."	I4
	Energy Cost	"The increase in energy costs has had an impact. We've had cases of companies saying, 'With this cost, I can't run a factory'."	I3
		"We had several suppliers whose factories in Germany were at risk of not being able to produce because they had to ration energy there."	I5

Source: Elaborated by the author

Annex IV – Resilience definitions

Interview	Definition
I1	"Above all, there has to be a resistant supply network. Because, as I said, we have to have excellent communication. The processes have to be very smooth."
I2	"A resilient supply chain would be one in which I would be able to have safety stocks that are not necessarily significant, but in which there could also be safety stocks throughout the chain."
I3	"A resilient supply chain means that nothing ever is out of stock, that the supply chain is set up robustly enough to ensure that nothing is ever out of stock, at the extreme, that the pharmacy doesn't miss a box of medicine for the patient."

I4	"The supply chain will be more resilient the better it serves the business. It's a supply chain that continues to fulfil its function, which is to support the business."
I5	"A resilient supply chain is a material procurement chain in which we have to deal with problems, these unforeseen events and constantly adapt to what is the reality at the moment."
I6	"It is a chain that is prepared to respond to any adversity that may arise."
I7	"The fact is that a supply chain, as well as having the flow of information and the flow of material products totally interconnected, also (...) has three important pillars: predictability, flexibility and stability."

Source: Elaborated by the author

Annex VI – Identified supply chain resilience practices and quotes

Dimension	Strategy	Quote	Interview
Visibility	Demand forecasting	"our main client, fortunately, works very well with forecasts"	I5
	Disruption identification sharing	"In a crisis situation there needs to be more sharing (...) we try to promote the sharing of information."	I3
	Opportunities identification sharing	"when expansion possibilities arise, when business potential arises (...) we try to maintain a rapid communication channel "	I2
	Maintaining communication channels	"One solution we've been working on is to establish long-term relationships"	I4
		"we try to maintain open-door communication as much as possible, this applies in both directions "	I2
	Transparent communication	"Both transparency, both knowing that something is going to happen and that they (the clients) will be informed straight away"	I1
	Scheduled supply orders	"everything has to be done well in advance, I have to place orders a year in advance."	I1
		"was to try and place the orders further in advance"	I5
	Supply forecasting	"And giving suppliers visibility for a longer period of time. To be able to give them predictability and visibility"	I4
Flexibility	Alternative materials suppliers qualifying	"we have been qualifying a growing number of suppliers, manufacturers of various materials that are very important to us"	I4
	Alternative materials manufacturing location	"we have suppliers who have factories in India but then they also have factories in Croatia which are the same factories with exactly the same manufacturing processes with the same raw materials if it's all the same, let's validate their factory"	I7
	Flexible manufacturing methods	in our packaging we have single carpet lines, which make one blister, and double carpet lines, which make two blisters, and we had the possibility of exchanging them""	I6

	Transport flexibility	"So, when it comes to transport, whether by road in Europe or by sea in India, or by air in India and China, we always try to have more than one alternative"	I3
Redundancy	Materials safety stocks	"because typically, when it comes to making safety stock, you tend to do it in terms of materials"	I7
		"We had to increase the purchase of materials, so stocking up basically meant stocking up"	I5
	Finished product safety stock	"the other is always trying to have safety stocks for the finished product"	I2
	Diverse portfolio	"It's what we've been building, which is a broad and diverse portfolio so that effectively when a failure happens somewhere the global impact (...) isn't significant"	I4
	Spare manufacturing capacity	"we have the installed capacity here so that if anything happens we can somehow transfer production from here to another factory"	I7
	Alternative finished product manufacturers	"is to qualify alternative manufacturers to make our products"	I4
Collaboration	Competitors collaboration	"We had a pharmaceutical company in Italy who, not knowing us at all, gave us some quantity that made no difference to them"	I6
	Supplier collaboration	"We work a lot with brokers who are closer to us. And who are, in fact, business partners for Medinfar "	I4
	Stock risk sharing	"we have suppliers who basically end up doing the stocking themselves"	I5
	Sector collaboration	"a third hypothesis that arose, and which was greatly increased here, was to be able to ask other Portuguese pharmacists for help "	I6
	Client collaboration	“what we do is we challenge the client to do task forces with us”	I7

Source: Elaborated by the author