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The Russian-Ukrainian Conflict from Disruption to Resilience: The case of the Italian Cast-Iron Foundries Supply Chain

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A mio nonno Giovanni,
perche senza di te nulla sarebbe stato possibile, la tua forza sarà sempre la mia stella polare.

Ai miei genitori,
grazie per avermi dato le ali, per avermi lasciato volare e per avermi aiutato a rialzarmi quando cadevo.

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A Raul,
mio caro grande amico, sei un faro nella tempesta e la spalla su cui posso sempre contare.

Gutta cavat lapidem.

(Lucrezio)

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Introduction

Thesis Introduction

As sadly confirmed by the recent covid-19 pandemic, supply chain disruptions represent a real danger for the survival of commercial activities and sometimes even of entire production categories. According to (Mentzer, et al., 2001), a supply chain is very broadly defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer (Tarver, 2022). Therefore, supply chain disruptions are unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain and, as a consequence, expose firms within the supply chain to operational and financial risks (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007).

Recent history is not new to supply chain disruptions, in fact they can be caused by a variety of factors, including natural disasters such as the 2011 earthquake in Japan, logistic delays and failures such as the blockade of the Suez Canal in 2021, pandemics such as Covid-19 and many others.

Starting from February 24th, the invasion of the Ukrainian territory by the Russian Federation is threatening to generate a new supply-chain disruption. This time, unfortunately, the terrible consequences in terms of human lives add up to the economic ones. Since both countries are major suppliers of raw materials, the destruction of Ukraine, combined with the economic sanctions imposed by most Western countries on Russia and the naval blockade of the Black Sea, have severely affected global markets. According to Wuester & Winkler (2022), what makes Russia and Ukraine so important within the international economy is that they mainly export primary and intermediate goods used in other countries' exports at an early stage of production (energy, metals, chemicals, corn, wheat). Therefore, the countries are clearly marked by high forward GVC participation or 'upstreamness' (Wuester & Winkler, 2022).

Although in absolute economic terms the two warring countries cannot be defined as great powers, disruptions of Russian and Ukrainian exports will especially affect regional economies that are highly dependent on these specific supplies. Among the latter, the Italian cast iron supply chain deserves special consideration since its supply of cast iron comes almost entirely from the two warring countries, which in 2021 jointly represented the 81% of the Italian cast-iron imports (Assofond, 2022).

Indeed, cast iron exports are dominated by three countries (Russia, Brazil, and Ukraine), together accounting for over three-quarters of global exports. Hence, replacing pig iron imports from Russia and Ukraine would be much more difficult than products for which the global market is less concentrated. From this point of view, pig iron represents for Italy an emblematic case of dependence on foreign supplies and therefore of strong exposure to supply risk in the event of disruptions along the supply chain.

Among the categories most exposed to a potential disruption of the cast iron supply chain is certainly the sector of Italian foundries, and in particular those that produce cast iron since this is the basic material to

produce their castings. Foundry products play a role of fundamental importance within the economy and society, in fact, they are destined for a very broad market that ranges from a variety of sectors including automotive, various mechanics, construction, street furniture, aerospace, electricity production, household appliances, art and design (Porru, Arici, & Corelli, 2017).

The Russian-Ukrainian military crisis has completely changed the scenario and threatens to have a heavy impact on the economy of the cast-iron foundries (Assofond, 2022). The reaction of the markets to the war was indeed severe and very rapid: the prices of pig iron showed significant growth, while those of electricity doubled reaching 700 euro/MWh (about 6 times the prices of 2021 and 18 times those of 2020) on 8 March 2022 (Assofond, 2022). In addition to the tsunami in prices and in the light of the above premise, the other consequence, perhaps even more tragic for the cast iron foundry sector given the very strong dependence on the procurement of raw materials, was the cancellation of supplies of cast iron from Ukraine and Russia (Assofond, 2022).

Research Topic

It was only 1958 when Forrester introduced a theory of distribution management that recognized the integrated nature of organizational relationships. In that year, Forrester enunciated the principle according to which companies are so intertwined that system dynamics can influence the performance of functions such as research, engineering, sales, and promotion (Mentzer, et al., 2001).

Later in his paper, the author proposed that "there will come general recognition of the advantage enjoyed by the pioneering management who have been the first to improve their under-standing of the interrelationships between separate company functions and between the company and its markets, its industry, and the national economy" (Forrester, 1958, p. 37). Through this sixty-year-old quotation, Forrester precisely identified the phenomenon that was later defined by the literature as Supply Chain Management (SCM).

Starting around the end of the century, in the wake of examples of companies that have achieved resounding successes such as Dell, Walmart and Amazon, the mentality of managers began to change, seeing the purpose of supply chain management not only as a cost driver, but as a source of competitive advantages, therefore forcing companies to always find new ways to stabilize, control and coordinate the flow of materials.

In other words, the competitiveness of international companies has increasingly been linked to their ability to deliver customized products quickly and timely all over the world. Accordingly, competition is no longer just between firms at the same level in the production process, but today we are witnessing a competition between supply chains, from raw materials to customers (Jespersen & Skjott-Larsen, 2005).

On other hand, recent history is full of examples of supply chain disruptions that have impacted the performance of companies. For example, due to a fire at a Phillips semiconductor plant in 2000, Ericsson production was disrupted costing the company $400 million in losses. In the wake of these catastrophic events,

both scholars and practitioners have undertaken a series of studies aimed at controlling and mitigating the negative effects caused by risks and disruptions in the supply chain, leading to the emergence of the field of study called Supply Chain Risk Management (SCRM).

Numerous journal articles reviewing the literature in the field of SCRM have been published in the last thirty years. Among them we can mention Tang C. S. (2006), who reviewed more than 200 journal articles published between 1964 and 2005 and classified them into four categories: supply management, demand management, product management, and information management for managing supply chain risks. On the other hand, Rao & Goldsby (2009) reviewed 55 published between 1998 and 2008, thus developing a typology of risk factors, including environmental, industrial, organizational, problem-specific, and decision-maker related factors.

Since there was no consensus on what exactly is meant by SCRM, Ho, Zheng, Yildiz, & Talluri (2015) proposed the following definition: "an inter-organizational collaborative endeavour utilizing quantitative and qualitative risk management methodologies to identify, evaluate, mitigate, and monitor unexpected macro and micro level events or conditions, which might adversely impact any part of a supply chain" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 5). In addition, the literature on SCRM has provided several qualitative and quantitative methods to manage supply chain risks. Despite fundamental disagreement about the assessment and the validity of the different methods, the majority of authors in the field agree on the general framework which identifies four main phases of SCRM, namely: risk identification, risk assessment, risk mitigation, and risk monitoring.

Therefore, the ability to restructure the supply chain in the face of changing conditions (disruptions and supply risks) is critical to maintain continuity of supply chain performance. Thus, beyond understanding how managers might work to prevent disruptions through risk management, it must be better understood how managers respond to and recover from the supply chain disruptions they experience (Macdonald & Corsi, 2013). Therefore, this thesis fits fully into the wake of the SCM literature, touching on topics dear to the SCRM literature and the restructuring of Supply Chains.

Research Questions

The research question at the center of this thesis directly stems from the SCM literature and the considerations above-mentioned**:** *How did the Italian foundry pig iron supply chain respond to the shock of the Russian-Ukrainian conflict? How and through what strategies did they resist the supply chain disruption?* By using a case study methodology, the focus of this paper will be mainly on the disruption and restructuring of the supply chain of Italian cast iron foundries, both trying to understand how the industry is moving overall at a macro level, which solutions they are adopting as a category, and analysing their effects at a micro level through semi-structured interviews with some individual foundries. Thus, the research focuses both on how

the industry and the supply chain are restructuring, and on the heterogeneity of the business strategies adopted by individual foundries.

Most of the leading companies deal with this range of supply-chain risks by holding reserves, which usually includes excess inventory, excess capacity and redundant suppliers. Overcoming the "classic" prescriptions mentioned above and by adopting a vision of the supply chain as a complex adaptive system (CAS), in the face of a supply disruption companies connected in a complex network can adapt and restructure their connections. In this case, the CAS framework provides a useful theoretical foundation as firms in a supply chain operate as an interconnected network in a dynamic environment. In such environment, even a small change at one node in the chain can cause a disruption to spread throughout the supply chain. Positing that firms in a supply chain constitute self-organizing networks, several authors have argued that some supply chains can be adaptive or resilient. This means that when hit with a disruption, they can adapt or restructure themselves to reach a desirable state which can be back to the original state, an equivalent state, or a better state (Zhao, Zuo, & Blackhurs, 2019).

From CASs perspective, when facing a disruption, the ability of companies to adapt and restructure is critical for minimizing the losses. As I said, in recent years the concept of resilience to supply chain disruptions has been frequently explored, however without incorporating the concept of CAS. In other words: "understanding how disruptions impact multiple tiers in a supply chain and how the structure of the network may play a role in this impact is lacking" (Zhao, Zuo, & Blackhurs, 2019, p. 191). Therefore, this thesis aims to add a further piece of knowledge on how interconnected companies behave within a complex network in the face of a supply disruption. Through the interview of supply chain managers operating within Italian cast iron foundries, it is possible to examine their resilience and the effect of adaptive behaviours in real-world supply chain networks.

According to Robert Yin: "A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2009, p. 47). Therefore, the research question will be explored using a multiple case-study design, where the units of analysis are represented by a series of Italian cast iron foundries, which were first identified and then studied through semi-structured interviews aimed at verifying the following three hypotheses:

- ***(H1)**: the Russian-Ukrainian conflict has generated an upstream disruption within the cast iron supply chain, which in turn has represented a supply risk for the Italian cast iron foundries.*
- ***(H2)**: Due to the Russian-Ukrainian conflict, Italian cast iron foundries are operating in an ambiguous environment.*
- ***(H3)**: In the face of the supply disruption caused by the Russian-Ukrainian conflict, foundries have adapted by restructuring connections and building resilience.*

Thanks to the methodological flexibility guaranteed by the case study design, the evidence gathered through the semi-structured interviews will also be triangulated with the data present in the database of Assofond, the association of Italian foundries.

This thesis aims to provide a double contribution, both to the literature on SCRM, integrating the concept of Complex Adaptive Systems to understand how the structure of the network may play a role in the propagation of disruptions along the supply chain, and to the business community, examining the resilience of the Italian foundry sector and the effect of adaptive behaviours in real-world supply chain networks.

Thesis Outline

The structure of the thesis is as follows: the first chapter will be dedicated to the literature review, following the evolution of the concept of Supply Chain, Supply Network, and Complex Adaptive System. Furthermore, this chapter will review the main contributions in the field of Supply Chain Management, Supply Chain Risk Management, Supply Chain ambiguity and the concepts of Supply Chain Resilience and Supply Chain Restructuring. In this chapter, the three hypotheses arising from the literature and which inform this thesis will also be presented and argued.

The second chapter will instead be dedicated to the practical presentation of the Italian cast iron supply chain. Starting from the fundamentals of the Russian-Ukrainian conflict and the consequent destruction of the supply chains that referred to these two countries, I will gradually try to narrow the focus by first analysing the Russian and Ukrainian market and trade relations, then the specific bilateral ones with Italy in order to highlight the extreme dependence that it suffers from the two warring countries. The third paragraph of the chapter will instead perform the function of underlining the social and economic importance of the Italian foundry sector. The fourth and final paragraph will deal with the specific vulnerabilities of this sector in light of the conflict.

Moving on to the third chapter, this will be dedicated to the research methodology, highlighting the typical characteristics of the case study methodology and explaining the reasons for this choice. The second paragraph of this chapter will explain in detail the research design of this thesis, while in the third the main limitations and strengths of the case study will be exposed.

The fourth chapter will therefore be dedicated to the analysis and discussion of the evidence obtained from the semi-structured interviews. The chapter will be divided into three paragraphs corresponding to the three different hypotheses raised. Lastly, in the conclusion I will try to summarize what has been done, highlighting both the evidence obtained and the major limitations of the thesis. Particular attention will be devoted to the exploration of future analytical paths to follow in order to deepen the theme and which have not been carried out here due to space problems.

First Chapter: The Literature on Supply Chain

1.1. From Supply Chains (SC) to Supply Networks (SN) and Complex Adaptive Systems (CAS)

"Management is on the verge of a major breakthrough in understanding how industrial company success depends on the interactions between the flows of information, materials, money, manpower, and capital equipment. The way these five-flow systems interlock to amplify one another and to cause change and fluctuation will form the basis for anticipating the effects of decisions, policies, organizational forms, and investment choices." (Forrester, 1958, p. 37)

It was only 1958 when Forrester introduced a theory of distribution management that recognized the integrated nature of organizational relationships. In that year, Forrester enunciated the principle according to which companies are so intertwined that system dynamics can influence the performance of functions such as research, engineering, sales, and promotion (Mentzer, et al., 2001).

Later in his paper, the author discussing the future proposed that "there will come general recognition of the advantage enjoyed by the pioneering management who have been the first to improve their understanding of the interrelationships between separate company functions and between the company and its markets, its industry, and the national economy" (Forrester, 1958, p. 37). Through this sixty-year-old quotation, Forrester precisely identified the phenomenon that was later defined by the literature as Supply Chain Management (SCM). The topic of this thesis fits fully into the aforementioned stream of research.

Before narrowing down the focus, for heuristic purposes it is necessary to clarify the concept of Supply Chain (SC). This is also because multiple definitions of the phenomenon have been provided over the years within the literature, without however finding an agreement on which is the most suitable. According to La Londe and Masters (1994), a supply chain is a set of firms that pass materials forward (La Londe & Masters, 1994). Normally, several independent firms are involved in manufacturing a product and placing it in the hands of the end user in a supply chain—raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies are all members of a supply chain (Mentzer, et al., 2001). Similarly, Lambert, Stock, and Ellram define a supply chain as the alignment of firms that brings products or services to market (Lambert, Stock, & Ellram, 1998). According to Christopher, a supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer. Thus, Christopher identifies the supply chain with a multiplicity of companies, both upstream (supply) and downstream (distribution), and the ultimate consumer (Christopher, 1992).

For the purpose of this thesis, I will adopt the definition provided by Mentzer, et al. (2001), according to which :"Supply chain is defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a

source to a customer" (Mentzer, et al., 2001, p. 4). The author then identifies three degrees of supply chain complexity: a "direct supply chain," an "extended supply chain," and an "ultimate supply chain". The first category includes supply chains made up of a company, a supplier, and a customer involved in the upstream and/or down-stream flows of products, services, finances, and/or information. The second type of supply chain includes suppliers of the immediate supplier and customers of the immediate customer, all involved in the upstream and/or downstream flows of products, services, finances, and/or information. The third and final typology includes all the organizations involved in all the upstream and downstream flows of products, services, finances, and information from the ultimate supplier to the ultimate customer (Mentzer, et al., 2001).

Given the significant complexity reached by some supply chains, they are often represented graphically as a schematic network that illustrates the relationships between its elements and seems to resonate more with the definition of "ultimate supply chain" provided by Mentzer, et al. (2001). Each vertical level of the supply chain (suppliers, plants, etc.) is called an "echelon", while a location in the network is referred to as a "stage" or "node". The link between nodes represents some type of flow (goods, information, money). The portion of the supply chain from which the products originate is referred to as "upstream", while the demand end is defined to as "downstream" (Sneyder & Shen, 2019).

Given the potential for countless alternative supply chain configurations and that any one organization can be part of numerous supply chains, someone argues that the phrase "supply chain" is a bit of a misnomer, since "chain" implies a linear representation of the concept in which each echelon has only a single stage and that it looks more like a serial system. In reality, in today's supply chains each echelon may have dozens, hundreds or even more nodes, leading us directly to the discussion of the Supply Networks (SN) (Sneyder & Shen, 2019).

More specifically, nearly two decades have passed since Choi, Dooley, & Rungtusanatham (2001) introduced a network-oriented view of supply chain management that spawned a broad and active area of research ever since (Park, Bellamy, & Basole, 2018). According to Park, Bellamy, & Basole (2018):" a supply network is defined as a firm's direct and indirect partners, as well as relationships among them. The supply network perspective extends the scope of inquiry by accounting for relationships among a firm's partners and its distant and indirect partners (i.e., partners of the direct partners and beyond)" (Park, Bellamy, & Basole, 2018, p. 5).

Through this extension of the scope of inquiry, the network-oriented view of supply chains has allowed scholars and practitioners to realize the importance of sensing risk factors that emanate far from the focal firm but may cause a systemic failure in operations across its supply chain. This, in turn, has had important implications in the field of supply chain risks management, helping in the identification and mitigation of latent supply chain risks and disruptions. The stream of study centered on a network-oriented vision has allowed managers and scholars to raise their awareness of an inherent complexity and dynamism intrinsic to

the network itself. The recognition of a series of structural dependencies within the supply network has, for example, allowed Yan, Choi, Kim, & Yang (2015) to illuminate the role of lower-tier suppliers in a supply network with no direct ties to focal firms that bring identifiable products to market. These suppliers are nonetheless critical because they are uniquely positioned to profoundly influence performance at multiple tiers in the supply network and, ultimately, the performance of the focal firm (Park, Bellamy, & Basole, 2018).

As another example, Pathak, Wu, & Johnston (2014) highlighted the importance of the interaction among structural drivers of supply networks as well as the moderating roles of internal and external factors. Within their work they examined the co-opetition dynamics arising from the formation and dissolution of supply network ties. Among other things, the authors emphasize how individual firms' efforts to impede or facilitate ties among its partners also shape the structural form of the overall supply network. Therefore, the result is that structural drivers of supply networks are not necessarily independent of one another over time, instead, one may foster or hinder the growth of another (Park, Bellamy, & Basole, 2018).

Going even further, Choi, Dooley, & Rungtusanatham (2001) argued that since managers have realized the importance of systems-level or supply chain optimization, firms have spent increasing amounts of time, money, and effort in an attempt to predict and control their extended supplier system. However, firms' efforts to manage supply chains have often led to frustration and helplessness. Managers have struggled with the dynamic and complex nature of supply networks (SNs) and the inevitable lack of prediction and control. Following the thought of the author, "good intention is not enough. Managers must possess a mental model of a SN that more accurately reflects its true underlying complexity and dynamism" (Choi, Dooley, & Rungtusanatham, 2001, p. 1). Therefore, going beyond the simple concept of the Supply Network, the authors proposed that "it is not enough to recognize a SN as simply a system — a SN is a complex adaptive system (CAS), meaning that it’s a system that emerges over time into a coherent form, and adapts and organizes itself without any singular entity deliberately managing or controlling it (Choi, Dooley, & Rungtusanatham, 2001, p. 1).

CAS tend to focus on the interplay between a system and its environment and the co-evolution of both. In the context of a CAS, the system would refer to a network of firms that collectively supply a given part or subassembly to a buying firm (SN). On the other hand, the environment would consist of end consumer markets that exert demand for the products and services provided by the SN, directly or indirectly connected economic systems (i.e., potential supply bases not presently a part of the network), and the larger institutional and cultural systems that both define and confine the SNs interpretation of reality and its subsequent behaviour (Choi, Dooley, & Rungtusanatham, 2001). Thus, the originality of the concept lies precisely in this second part of the definition, i.e., in the inclusion of all the elements that surround the Supply Network (SN) and which constitute its surrounding environment. Furthermore, following the authors, the SN and its environment are not separate entities that exist independently of each other, but these two interact and create dynamic, emerging

realities. In other words: “because there is feedback among the systems in terms of competition or co-operation and utilization of the same limited resources, the environment forces changes in the entities that reside within it, which in turn induces changes in the environment. Such bilateral dependencies ensure that a great deal of dynamism will exist in the environment" (Choi, Dooley, & Rungtusanatham, 2001, p. 6).

From the above definitions emerges the distinction between the concept of Supply Chain (strictly speaking) and what we will later define as Supply Chain Management. In other words, supply chains exist whether they are managed or not, and this is because even if none of the actors involved in the SC put into practice any of the concepts discussed later in this paper to manage the supply chain, the supply chain— as a phenomenon of business—still exists. Therefore, there is a clear distinction between supply chains as phenomena that exist in business and the management of those supply chains. The former is simply something that exists (often also referred to as distribution channels), while the latter requires management efforts by the organizations within the supply chains (Mentzer, et al., 2001). Therefore, the concept of Supply Chain Management (SCM) will be at the center of the next paragraph.

1.2. Supply Chain Management (SCM)

The need for supply chain management arises from the managers' awareness that buying, selling, manufacturing, assembling, warehousing, transporting and delivering goods, all the activities included within the supply chain, come with important costs. Therefore, at first, the objective of managers when it comes to supply chain management was to reduce its costs through a series of strategies aimed at improving its efficiency, such as for example reducing inventory and exploiting economies of scale in transportation (Sneyder & Shen, 2019).

Starting around the end of the century, in the wake of examples of companies that have achieved resounding successes such as Dell, Walmart and Amazon, the mentality of managers began to change, seeing the purpose of supply chain management not only as a cost driver, but as a source of competitive advantages. Dell demonstrated how through extraordinary supply chain management the company was able to deliver fully customized computers to customers' homes within days. Amazon, on the other hand, has gone further by building an unrivalled supply chain, able to provide the customer with various shipping options and flexible return policies at zero additional costs, satisfying the customer's desire for instant gratification and making available virtually every type of existing goods (Sneyder & Shen, 2019).

In those years, the popularity of the term SCM began to increase more and more, to the point that it is now difficult to find a magazine in the management sector that does not mention the term at least once. One of the reasons for this popularity certainly has to do with the trends in global sourcing, an emphasis on time and quality-based competition, and their respective contributions to greater environmental uncertainty. The

globalization of the supply has forced companies to always find new ways to stabilize, control and coordinate the flow of materials (Mentzer, et al., 2001).

In other words, the competitiveness of international companies has increasingly been linked to their ability to deliver customized products quickly and timely all over the world. Accordingly, competition is no longer just between firms at the same level in the production process, but today we are witnessing a competition between supply chains, from raw materials to customers. Therefore, today the creation of trust-based and long-term business relationships with suppliers, customers and all the strategic partners becomes an indispensable feature for every company (Jespersen & Skjott-Larsen, 2005).

The globalization of supply, the consequent trend towards an increased integration and cooperation between the various companies within the supply chain and the fierce competition at an international level have contributed to determine greater complexity in the management and control technology, which in turn require greater coordination between the various components of the supply chain. To delve deeper into the subject, according to Jespersen & Skjott-Larsen (2005) the today's market environment in characterised by a set five of features:

i. Turbulent and dynamic markets with rapid and unforeseeably change in customer's requirements.
ii. Strongly segmented markets, where different customers have different requirements for products and services.
iii. Market requirements for multiple products varieties and customisation of thereof.
iv. Increasing customer demand for "experiences" and not just products.
v. Global competition, which forces companies to become faster, better and cheaper.

These are the challenges that have contributed to the creation of a marketplace uncertainty, which in turn requires greater flexibility on the part on individual companies and supply chains. At the same time, these challenges have made the field of Supply Chain Management so fertile and important for the competitiveness of companies.

The concept of SCM is still difficult to grasp, indeed, the literature over the years has provided a multitude of definitions, each of which highlights different aspects of the phenomenon. According to Handfield & Nicholas (2002), "Supply Chain Management is the integration and management of supply chain organizations and activities through cooperative organizational relationships, effective business processes, and high levels of information sharing to create high-performing value systems that provide member organizations a sustainable competitive advantage" (Jespersen & Skjott-Larsen, 2005, p. 11). Few years before, (Christopher M. , 1998) defined SCM as "The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole" (Jespersen & Skjott-Larsen, 2005, p. 11). The latter definition places emphasis on management of relationships in order to achieve better results for all member of the supply chain (highlighting his vision as SN) and is quite different from the

more recent definition provided by the Council of Supply Chain Management Professionals (CSCMP), which instead focuses on a comprehensive view. According to the CSCMP, Supply chain Management "encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies" (Sneyder & Shen, 2019, p. 2).

Worthy of mention is the definition elaborated by Jespersen & Skjott-Larsen (2005), according to which "SCM is the management of relations and integrated business processes across the supply chain that produces products, services and information that add value for the end customer" (Jespersen & Skjott-Larsen, 2005, p. 12). The author provided a detailed description of the keywords contained in his definition: the first that appears in order is "relations", used here "as the term for all activities linked with establishing, maintaining and developing business relations with supply chain partners" (Jespersen & Skjott-Larsen, 2005). The second keyword is "integrated", defined by the author as "coordination across functional lines and legal corporate boundaries" (Jespersen & Skjott-Larsen, 2005). Coordination is understood here as including several types: organizational in the form of cross-organisational teams; system-related in the form of integrated ICSs; planning related, for example in the form of exchange of data, inventory status, sales forecasts etc. Then, the third keyword contained in the definition is "business processes", which include those directly related to the production of goods, services and information. Examples of the latter include materials supply, order fulfilment, customer service and product development (Jespersen & Skjott-Larsen, 2005).

However, that's not the whole story: Jespersen & Skjott-Larsen (2005) also provided a very useful component analysis of the SCM concept borrowed from Lampert, Cooper, & Pagh (1998). According to the authors, Supply Chain Management can be divided into three large macro-components, which are closely interconnected:

1. *Network Structure*
2. *Business Processes*
3. *Management*

Since I have already devoted enough space to the analysis of the Network Structure and SNs concept, I will limit myself to saying that it includes the most important collaboration partner in the supply chain, as well as the relationships between these players. Therefore, the purpose of the Supply Chain Network Structure is to identify who are the key supply chain members with whom to link processes (Jespersen & Skjott-Larsen, 2005).

Business processes include the activities and information flows related to the conduct of materials, products and services through the supply chain and to customers. The question here is to define what processes should be linked (integrated) with each of these key supply chain members. The number of business processes deemed to be beneficial to integrate and managed between companies will likely vary from company to company. Sometimes it's better to link just one key process, while sometimes it's appropriate to link multiple processes. Among the most common business processes the author mentions order processing, customer service, distribution, product development and supply. This last business process is the one that most informs the development of this thesis. It includes all the activities from choosing a vendor, coming to an agreement and the continued organization of purchasing. According to the authors, the supply process today is no longer a simple routine but a real strategic process due to the tendency to outsource production processes to the supplier link in the supply chain (Jespersen & Skjott-Larsen, 2005).

The SCM management components are the third and final element of the SCM framework proposed here. According to Lampert, Cooper, & Pagh (1998), there are certain management components that are common across all business processes and member of the supply chain, and they are critical to the success of SCM because "they essentially represent and determine how each process link is integrated and managed. The level of integration and management of a business process link is a function of the number and level of components added to the link" (Lampert, Cooper, & Pagh, 1998, p. 11). Therefore, "adding more management components or increasing the level of each component can increase the level of integration of the business process link" (Lampert, Cooper, & Pagh, 1998, p. 11). According to the authors, these management components could be broadly divided into two groups: the first one is the physical and technical one, which is formed by the most visible, tangible, measurable and easy to change components. If managers' attention is focused solely on this group of management components, managing the supply chain is likely to be a failure. The second group includes the managerial and behavioural components: these are less tangible and visible and therefore more difficult to assess and alter. These last group of components defines the entire organizational behaviour and influence how the physical and technical management components can be implemented. In other words, if the components of the second group are not aligned to drive and reinforce an organizational behaviour supportive to the objectives of the supply chain and operations, the entire supply chain will lose competitiveness and therefore profitability. On the other hand, if there is a change in the physical and technical components, this should be followed by a readjustment of the managerial and behavioural ones (Lampert, Cooper, & Pagh, 1998). In conclusion, according to the authors, "the groundwork for successful SCM is established by understanding each of these SCM components and their interdependence" (Lampert, Cooper, & Pagh, 1998, p. 11).

Below is the list of the fundamental management components divided into the two groups to which they belong:

Physical and Technical Management Components:

1. *Planning and Control Methods*
2. *Workflow/Activity structure*
3. *Organisation Structure*
4. *Communication and Information Flow Facility Structure*
5. *Product Flow Facility Structure*

Managerial and Behavioural Management Components

6. *Management Methods*
7. *Power and Leadership Structure*
8. *Risk and Reward Structure*
9. *Culture and Attitude*

In their book titled "Fundamentals of Supply Chain theory", Sneyder & Shen (2019) have provided a convenient framework to think about when it comes to supply chain management decisions. According to the authors, SCM decisions can be divided into three levels based on the time horizon in which they take place. The first level of SCM decisions is defined as strategic, it involves decisions that take effect over a long-time horizon like years or decades. They can have a huge impact on all the functions of the firm and examples of them can be the choice of location factories, warehouses, or long-term contracts with suppliers. The second level of decision is the tactical one. It involves decisions over a moderate time horizon, typically months. They are less difficult to change than the previous type of decisions, but the change takes place not without difficulty. Examples of tactical decisions can be inventory replenishment policies at warehouses. The last level of SCM decision is related to operational aspects concerning the supply chain. They have a very limited time horizon such as days or weeks during which policies must be executed but cannot be changed. Examples of the latter are filling customer orders or routing of delivery vehicles (Sneyder & Shen, 2019).

I would like to conclude the paragraph dedicated to the concept of SCM by mentioning the definition proposed by Mentzer, et al. (2001), who formulated the concept of SCM as follows: "supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long -term performance of the individual companies and the supply chain as a whole" (Mentzer, et al., 2001, p. 18). This definition marks an important step towards a synthesis between the different aspects highlighted by the previous definitions, it is in fact the result of a careful analysis aimed at conveying all the characteristics of the SCM proposed in the literature. To create an eclectic synthesis of all

aspects of SCM, the author has classified the definitions of the different authors into three broad categories: a management philosophy, implementation of a management philosophy, and a set of management processes.

Starting from the first category, SCM as a philosophy takes a systems approach to viewing the supply chain as a single entity, rather than as a set of fragmented parts, each performing its own function. Specifically, "the philosophy of supply chain management extends the concept of partnerships into a multifirm effort to manage the total flow of goods from the supplier to the ultimate customer" (Mentzer, et al., 2001, p. 7). Therefore, according to this point of view "SCM is a set of beliefs that each firm in the supply chain directly and indirectly affects the performance of all the other supply chain members, as well as ultimate, overall supply chain performance" (Mentzer, et al., 2001, p. 7). Mentzer, following Ross (1998), argued that SCM as a management philosophy seeks synchronization and convergence of intrafirm and inter-firm operational and strategic capabilities into a unified, compelling marketplace force. Furthermore, SCM as a philosophy directs supply chain members to focus on developing innovative solutions to create unique, individualized sources of customer value. Therefore, satisfaction and customer value, achieved through the synchronization of all the activities carried out within the supply chain, is the ultimate purpose of SCM, and not just logistics. In other words, SCM philosophy drives supply chain members to have a customer orientation (Mentzer, et al., 2001).

To summarize the above, the author condenses the characteristics of SCM as a philosophy into three topics:

1. A systems approach to viewing the supply chain as a whole, and to managing the total flow of goods inventory from the supplier to the ultimate customer.
2. A strategic orientation toward cooperative efforts to synchronize and converge intrafirm and interfirm operational and strategic capabilities into a unified whole; and
3. A customer focus to create unique and individualized sources of customer value, leading to customer satisfaction (Mentzer, et al., 2001).

Following his argument, to adopt a supply chain management philosophy firms must establish management practices that permit to act or behave consistently with the philosophy. From here derive the activities that make up SCM in Mentzer's line of reasoning. First, to be fully effective in today's competitive environment, firms must expand their integrated behaviour to incorporate customers and suppliers through external integration. Here, the philosophy of SCM turns correctly into its implementation. The second activity to implement the SCM philosophy consists in mutually sharing information among supply chain members. Sharing information such as inventory levels, forecasts, marketing strategies etc reduces uncertainty between supply partners and results in enhanced performance. Next, to achieve effective SCM it is necessary to mutually share risks and rewards that yield a competitive advantage. Focusing on long-term cooperation, sharing risks and rewards helps align incentives among supply chain members. Indeed, the fourth activity of

the SCM listed by Mentzer is cooperation. According to the author, it "refers to similar or complementary, coordinated activities performed by firms in a business relationship to produce superior mutual outcomes or singular outcomes that are mutually expected over time" (Mentzer, et al., 2001, p. 8). This cooperation, which also requires cross-functional coordination, affects different levels of management, both top and operational. Furthermore, it involves joint planning and ends with joint control activities to evaluate performance of the supply chain members. In addition, the cooperation helps to reduce inventories and increase cost efficiency. The fifth activity is instead borrowed from La Londe & Masters (1994) and is represented by the sharing of the same goal and the same focus on serving customers as a form of policy integration to avoid redundancy and overlaps between the supply chain members. The sixth activity is the integration of processes from sourcing to manufacturing, and to distribution across the supply chain. This can be achieved through cross-functional teams, in-plant supplier personnel, and third-party service providers. The seventh and final SCM activity is stated by Mentzer as a partnership to build and maintain long-term relationships. The author argues that "the relationship time horizon extends beyond the life of the contract—perhaps indefinitely—and, at the same time, the number of partners should be small to facilitate increased cooperation" (Mentzer, et al., 2001, p. 10).

The third macro-category proposed by Mentzer is SCM as a set of management processes as opposed to a focus on the activities. According to Davenport, processes are "structured and measured set of activities designed to produce specific output for a particular customer or market" (Mentzer, et al., 2001, p. 10). On the other hand, Ross proposed that "Supply chain process are the actual physical business functions, institutions, and operations that characterize the way a particular supply chain moves goods and services to market through the supply pipeline" (Mentzer, et al., 2001, p. 10). In other words, a process could be defined as a specific ordering of work activities with a clear beginning, an end, clearly identified inputs and outputs, and a structure for action (Mentzer, et al., 2001). In the same vein, Lambert, Stock, & Ellram (1998) argued that to successfully implement SCM, all firms within a supply chain must overcome their own functional silos and adopt a process approach. Thus, all the functions within a supply chain are reorganized as key processes. In addition, the critical differences between the traditional functions and the process approach are that the focus of every process is on meeting the customer's requirements and that the firm is organized around these processes (Mentzer, et al., 2001). These key processes typically include customer relationship management, customer service management, demand management, order fulfilment, manufacturing flow management, procurement, and product development and commercialization (Lambert, Stock, & Ellram, 1998).

Mentzer's comprehensive definition is useful also because allows us to analyse in more detail the purpose and consequences of SCM.

As suggested by the author, the ultimate purpose behind SCM is to increase the overall supply chain competitive advantage. According to Porter (1985), competitive advantages can be achieved through two main

strategies: cost-leadership and differentiation. Furthermore, following to the author, competitive advantage grows fundamentally out of the customer value a firm creates, and aims to establish a profitable and sustainable position against the forces that determine industry competition (Mentzer, et al., 2001). In the case of SCM, improving a firm's competitive advantage and profitability can be accomplished by enhancing overall customer satisfaction. In the same vein, La Londe (1997) proposed that SCM aims at delivering enhanced customer service and economic value through synchronized management of the flow of physical goods and associated information from sourcing to consumption. Therefore, the reasoning is as follows: "the implementation of SCM enhances customer value and satisfaction, which in turn leads to enhanced competitive advantage for the supply chain, as well as each member firm. This, ultimately, improves the profitability of the supply chain and its members" (Mentzer, et al., 2001, p. 15).

Within the literature, a series of specific objectives to improve profitability, competitive advantage, and customer value/satisfaction of a supply chain have been suggested. For instance, Houlian (1988) suggests that key objective of SCM is to lower the costs required to provide the necessary level of customer service to a specific segment. Customer service can be improved also through increased stock availability and reduced order cycle time (Cooper & Ellram, 1993) or through a customer-enriching supply system focused on developing innovative solutions and synchronizing the flow of products, services, and information to create unique, individualized sources of customer service value (Ross, 1998). Finally, low cost and differentiated service help build a competitive advantage for the supply chain (Cavinato, 1992). Concluding the reasoning, "SCM is concerned with improving both efficiency (i.e., cost reduction) and effectiveness (i.e., customer service) in a strategic context (i.e., creating customer value and satisfaction through integrated supply chain management) to obtain competitive advantage that ultimately brings profitability (Mentzer, et al., 2001, p. 15).

In conclusion, after providing a series of definitions and frameworks relevant to understanding the concept, purpose and consequences of SCM, the next paragraph will be dedicated to the topic of Supply Chain Risk Management.

1.3. Supply Chain Disruptions: Risks and Supply Chain Risks Management (SCRM)

As I said in the introduction, recent history is full of examples of supply chain disruptions that have impacted the performance of companies. For example, due to a fire at a Phillips semiconductor plant in 2000, Ericsson production was disrupted costing the company $400 million in losses. In 2011, the earthquake, tsunami, and the subsequent nuclear crisis that occurred in Japan caused Toyota's production to drop by 40,000 vehicles, costing the company $72 million in lost profits per day. In the wake of these catastrophic events, both scholars and practitioners have undertaken a series of studies aimed at controlling and mitigating the negative effects caused by risks and disruptions in the supply chain, leading to the emergence of the field of study called

Supply Chain Risk Management (SCRM) (Ho, Zheng, Yildiz, & Talluri, 2015).

Before delving deeper into the concept of SCRM, it is necessary to precisely define what is meant within the literature by supply chain disruption. Broadly speaking, a disruption in a supply chain is defined as "an event that disrupts the flow of goods or services" (Zhao, Zuo, & Blackhurs, 2019, p. 190). A more comprehensive but similar definition has been provided by Craighead et al. (2007), who propose that "supply chain disruptions are unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain and, as a consequence, expose firms within the supply chain to operational and financial risks" (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007, p. 1). A further definition argues that supply chain disruptions occur "when, for any number of reasons, there is a break in the supply channel, where a member in the link is unable to perform its assigned task(s) thereby severing the flow of activities from the origin to the destination" (Umar, 2023, p. 1).

As we will see later, losses stemming from supply chain network disruptions may manifest in a lot of ways such as financial loss, loss in operational performance, loss of market position and many more. Moreover, because of the interconnected nature of supply chain networks, a disruption may propagate and cascade through the supply chain, with increasing magnitude or severity of impact. Thus, a disruption may not originate from the focal firm's immediate suppliers but rather elsewhere in the network (Zhao, Zuo, & Blackhurs, 2019).

Numerous journal articles reviewing the literature in the field of SCRM have been published in the last thirty years. Among them we can mention Tang C. S. (2006), who reviewed more than 200 journal articles published between 1964 and 2005 and classified them into four categories: supply management, demand management, product management, and information management for managing supply chain risks. Rao & Goldsby (2009) reviewed 55 published between 1998 and 2008, thus developing a typology of risk factors, including environmental, industrial, organizational, problem-specific, and decision-maker related factors. In addition, Tang & Musa (2011) used the literature citation analysis on 138 journal articles published between 1995 and first half of 2008, identifying and classifying potential risks associated with material flow, financial flow, and information flow. Colicchia & Strozzi (2012) also used the same research method on 55 articles in order to identify the evolutionary patterns and emerging trends in SCRM. Finally, Sodhi, Son, & Tang (2012) reviewed 31 journal articles and conducted surveys with many researchers in order to identify gaps in the subject (Ho, Zheng, Yildiz, & Talluri, 2015).

The aforementioned review articles made significant contributions to the SCRM research, however, in 2015 Ho, Zheng, Yildiz, & Talluri (2015) identified significant knowledge gaps that prompted them to formulate their own contribution. First, according to the authors, each of these review articles focused on a particular topic of SCRM, such as risk classification (Tang & Musa, 2011), risk factor analysis (Rao & Goldsby, 2009), risk management methods (Tang C. S., 2006), or research gap identification (Colicchia & Strozzi, 2012). On the contrary, none of these review articles cover all the SCRM topics (Ho, Zheng, Yildiz,

& Talluri, 2015). Secondly, since these articles are now dated, none of them is recent enough to cover many new studies published after 2010. Moreover, some of them (3 out of 5) reviewed only a relatively small number of articles. To fill these gaps, Ho, Zheng, Yildiz, & Talluri (2015)'s paper developed a comprehensive review of all relevant journal articles in the area of SCRM published in the last years. The paper also proposes new and more eclectic definitions of Supply Risks and SCRM through the classification into supply chain risk types, risk factors, and risk management methods.

Starting from the definitions, we should say that there is no consensus on what exactly is meant by Supply Chain Risks and Supply Chain Risk Management. Over time, multiple definitions of the concept have been provided, however, without a common understanding and clear definition, a communication difficulty has arisen between researchers and practitioners with the consequent problem of access to empirical cases. Despite the applicability of these definitions in specific domains, they tend to focus on a specific function or a part of a supply chain, and do not span across the entire chain. To address this issue, Ho, Zheng, Yildiz, & Talluri (2015) have developed a comprehensive definition of the terms. Hence, the authors define the concept of Supply Chain Risks as follows: "the likelihood and impact of unexpected macro and/or micro level events or conditions that adversely influence any part of a supply chain leading to operational, tactical, or strategic level failures or irregularities" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4-5).

Regarding the definition of Supply Chain Risks Management, the authors complains that while all the previous definitions have emphasized collaboration with supply chain partners, some of their limitations are related to the focus on specific elements of SCRM and their lack of spanning the SCRM processes in their entirety, type of SCRM methods, and types of events. Therefore, the authors proposed the following definition of SCRM: "an inter-organizational collaborative endeavour utilizing quantitative and qualitative risk management methodologies to identify, evaluate, mitigate, and monitor unexpected macro and micro level events or conditions, which might adversely impact any part of a supply chain" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 5).

In addition, by examining the different points of view present in the literature, Ho, Zheng, Yildiz, & Talluri (2015) developed a very useful conceptual framework of supply chain risks and risks management. First, they proposed the division of supply chain risk types into two broad categories: macro risks and micro risks. According to the authors, "Macro risks" refer to adverse and relatively rare external events or situations which might have negative impact on companies. Macro risks consist of natural risks (e.g., earthquakes, weather related disasters) and man-made risks (e.g., war and terrorism, and political instability)" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4). As for micro risks, they "refer to relatively recurrent events originating directly from internal activities of companies and/or relationships within partners in the entire supply chain" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4). As the terms suggest, macro risks can have a much greater negative impact on supply chains than micro risks.

Moreover, Ho, Zheng, Yildiz, & Talluri (2015) further identify four subcategories of micro risk types: demand risk, manufacturing risk, supply risk, and infrastructural risk. The author defines manufacturing risks as follows: "adverse events or situations within the firms that affect their internal ability to produce goods and services, quality and timeliness of production, and profitability" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4). As regards demand and supply risks, they refer to "adverse events at the downstream and upstream partners of a firm, respectively" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4). Infrastructural risks are defined by the author as risks relating to information technology, transportation and financial systems; in fact, the disruption of such systems can cause serious problems in the supply chain.

These types of risk collectively identified by the authors are driven by a series of supply chain risk factors. Indeed, risk factors are "various events and situations that drive a specific risk type" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 6). By sifting through the vast literature on this topic, the authors grouped together a very large number of risk factors that drive the different types of risk. Given the large number of these risk factors, it is not possible to list them in this paragraph. However, they have been summarized in the table (1) in the appendix.

The literature on SCRM has provided several qualitative and quantitative methods to manage supply chain risks. Despite fundamental disagreement about the assessment and the validity of the different methods, the majority of authors in the field agree on the general framework within which to categorize these approaches. The general framework identifies four main phases of SCRM, namely: risk identification, risk assessment, risk mitigation, and risk monitoring.

Risk identification is the first step in the SCRM process. It involves the identification of risk types, factors, or both. While risk identification is beyond the scope of this thesis, some of the methods developed by the researchers include those aimed at identifying potential supply chain risks such as the analytic hierarchy process (AHP) method and the supply chain vulnerability map; those aimed at identifying risk factors using the AHP and the hazard and operability analysis method; while some other scholars proposed qualitative tools to identify both risk types and risk factors, such as a qualitative value-focused process engineering methodology and a supply chain risk identification system, based on knowledge-based system approach (Ho, Zheng, Yildiz, & Talluri, 2015).

The second process in SCRM consists of risk assessment and is related with the probability of an event occurring and the significance of the consequences. Again, over the years the literature has provided a series of specific risk assessment methods for each type of risk, focusing especially on supply risks. For instance, regarding the latter category which is more relevant for the purposes of this thesis, the majority of articles analysed by Ho, Zheng, Yildiz, & Talluri (2015) studied the supplier evaluation and selection problem while considering a variety of supply risks, such as poor quality, late delivery, uncertain capacity, dispersed geographical location, supplier failure, supply destructions. Furthermore, a wide range of quantitative methods

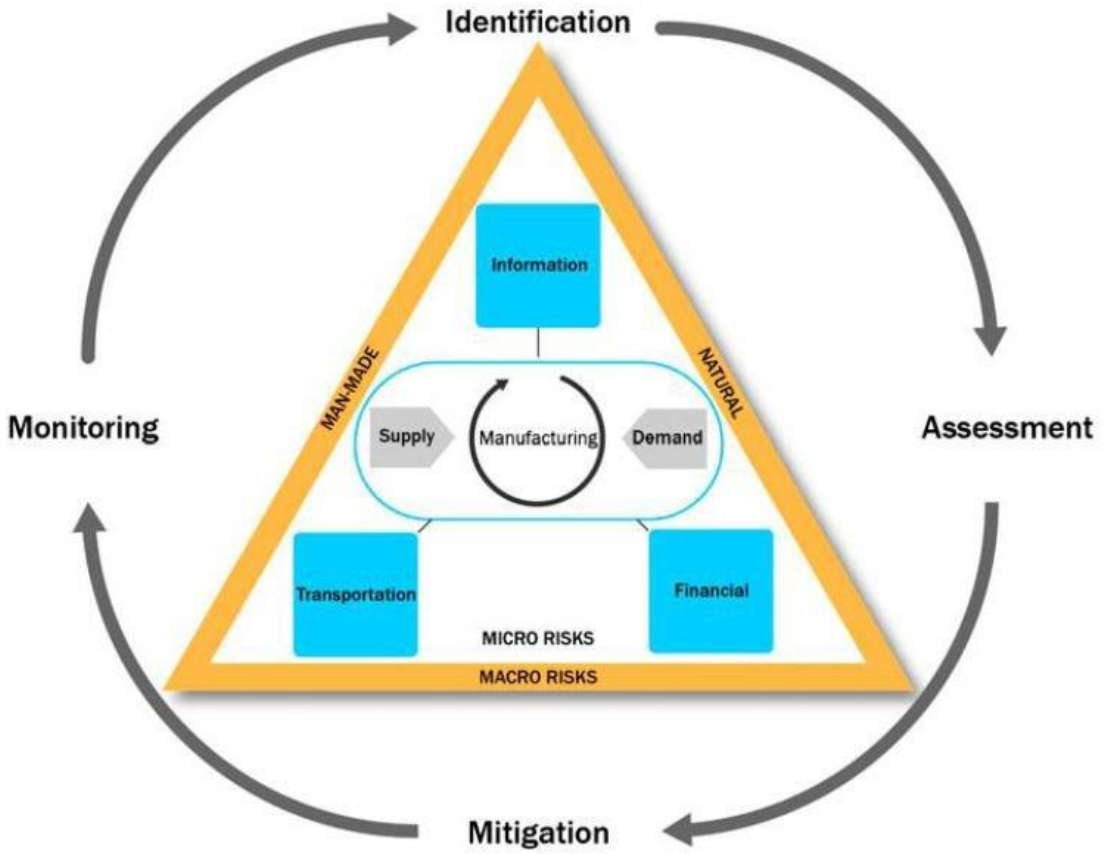
have been proposed for supply risk assessment, including mathematical programming and data envelopment analysis (DEA) approaches, multi-criteria decision making and AHP approaches, decision tree approach. Other scholars have also analyzed and assessed other supply risks such as second-tier supply failure, offshore sourcing risks, supplier unreliability etc (Ho, Zheng, Yildiz, & Talluri, 2015).

Risk mitigation is the third process of SCRM and consists in reducing risk exposure and minimizing the likelihood of an incident along the supply chain. Again, risk mitigation methods have been proposed for each of the risk types mentioned. Among them, particular attention was devoted to supply risk mitigation. The first studies in this regard were empirical studies which showed that supply risk can be mitigated by implementing behaviour-based management techniques, by building strategic supplier relationships, through early supplier involvement, by reducing supply base complexity and by increasing flexibility. Subsequently, most of the attention has been confined to the sourcing decisions. Therefore, initially some scholars tried to determine the optimal number of suppliers in the presence of catastrophic risks or supplier failure risks. The results indicated that additional suppliers are needed when the disaster loss increases significantly, or the suppliers become less reliable. Then, other scholars evaluated single, dual or multiple sourcing strategies and a consensus emerged that a dual sourcing strategy outperforms a single sourcing one in the presence of a supply disruption, however, the benefits of multiple sourcing strategies are not significant since the addition of a third or more suppliers bring much less marginal benefits. Furthermore, a number of scholars determined the supplier selection and order allocation to minimize supply risk using quantitative methods, such as fuzzy multi-criteria decision-making model (Ho, Zheng, Yildiz, & Talluri, 2015).

The fourth and last step of SCRM consists in Risk Monitoring, which is the crucial step where companies measure and review the efficiency of their entire risk management allowing them to know the types of risks that affect their operations. This passage has certainly attracted less scholarly attention over the years than the others, however, for instance some scholars developed an integrated abnormality diagnosis model, combining the fuzzy set theory and the radial base function neural network, to provide pre- warning signals of production quality in the food production supply chain. Their simulation results showed that the proposed pre-warning system can effectively identify abnormal data types, and accurately determine whether a warning should be issued (Ho, Zheng, Yildiz, & Talluri, 2015).

The whole SCRM framework developed by Ho, Zheng, Yildiz, & Talluri (2015) is illustrated by the image below (Figure 1).

Figure 1: The SCRM framework.



Source: (Ho, Zheng, Yildiz, & Talluri, 2015)

As we have seen within the framework developed by Ho, Zheng, Yildiz, & Talluri (2015), "Macro risks refer to adverse and relatively rare external events or situations which might have negative impact on companies". They are divided into natural risks and man-made risks. This last type of risks includes and is driven by one of the most relevant risk factors for the purposes of this thesis: the risk generated by war. Although the war has not affected the Italian territory, as we reported in the introduction, it had a heavy impact on the supply chain of Italian cast-iron foundries. In particular, I argued that the Russian-Ukrainian conflict has created an upstream disruption within the cast iron supply chain.

The SCRM framework described above is also useful for identifying the second type of risk incurred in the supply chain of the foundries and therefore relevant for the purpose of this thesis, which is described by the authors as supply risk. According to the table of risk factors attached in the appendix, this type of risk is driven by a series of factors such as the impossibility to provide competitive pricing, single supply sourcing, small supply base, supplier dependency, global outsourcing, narrow number of immediate suppliers, lack of supplier visibility, transit time variability, sudden hike in costs.

Among the risk factors listed, particular attention was paid to the concept of supply base complexity as related to the concept of supply risk. Choi & Krause (2006) argue that while supply network "includes all companies that take part directly or indirectly in supplying industrial inputs to a focal company with or without that company's knowledge" (Choi & Krause, 2006, p. 639) and is basically outside the managerial purview of the focal company, "a focal firm's supply base is defined as only those suppliers that are actively managed through contracts and the purchase of parts, materials and services" (Choi & Krause, 2006, p. 639). According to the authors, supply base complexity is a factor of the number of suppliers in the supply base, the level of supplier interaction, and the degree to which these suppliers vary in terms of organizational culture, size, location, technology, and so on (Choi & Krause, 2006). Therefore, complexity is associated with the number of elements within the system and the degree to which these elements are differentiated (Choi & Krause, 2006). Within their paper, the authors argue that "overall, it appears then that the level of supply risk is expected to be high both at the low end and high end of the supply base complexity level" (Choi & Krause, 2006, p. 646). The conceptualization of the complexity inherent in the supply base is useful as it allows to analyze and describe an additional dimension of the supply chain as related to supply risks.

Therefore, after having exposed the concept of supply chain disruption and the risks associated with it, my first hypothesis is:

(H1): *the Russian-Ukrainian conflict has generated an upstream disruption within the cast iron supply chain, which in turn has represented a supply risk for the Italian cast iron foundries*.

As we will see later, in order to validate this first hypothesis (H1), part of the empirical chapter of this thesis will be devoted to the identification of which of the risk factors that drives supply risks affected (if this occurred) the Italian cast iron foundries. Furthermore, to operationalize the two concepts of "upstream disruption" and "supply risk" we will take into account the parameters suggested by Chopra & Sodhi (2004) and which will be analyzed in detail in the methodological section.

Going beyond the concepts of risk and uncertainty, the next paragraph will be dedicated to the concept of ambiguity in the supply chain.

1.4. The Concept of Supply Chain Ambiguity

As we have seen, the literature on SCM and SCRM recognized and well documented that a firm's supply chain is subject to risk and uncertainty. However, according to Gunessee & Subramanian (2020), the literature still suffers from a gap generated by the neglect of ambiguity. The authors argue that “ambiguity is the imprecision involved in situations when the decision-maker is making a judgement, assessment or forecasts” (Gunessee & Subramanian, 2020, p. 1202). Before the contribution of the authors, ambiguity's consideration in the supply chain literature was limited and tended to assimilate the concept with that of risk or uncertainty. However, ambiguity should be distinguished from both risk and uncertainty as risk “defines

states of the world or situations that can be exhaustively and exclusively specified and can be so as information unfolds over time" (Gunessee & Subramanian, 2020, p. 1203) while "an ambiguous situation instead cannot be exhaustively and exclusively stated or that information will bring clarity. Thus, ambiguity can be defined as situations or events whose outcomes and likely occurrence are unclear and cannot be coded with precision" (Gunessee & Subramanian, 2020, p. 1203). Moreover, the author continues the distinction as follows: "risk is a situation where we can assign objective probabilities to outcomes or events. Uncertainty is where we can describe the events but cannot assign objective probabilities (though sometimes subjective probabilities can be assigned). Ambiguity corresponds to a situation where there is no sufficient information to assign objective probabilities and where even a subjective probability distribution cannot be defined uniquely" (Gunessee & Subramanian, 2020, p. 1203).

Through their contribution, the authors have developed a typology of ambiguity applied to the context of supply chains. In particular, the authors provide four different types of ambiguity:

- Interpretative ambiguity
- Causal ambiguity
- Evaluative ambiguity
- Probabilistic ambiguity

The first type of ambiguity "implies a situation being open to more than one interpretation, with an unambiguous situation described as having clear understanding as it has one meaning" (Gunessee & Subramanian, 2020, p. 1205). Indeed, within the organizational life it is quite possible that multiple inconsistent interpretations of situations/events are developed by managers, and this can lead to the worsening of a situation which may already be critical in itself.

Causal ambiguity, on the other hand, concerns the unclear nature of causal connections between factors. The authors cite as an example an organization that is unable to determine how it has achieved a competitive advantage as a result of some purchasing activity.

Evaluative ambiguity is about decision-makers' assessment of situations including impact and outcomes. For example, it could arise in connections to a supplier's performance when it is difficult to ensure product and process specification confirmation and identifying responsibilities if something goes wrong.

Lastly, probabilistic ambiguity is the classical type of ambiguity which encapsulates "uncertainty about probabilities" and extreme ambiguity. Probabilistic ambiguity relates to decision-makers being unsure about the exact likelihood of potential outcomes and unaware of what future scenarios are possible (Gunessee & Subramanian, 2020, p. 1205).

The authors argue that ambiguity can be observed both in "normal" contexts (day-to-day management

of operations) and in disruptive situations where the normal flow of goods and resources in the supply chain is altered. What demarcates an unambiguous situation from an ambiguous one is "two set of factors, information and cognitive factors and supply chain complexity factors. The former are individual or behavioural factors, while the latter are organizational factors" (Gunessee & Subramanian, 2020, p. 1206).

Indeed, at the heart of the concept of ambiguity lies information. The ambiguity of a situation, in fact, is directly proportional to the amount of information available, whether missing or incomplete, to its lack of clarity due to possible multiple and sometimes conflicting meanings that can be attributed to the data or to the novelty of the situation due to lack of signals. A situation of extreme ambiguity occurs when all information is conflicting, unreliable or unknown, and this can lead to a lack of resolution on how to proceed. On the other hand, information becomes clear and consistent when "probabilities could be assigned to possible outcomes (turning probabilistic ambiguity into risk); signals or data being better interpreted to tell coherent stories and when we can shape the meaning of a decision situation through our evaluation of outcomes to decipher cause from effect" (Gunessee & Subramanian, 2020, p. 1206). Therefore, the status and availability of information in a situational context can be a source of ambiguity.

Following the authors, another source of ambiguity can be represented by human cognition, or rather by its limits. In fact, "people and even organizations are limited in their ability and capacity in processing information because of “bounded rationality. With such limited cognitive ability, it implies people may not interpret information in a reasoned and logical manner (rationally) or have impaired ability to evaluate evidence and make connections from such evidence to form correct understandings of cause and effect (e.g., interpretative, causal and evaluative ambiguities). At times people's probabilistic judgments or risk perception are impaired as well due to cognitive limitations, giving rise to probabilistic ambiguity” (Gunessee & Subramanian, 2020, p. 1206). Thus, the state of information as well as the notion of bounded rationality play a crucial role in the formation of ambiguity. The limitation of human rationality starts from the assumption that decisions are made under incomplete information, as not everything can be known. Lack of information combined with limited rationality increases the decision-maker's difficulty to interpret or evaluate outcomes of situations, assign probabilities to their likely occurrence, or make causal attribution.

On the organizational side, according to the authors what generates ambiguity is the complexity of the supply chains. In particular, two factors drive complexity: change in an organisation's external environment and global sourcing. As regards the first factor generating ambiguity, this is not new to the treatment of this thesis. Indeed, Gunessee & Subramanian (2020) argue that: "organizations operate in business environments that are not static but dynamic and ever changing. With such external environment in a state of flux this generates complexity for an organization and its supply chain. Changing business environments gives rise to ambiguities through gathering and processing of information" (Gunessee & Subramanian, 2020, p. 1207). On the other hand, global sourcing contributes to ambiguity to the extent that companies must cope with increased

reliance of international supply chain partners, more customer base to serve, supply lead time variability and international transportation. This has especially led to ambiguity related to the difficulty to evaluate the potential consequences of such global sourcing (evaluative ambiguity).

In conclusion, my second hypothesis follows directly from these premises. The Russian-Ukrainian conflict has generated a situation whose outcome is at best unclear. The information arriving in Italy is insufficient and unreliable given the heavy propaganda and the technical difficulty in finding the news. In particular, the impossibility of assigning probabilities to the different outcomes and of evaluating their impact on the cast iron supply chain configures at least one hypothesis of evaluative and probabilistic ambiguity. Furthermore, following the author, in the case of Italian cast iron foundries it is not only the incomplete, conflicting or sometimes totally unknown state of information that generates ambiguity, but rather it joins the complexity of the supply chain. Indeed, the ever-changing organizational external environments coupled with global sourcing are major contributors to the creation of ambiguity within the cast iron foundry industry. My second hypothesis therefore is:

(H2): *Due to the Russian-Ukrainian conflict, Italian cast iron foundries are operating in an ambiguous environment.*

In the remainder of their contribution, Gunessee & Subramanian (2020) sets out a series of strategies to cope with ambiguity at both the individual and organizational levels. For the purposes of this thesis, I will only consider the latter as deemed more relevant to our case. In delineating the strategies implemented by companies to cope with supply chain under ambiguity, the authors borrow two concepts from the literature on SCRM which will be covered more specifically in the next paragraph. In fact, he refers to the concepts of mitigation and preparedness. Gunessee & Subramanian (2020) argue that "Supply chain ambiguity-mitigation strategies comprise means to reduce fuzziness that permeates ambiguous situations (normal or disruptive). Instead, supply chain ambiguity-preparedness strategies are proactive strategies used by organizations to deal with ambiguous disruptions, whether they are mild or severe" (Gunessee & Subramanian, 2020, p. 1208). Among the first, the authors list redundancy (holding strategic stocks), capacity (backup facilities/raw materials), lean operations (simplifying process) and postponement (delaying activities).

As regards the concept of preparedness, it recalls the concept of resilience that will be the topic of the next paragraph. The authors define preparedness as follows: "Preparedness means the enterprise has developed a supply chain that is ready to cope with supply chain disruptions. This can be achieved by building supply chain resilience, which can be defined as the ability to recover, adapt, grow and flourish in the face of uncertain/turbulent change to a supply chain and to return to a desired steady state" (Gunessee & Subramanian, 2020, p. 1208).

1.5. The Concepts of Supply Chain Restructuring: From Risks and Ambiguity to Resilience

After sifting through the literature on Supply Chain (SC), Supply Chain Management (SCM) and Supply Chain Risk Management (SCRM), in the previous paragraph we have outlined the concept of Ambiguity in supply chain. Conversely, this paragraph will be dedicated to the topic of Supply Chain Restructuring.

As we have seen above, supply chain risks can become real supply chain problems, causing unexpected changes in the flow of goods due to disruptions. Interruptions can be frequent or infrequent; short or long term; and cause problems for the affected organizations, ranging from minor to severe. Most companies develop plans to protect against low-impact, recurring risks in their supply chains. Many, however, are all but ignorant of high-impact, low-probability risks (Chopra & Sodhi, 2004). The ability to restructure the supply chain in the face of changing conditions (disruptions and supply risks) is critical to maintain continuity of supply chain performance. Flows of materials within the supply chain network need to be redirected and structures need to be adapted to allow for continuity in operations (Zhao, Zuo, & Blackhurs, 2019). As a result, managers will continue to face the critical challenge of recovering from supply chain disruptions and attempting to minimize their impact. Thus, beyond understanding how managers might work to prevent disruptions through risk planning, it must be better understood how managers respond to and recover from the supply chain disruptions they experience (Macdonald & Corsi, 2013).

As already mentioned, most of the leading companies deal with this range of supply-chain risks by holding reserves, which usually includes excess inventory, excess capacity and redundant suppliers. Therefore, in this context the big challenge for managers is to mitigate risk by intelligently positioning and sizing supply-chain reserves without decreasing profits. In fact, while stockpiling inventory may shield a company against delivery delays by suppliers, building reserves in an undisciplined fashion also drives up costs and hurts the bottom line (Chopra & Sodhi, 2004). According to Chopra & Sodhi (2004): " The managers' role here is akin to that of a stock portfolio manager: attain the highest achievable profits (reward) for varying levels of supply-chain risk and do so efficiently. This means the manager must seek additional profits for any level of risk protection and preparedness or increase prevention and preparedness without reducing profits" (Chopra & Sodhi, 2004, p. 54-55).

Building excess inventory is not always a simple solution, in fact, it can get very costly since while holding costs are incurred continually, the excess inventory would be used only in the rare event of a disruption. In essence, the company pays (and continues to pay) for reserves that may never be tapped. Therefore, this approach makes more sense as the probability of predicting disruption increases (Chopra & Sodhi, 2004). Furthermore, stockpiling inventory as a hedge against disruption also makes sense for commodity products with low holding costs and no danger of obsolescence. In the case of products with high holding costs and/or

a high rate of obsolescence, using redundant suppliers is a better strategy. By doing so the company can prepare for disruptions without building up fast-depreciating inventory. The downside of such an approach is the possible loss of efficiency due to small economies of scale. (Chopra & Sodhi, 2004).

Overcoming the "classic" prescriptions mentioned above and by adopting a vision of the supply chain as a complex adaptive system (CAS), in the face of a supply disruption companies connected in a complex network can adapt and restructure their connections. In this case, the CAS framework provides a useful theoretical foundation as firms in a supply chain operate as an interconnected network in a dynamic environment. In such environment, even a small change at one node in the chain can cause a disruption to spread throughout the supply chain. Positing that firms in a supply chain constitute self-organizing networks, several authors have argued that some supply chains can be adaptive or resilient. This means that when hit with a disruption, they can adapt or restructure themselves to reach a desirable state which can be back to the original state, an equivalent state, or a better state (Zhao, Zuo, & Blackhurs, 2019).

From CASs perspective, when facing a disruption, the ability of companies to adapt and restructure is critical for minimizing the losses. Equally critical is the effectiveness of adaptive strategies in improving network resilience after node removal or the emergence of a supply risk. In recent years the concept of resilience to supply chain disruptions has been frequently explored, however without incorporating the concept of CAS. In other words: "understanding how disruptions impact multiple tiers in a supply chain and how the structure of the network may play a role in this impact is lacking" (Zhao, Zuo, & Blackhurs, 2019, p. 191). Therefore, this thesis aims to add a further piece of knowledge on how interconnected companies behave within a complex network in the face of a supply disruption. Through the interview of supply chain managers operating within Italian cast iron foundries, it is possible to examine their resilience and the effect of adaptive behaviour in real-world supply chain networks.

The study of Zhao, Zuo, & Blackhurs (2019) proposes and examines two types of adaptive strategies to restructure a supply chain network: first, a reactive strategy, which aims to restructure the network in response to a disruption event among first-tier suppliers. Therefore, reactive strategies are used when an immediate supplier of a focal firm fails. Secondly, the authors develop and propose the concept of proactive strategies. These strategies focus on restructuring the network after observing a distant firm failure (beyond first tier) in order to avoid possible disruptions to the focal firm. Proactive strategies represent a forward-looking approach because they anticipate a disruption which has already occurred in another part of the network and will hit the focal firm; consequently, the company will identify the weakest spot specific to the disrupted distant firm in the network (Zhao, Zuo, & Blackhurs, 2019). In their study conducted through an Agent-Based Model, Zhao, Zuo, & Blackhurs (2019) claim to have captured phenomena in CAS by simulating how each individual (i.e., agent) makes decisions based on its interactions with the environment and other agents. Within the study, agents can adapt in response to a change in the system (disruption or supply risk) and

this adaptation could lead to a restructuring of the network. Specifically, their first model simulates how firms respond to disruptions via reactive behaviours, showing the impact of disruptions with and without adopting reactive strategies. The authors claim that “comparing simulation results where agents have reactive behaviours versus not, we can see that ignoring agent's adaptive behaviours from the model greatly increases the impact of the initial disruption. With a reactive strategy, the maximum numbers of disrupted firms are lower than 30, whereas the minimum numbers of disrupted firms after an initial high-degree node removal are higher than 1,400 without a reactive strategy” (Zhao, Zuo, & Blackhurs, 2019, p. 200).

In other words, the inclusion of an agent's reactive strategy in face of disruptions into their model plays an important role in reducing the negative impact of supply chain disruptions. Without considering such adaptive behaviours, many previous studies of complex network resilience may have overestimated the negative impact of a disruption (Zhao, Zuo, & Blackhurs, 2019).

Next, the authors argue that although the first model included firms' adaptive behaviours in seeking alternative suppliers when their original suppliers fail, reactive strategies are put into practice only when the firm is forced to deal with the impact of a failed tier-1 supplier. Therefore, companies may want to adopt a more proactive strategy in preparing for disruptions that occur even at a distant firm in the supply network and even before any of its immediate suppliers fails. To this end, "more proactive identifications of which supplier are the riskiest spot given a distant disruption allows a focal firm to prepare an alternative supplier to the riskiest spot" (Zhao, Zuo, & Blackhurs, 2019, p. 200). The authors also argue that by doing so companies acquire two advantages: "First, it faces less competition for alternative suppliers with other firms that only react to the failure of a direct supplier. Second, because such proactive behaviour occurs before the distant disruption actually hits the focal firm, it has more time to streamline supplies from the alternative supplier than when it only adopts the reactive strategy after a direct supplier has failed" (Zhao, Zuo, & Blackhurs, 2019, p. 200).

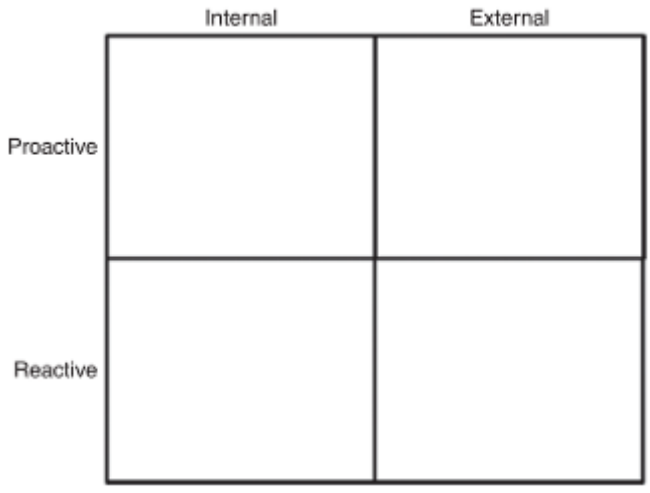
In order to test these above hypotheses, the authors developed a model that simulates the removal of high-degree distant firms from the focal one and compare the probabilities that it will be disrupted with and without using proactive strategies. Based on which distant firm is removed, their proactive strategies identify the riskiest spot among the focal firm's suppliers corresponding to the distant removal. Then the proactive strategies add a new supplier as a backup or alternative for the riskiest spot (Zhao, Zuo, & Blackhurs, 2019). The authors comment on the study results as follows: "Compared to the baseline with only reactive behaviors, proactive strategies can reduce the probabilities of disruptions for 150 (82.87%) of the 181 focal firms in our simulation" (Zhao, Zuo, & Blackhurs, 2019, p. 202).

Very similar to the supply-side resilience perspective provided by the authors above mentioned, Dabhilkar, Birkie, & Kaulio (2016) proposed that “Supply-side resilience can be defined as the capability of a buying firm to prepare for, respond to and recover from unexpected upstream supply chain disruptions by

returning to, or maintaining continuity of, operations at the desired level of connectedness and control over structure and function" (Dabhilkar, Birkie, & Kaulio, 2016, p. 949). As stated before, previous studies have typically conceptualized supply chain resilience as a property coming from accumulation of redundant capacity and inventory. Instead, Dabhilkar, Birkie, & Kaulio (2016) claim to have shifted the focus of resilience in supply chains from redundant capacity and inventory to dynamic capabilities. The latter are defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing circumstances" (Dabhilkar, Birkie, & Kaulio, 2016, p. 950). Indeed, according to the authors: "these capabilities can enhance a firm's reconfiguration of existing infrastructure to better manage disruptions" (Dabhilkar, Birkie, & Kaulio, 2016, p. 950).

The dynamic capabilities are formed from intentional practices undertaken in the business firm and help to deploy the resources and infrastructure to align with prevailing circumstances upon disruption. Similarly to the approach of Zhao, Zuo, & Blackhurs (2019), the authors frame these capabilities along two main dimensions: the first overlaps in the two approaches and is the "proactive or reactive" dimension, however, a further dimension is added called "internal or external" according to the capability's location (Dabhilkar, Birkie, & Kaulio, 2016). Since I have already described the first dimension before, I won't dwell on its definition. As regards the second one, "Internal means focus on practices within the boundaries of the buying firm for managing and mitigating risk sources, while external refers to practices related to the buying firm's capabilities to integrate and benefit from actions of actors in the wider supply chain networks" (Dabhilkar, Birkie, & Kaulio, 2016, p. 951). The practice of resilience can be classified according to both dimensions at the same time to create a 2x2 matrix as illustrated in the image (Figure 2).

Figure 2: The classification of resilience's practices



Source: (Dabhilkar, Birkie, & Kaulio, 2016)

This suggests four independent variables, namely, proactive-internal, proactive-external, reactive-internal and reactive-external bundles of possible resilience practices. As dependent variable, they suggest the buying firm's ability to return to its original or desired level of manufacturing operations performance after disruption by an unforeseen upstream supply chain incident. For assessing resilience, the key issue is the level of operations performance after recovery in areas that particular buying firm prioritizes among the performance objectives. The authors aim to demonstrate that each of these four bundles of practices helps buying firms to recover their manufacturing operations performance to its original or desired state in the event of an upstream supply chain disruption (Dabhilkar, Birkie, & Kaulio, 2016).

To do this, they utilized a sequential research approach including two interlinked CIT studies: first, a pre-study among 14 firms, and then, a main study among 22 other firms. The authors summarized the results of their research as follows: "analysis clearly shows that the four types of resilience capabilities cause operations performance to recover to a desired level after being disrupted by an upstream supply chain incident. Different performance objectives are affected across the 22 studied incidents, but on an aggregate level the study shows that all four supply-side resilience bundles lead to mitigated operational performance in all five dimensions (cost, quality, speed, delivery and flexibility)" (Dabhilkar, Birkie, & Kaulio, 2016, p. 964).

In conclusion, the third hypothesis of this thesis derives directly from the literature on supply chain restructuring and from the concept of resilience. Given that the Italian cast iron foundries are connected in a complex and dynamic network, the third hypothesis is the following:

(H3): *In the face of the supply disruption caused by the Russian-Ukrainian conflict, foundries have adapted by restructuring connections and building resilience*.

The first chapter dedicated to the literature review closes with this third hypothesis formulated. The literature review was dedicated to the selection of the relevant lines of thought, arguments and empirical evidence to logically develop the three hypotheses. The second chapter will be dedicated to the Russian-Ukrainian conflict, to the consequences this is having on global supply chains (disruptions), to the structure of Russian-Ukrainian trade in its global and bilateral dimension with Italy, to then conclude with a focus on the sector informing this thesis: the Italian cast iron foundries.

Second Chapter: The Italian Cast Iron Supply Chain

2.1. The Russian-Ukraine Conflict and the Disruption of Global Supply Chains

As sadly known since the dawn of time, the chaos and destruction generated by war cause, in addition to immense human pain, heavy economic disruptions. In fact, on the one hand, the destruction of production sites, destruction of supply chains, the disabling of state infrastructures and the displacement of people cause the rupture of economic activity. On the other hand, the reliance on foreign input producers can lead to the disruption of production when source countries experience a negative shock, such as a war that leads to economic sanctions. Although it is difficult to create a generalized measure of the economic costs of international wars, everyone agrees on the heavy social and economic repercussions that these cause to the point of having coined the term "development reverse" to describe the persistent negative economic effects of wars. As of 24 February 2022, the day President Vladimir Putin announced the start of "special operations", we are witnessing such a development in reverse unfolding in Ukraine. From that day on, Russian troops began the invasion of Ukrainian territory and after only a few weeks millions of people have left the country, and formerly prosperous towns now lie in ruins. At the same time, the international community punishes Russia with sanctions of an unprecedented scale, which have the potential to hurt the Russian economy significantly and end decades of economic collaboration (Stemmler & Korn, 2022).

Therefore, since the onset of the war Supply bottlenecks have worsened, especially in sectors largely dependent on Russia's and Ukraine's exports, and the global Geopolitical Risk Index[1] has more than doubled, reaching levels not seen since the outset of the war in Iraq in March 2003 (Ruta, 2022).

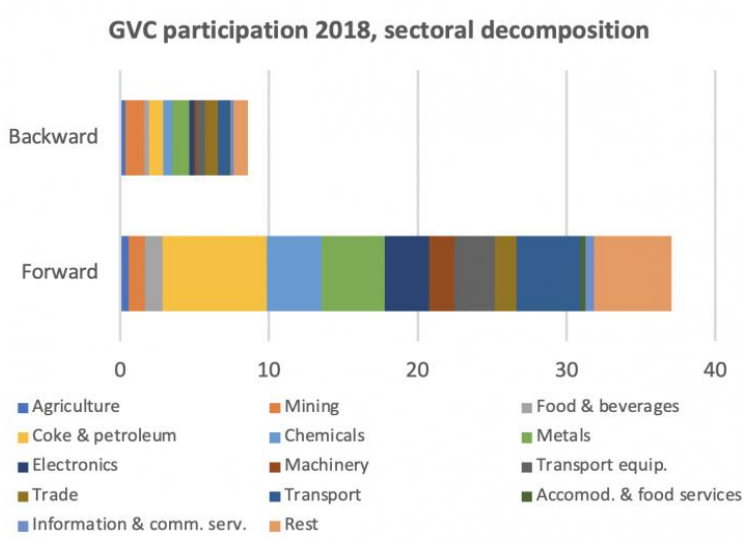
To assess the potential implications of war-related disruptions for global supply chain and their geographic dimension is useful to look at Russia's and Ukraine's trade specialisation. First, it must be said that the direct role of Russia and Ukraine in the global economy is small. Together, they account for only about 2% of global GDP at market prices and a similar proportion of total global trade, with limited bilateral trade for most countries. In absolute values, Russia ranks thirteenth for total exports and twenty-first for imports (OEC, 2020), while Ukraine ranks forty-sixth for total exports and forty-seventh for imports (OEC, 2020). Financial links with other countries are also generally modest. However, in one respect, Russia and Ukraine do have an important influence on the global economy. This is via their role as major suppliers in a number of commodity markets (OECD iLibrary, 2022). In particular, Russia's exports of oil, gas, and coal account for 15% of the world's exports of these commodities and the EU is its largest importer and the region with the highest import dependence from Russia. In addition to energy commodities, Russia is also a key exporter of materials used in the production of fertilizers (chemicals), especially potash, where it has a dominant position

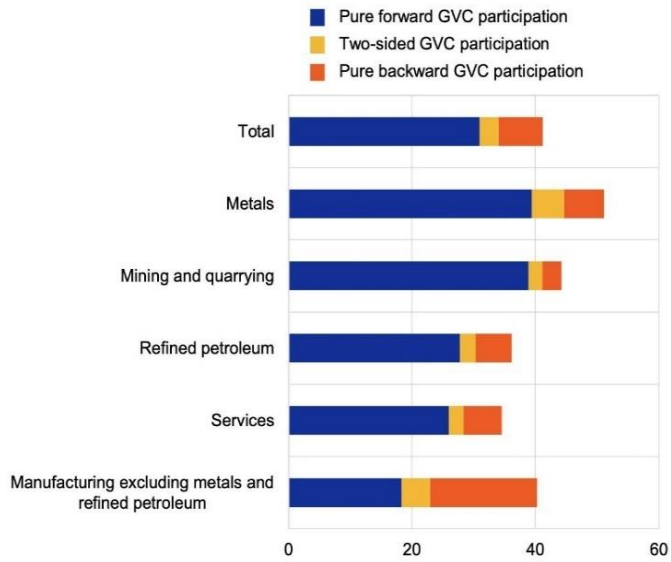
[1] Risk Index: https://www.matteoiacoviello.com/gpr.htm

and of critical raw materials, such as palladium, vanadium, and cobalt, which are most prominently used in the production of 3D printing, drones, robotics industries, batteries, and semiconductors, thus affecting also other sectors, such as electronic appliances, transportation, and most prominently the car sector. Russia is also the fourth largest producer of coking coal, used for steel production, where it also enjoys a dominant market position (Metelli, Mancini, Gerinovics, Gunnella, & Attinasi, 2022).

Moreover, war-related disruptions to production and trade flows from Russia may be amplified through global production networks given the country's significant forward integration (upstreamness)[2] in global value chains that places the country at the foundation of a wide array of global production. In fact, Russia is especially important as an exporter of primary and intermediate goods and services used in other countries' exports at an early stage of production. The country's share in global forward global value chains participation is around double the size of its share in gross global trade (2.8% versus 1.5%), and this is because the Federation has one of the highest forward participation rates in supply chains (figure 3), as more than 30% of its exports consist of inputs used by its trade partners as intermediate inputs, compared to a global average of just 18% (Metelli, Mancini, Gerinovics, Gunnella, & Attinasi, 2022).

Figure 3: Russia's forward and backward GVC participation





Sources: Vox EU (Wuester & Winkler, 2022)

Sources: World Bank WITS, ADB MRIO tables

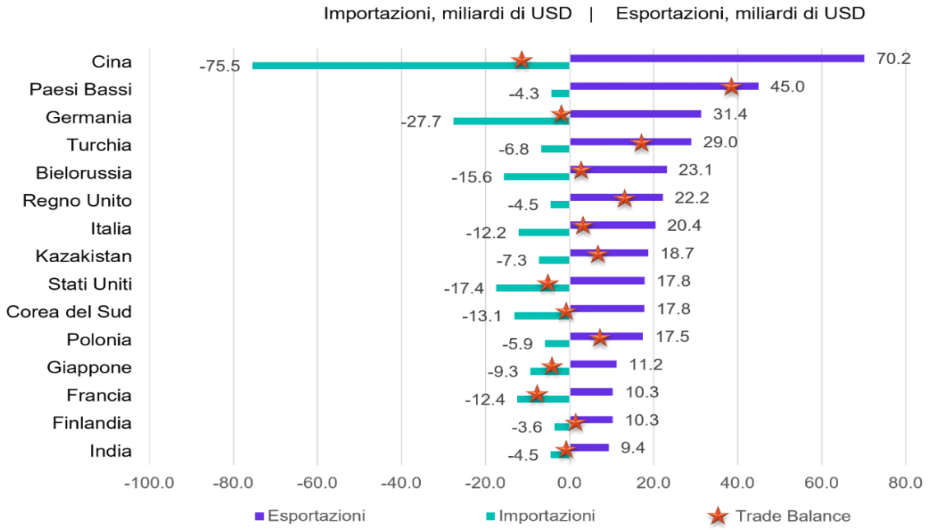
The explanation for this phenomenon can be found in Russia's specialization in energy and metal industries, which are intrinsically more forward integrated, being positioned upstream in the production

[2] Note: Forward GVC participation = Domestic value added embodied in third country exports (% of exports). Backward GVC participation = imported inputs in exports (% of exports) (Wuester & Winkler, 2022).

process. Therefore, consistently with the above literature, disruptions to Russia's exports might well propagate downstream through supply chain networks, having an impact also via the indirect trade (Metelli, Mancini, Gerinovics, Gunnella, & Attinasi, 2022). Disruptions of Russia's exports will feed into GVCs via major global production hubs for trade and will especially affect regional economies that are highly dependent on these supplies. While virtually all GVCs are affected by rising energy prices, GVCs that are especially reliant on chemicals and raw material inputs from Russia for their export production will be most affected. As a major commodity exporter, disruptions of trade with Russia have a global impact through price hikes, namely in energy sector, wheat, corn, and vegetable oils, fertilizers and metals. Logistics disruptions, inflated freight prices, and longer delays affect trade and transit flows between Russia and Europe but also between East Asia and Europe. The GVC production hubs of China (and to a lesser extent Japan and South Korea), Germany (and other Western European countries), and the US are among Russia's largest trade partners. However, the countries that are most dependent on exports from Russia, and thus particularly vulnerable to such trade disruption, are neighbouring and regional economies (Wuester & Winkler, 2022).

Another variable to take into consideration when it comes to analysing the economic repercussions of a conflict on trade and a country's supply chains is power relations. In other words, some global supply chains are made up of many competing suppliers globally (e.g. apparel), while others global suppliers have large market power (e.g. semiconductors). For example, pig iron exports are dominated by three countries (Russia, Brazil, and Ukraine), together accounting for over three-quarters of global exports. Hence, replacing pig iron imports from Russia will be more difficult than products for which the global market is less concentrated. Therefore, while a country's GVC risk depends largely on its direct trade links with Russia, GVCs reliant on products that have fewer substitutes will be affected more severely (Wuester & Winkler, 2022). In addition to pig-iron, Russia is a key exporter of several goods with few substitutes, including metals (with dependence on direct trade links highest for countries in the Europe and Central Asia, or ECA, region), fertilizers (with high dependence of both regional and global markets), and also extends to services supporting those exports (Wuester & Winkler, 2022). As we have seen, although Russia is not a superpower in economic and commercial terms, its exports are the basis of production in many strategic sectors. Below there is a summary chart of the major trading partners of Russia (figure 4) which shows the Federation's trade surplus with most of them and one summarizing Russia as a seller divided by key sectors and products (figure 5).

Figure 4: Russia's major trading partners.



Source: (Podkaminer, Sampson, Ratkovsky, & Walling, 2022)

Figure 5: Russia as a seller.

Russia as a seller

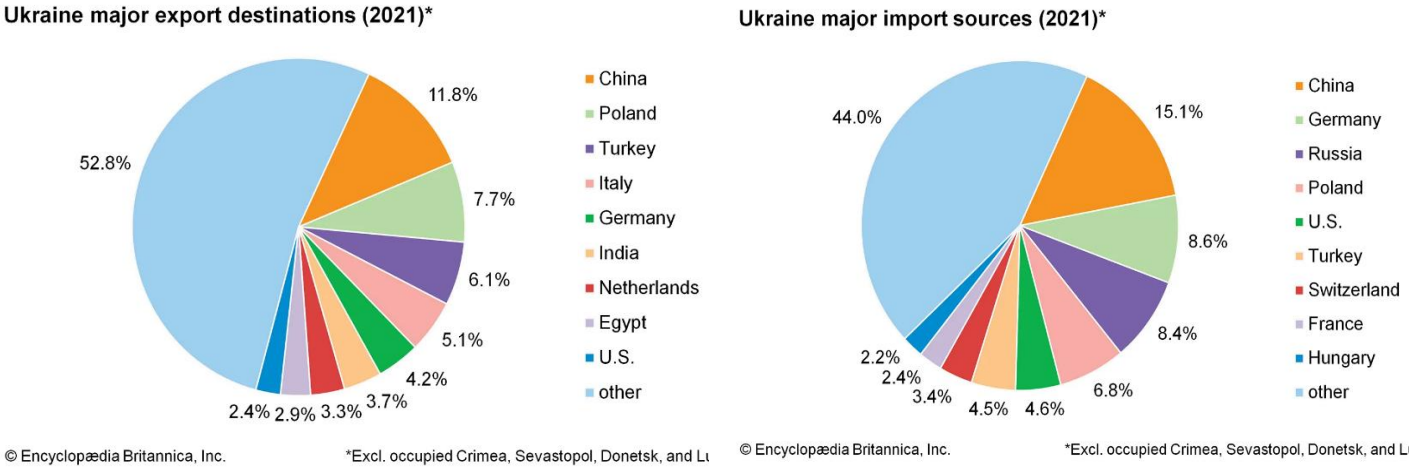
Sector	Key Products	Key Global / Regional Value Chains	Largest direct partners	Most dependent partners
Fuels	Crude oil	Many	CHN, DEU, NDL, POL, BLR	MNG, BLR, SVK, EST, KAZ
	Petroleum products	Many	USA, TUR, DEU, GBR, KOR	MNG, KAZ, KGZ, BLR, TJK
	Natural Gas	Many	ITA, JPN, BLR, SVK, CZE	BLR, SVK, EST, LVA, SRB
Metals	Palladium	Transp. equipment (catalytic converters)	USA, JPN, DEU, CHN, ITA	CAN, JPN, USA, ITA, KOR
	Iron and steel	Transport equipment, machinery	TUR, USA, BLR, ITA, BEL	KAZ, BLR, KGZ, AZE, UZB
	Copper, aluminum	Electronics, trans. equip, machinery	CHN, DEU, TUR, JPN, USA	BLR, KAZ, ARM, UZB, AZE
	Nickel	Metal (alloying), auto (batteries), electronic	CHN, FIN, DEU, NLD, USA	FIN, BLR, UKR, LVA, MDA
Chemicals	Fertilizers	Agribusiness	BRA, USA, CHN, IND, MEX	MNG, BLR, AZE, KAZ, MDA
Electronics	Cell phones, receivers, etc.	Electronics	BLR, KAZ, AZE, CHN, GEO	BLR, ARM, GEO, TJK, KAZ
Transport Equipment	Metal, auto parts	Transport equipment, machinery	CHN, FIN, DEU, NLD, USA	FIN, BLR, UKR, LVA, MDA
Services	Transport, business serv.	Business services, agribus., transport	DEU, NLD, JPN, AUT, USA, FIN	LIT, LVA, EST, SLV, FIN

Source: (Ruta, The Impact of the War in Ukraine on Global Trade and Investment, 2022)

Turning instead to the second country currently at war, we cannot say that Ukraine is a large supplier on a world scale, however, it concentrates its exports in a limited number of important sectors: steel (due to Ukraine's exports of iron ores, ferro silico manganese, pig iron), heavy manufacturing (flat and rolled steel products), semiconductors (neon gas), cars (ignition cables), industries using titanium, and the IT industry. Furthermore, Ukraine holds 52% of world exports of sunflower seed/safflower oil and 48% of oil-cake & other solid residues, 10.6% of maize and corn, 25% of Glazed ceramic flags & paving/hearth/wall tiles, 22% of non-

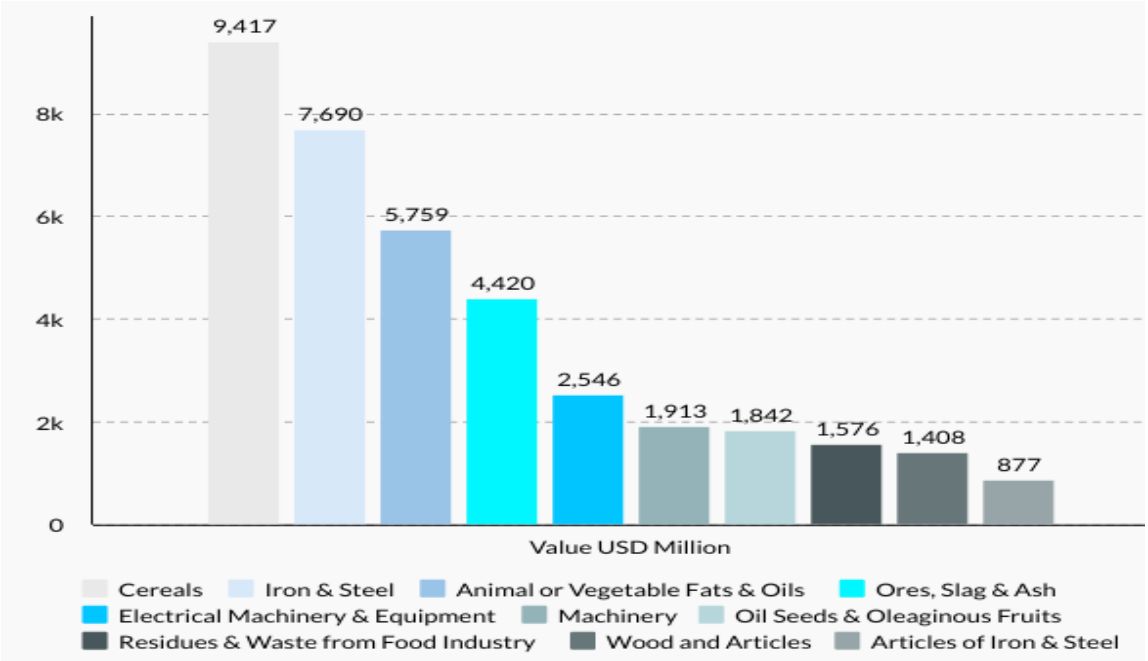
alloy pig iron containing by weight 0.5%/less of phosphorus and 15% of semi-finished products of iron/non-alloy steel (Ruta, 2022).The considerations on the type of materials exported and on the repercussions that a disruption of the Ukrainian global chain could arise are very similar to those made for Russia, both being characterized by upstreamness in the global supply chain (Ukraine less than Russia) and by exporting mainly raw materials. On the other hand, as we can see from the graph below (Figure 6), Ukraine is not a major export destination except for some countries in Eastern Europe (plus Italy) and Central Asia. As far as import sources are concerned, Ukraine mainly obtains supplies from China, Germany, Russia and Poland.

Figure 6: Ukraine Major Export/Import Destination



Source: (Britannica, 2022)

Figure 7: Ukraine top-ten exports products



Source: (Export Genius, 2022)

The graph (Figure 7) shows the main products exported by Ukraine globally and the relative economic values: in first place we find cereals for a value of almost 9.5 billion dollars, immediately followed by Iron and Steel, which account for about 7.4 billion dollars, while in third place on the podium are animal or vegetable fats ad oil for a value of 5.7 billion.

Therefore, as we have seen, the interruption of the supply chains occurred for different reasons but concern both the Russian and the Ukrainian ones, and both are problematic since they concern the first steps on which entire production chains depend.

As previously mentioned, one of the main reasons for the disruption in supply chains from Russia is due to the restrictive financial and trade sanctions imposed by a large group of Western countries, which represent about 55% of the world GDP and absorbed almost 60% of the Russian Exports in 2020. The sanctions imposed include a variety of trade restrictions (tariff increases, including in some cases the suspension of Russia's MFN status under WTO, import and export bans to selected non-energy products), the halting or cancellation of infrastructure projects (e.g., halt to the Nord Stream 2 from the part of Germany), and the financial system (exclusion of most Russian banks from SWIFT and freezing of half of the official foreign currency reserves). Moreover, a list of individuals, among which members of the Russian government and parliament and several oligarchs, faced travel bans and asset freezes in countries adopting restrictive measures against Russia. Private companies, including large shipping multinationals, decided to suspend their activities in Russia or announced their exit from the Russian market in the coming months. Others voluntarily curtailed their purchases of Russian products, including crude oil (Borin, et al., 2022).

In response, Russia retaliated by imposing restrictions on trade while implementing measures to support the ruble. The government forced Russian exporting firms to convert their foreign currency revenues into rubles and introduced strict controls on capital outflows by foreigners and residents. Moreover, Russian authorities announced the possible nationalization of foreign companies to counteract business shutdowns and announced a switch of energy contracts to rubles. Overall, bilateral barriers to trade increased enacting a substantial decoupling between Russia and the sanctioning countries. The actual rise in trade barriers is not easy to quantify, given that the list of restrictive measures is extremely complex and subject to frequent updates (Borin, et al., 2022).

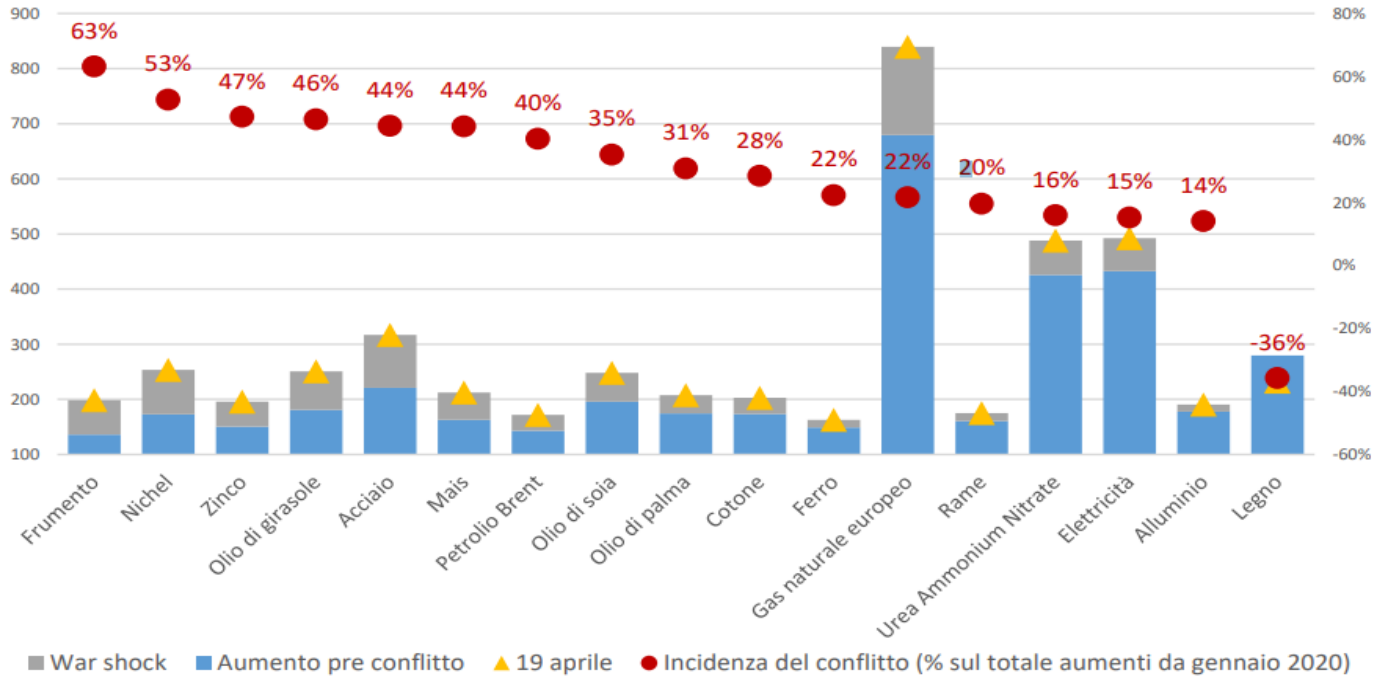
Moreover, sanctions and countersanctions represent a burden for logistics as they not only require shipping companies to check if a shipment is legally permissible, but also to make sure that every party to the transaction is compliant, including banks, insurers, and shippers. This for example resulted in cutting connections between Russian Baltic container ports (e.g., in St. Petersburg, Ust-Luga) and Northern European gateways (e.g., Antwerp, Rotterdam, Hamburg). However, Russia may still connect from the Black Sea or Far East to countries or with operators (e.g., Chinese shipping lines) not joining sanctions (Borin, et al., 2022).

On the other hand, Ukrainian ports are almost completely unable to operate commercial shipping.

Vessel traffic to Ukraine is no longer insured, and most ports are cut off or controlled by the Russian military. The export supply chain relies on long distance rail to one of the ports on the Black Sea. The main Ukrainian sea ports are in the Odessa area, which is currently under attack: Yuzhny (60 million tons throughput in 2020), Odessa (20 million tons), Chornomorsk (20 million tons), serving Western and Central Ukraine. The specialized river port at Mikolaiv (in 2020, total traffic 30 million tons, of which 13 million tons of grain) serves Eastern and Central Ukraine and is close to Russian-occupied Kherson. Mariupol farther east is under siege (Borin, et al., 2022).

The result of the logistical problems created by the war in Ukraine and the sanctions are the impediment of the flow of goods, oil and gas cost increases, product shortages, price spikes and catastrophic food shortages around the globe. As we can see from the graph (Figure 8), the impact of the war in Ukraine on commodity prices is intense and widespread, also contributing to the high inflation many countries are experiencing (6.1% in Italy[3]).

Figure 8: The prices of the principal export commodities of Russia and Ukraine have risen sharply.



Source: (Assolombardia, 2022)

In conclusion, the channels of transmission of the conflict to global trade can be summarized as follows: rising economic sanctions, decreasing foreign direct investments, bottlenecks in the global supply chain, rising energy and commodity prices, logistics and transport disruption (sea, air, road and rail transport), global geoeconomic uncertainty (Centro Studi Confindustria, 2022). After having exposed the origins of the Russian-

[3] Source: (Centro Studi Confindustria, 2022)

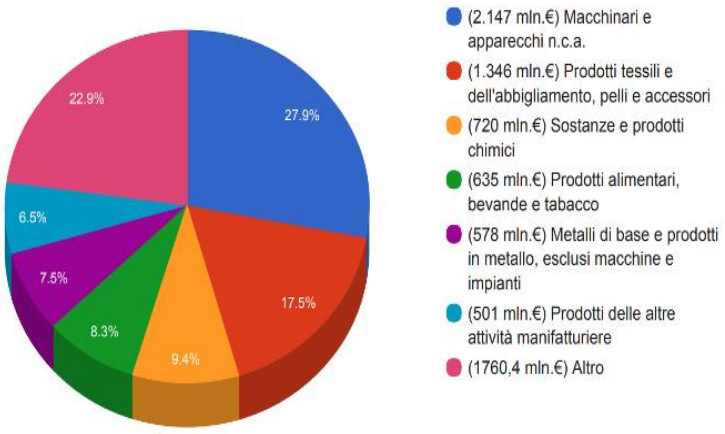
Ukrainian conflict, the consequences it is having on global supply chains, the role that these countries play within global trade (key sectors) and the channels through which the conflict is impacting supply chains, the next paragraph will be dedicated to the bilateral relations between Italy and the two conflicting countries. Of particular interest will be the weight of exports that these two countries cover in certain critical Italian sectors.

2.2. *The Italian bilateral trade relations with Russia and Ukraine*

According to Confindustria Study Centre, the total trade with Russia generated in 2021 amounts to around 23 billion euros, of which 7.6 billion in exports of goods and services (+8.8% compared to previous year) and 13.9 billion in imports (+54.5%), representing the destination of 1.5% of Italian goods exports and the origin of 3.7% of imports. Although since the invasion of Crimea in 2014 there has been a general loss of importance of the Russian market (sanctions) in almost all sectors for Italian exports, over 11,000 Italian industrial companies have exported to Russia in 2021 (Centro Studi Confindustria, 2022). Currently, there are 442 Italian companies with at least one office in Russia, these employ around 34.7 thousand people and produce a turnover of 7.4 billion euros (2.6% of that produced by all the Italian subsidiaries located in non-EU countries). Furthermore, Italian banking institutes (Unicredit and Intesa San Paolo in particular) are exposed for around 25 billion euros in Russia (La Repubblica, 2022).

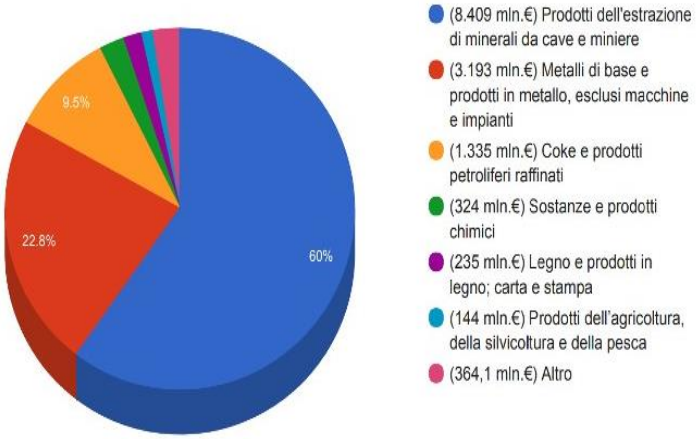
Italy exports (Figure 9) to the Russian Federation mainly machinery (2.147 million), clothing items (1.346 million), leather goods (384 million), food products (425 million), beverages (209 million), chemicals (720 million), electrical equipment (461 million), motor vehicles (315 million). On the other hand, from Russia we mainly import products (Figure 10) from mines and quarries (8.409 million), metallurgy products (3.175 mil.), coke and products deriving from petroleum refining (1,334 million), chemical products (324 million), wood and wood products (235 million) (Ministero Affari Esteri e della Cooperazione Internazionale, 2022).

Figure 9: Italian Export to Russia



Source: (Pagella Politica, 2022)

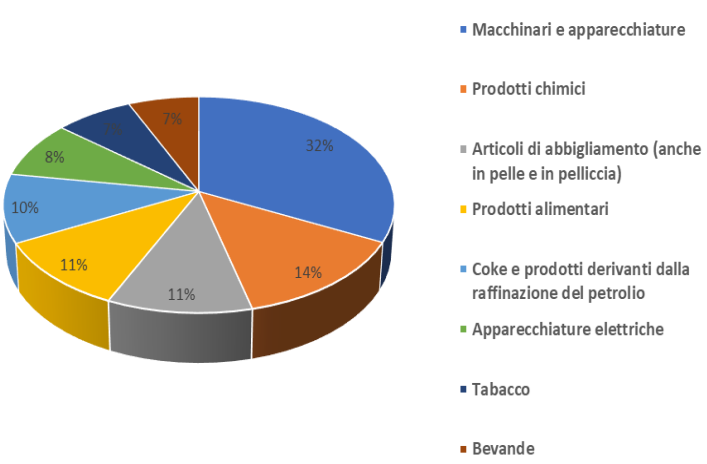
Figure 10: Italian Import from Russia



Source: (Pagella Politica, 2022)

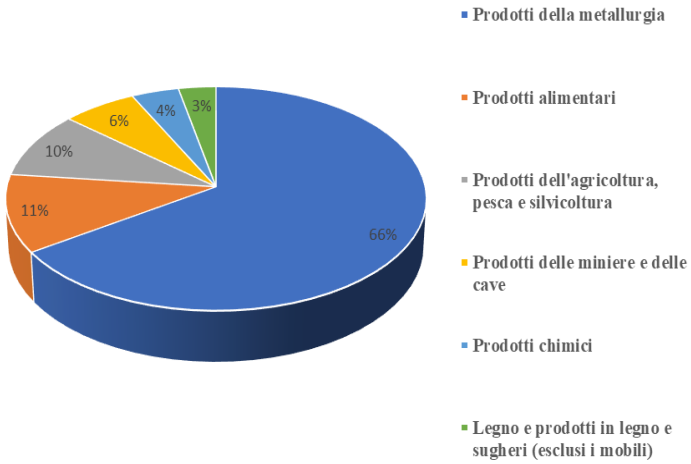
In the same year (2021), Ukraine was the destination of 0.4% of exports of goods Italian companies, fuelled by about 7,000 Italian industrial companies, and origin of 0.7% of imports. (Centro Studi Confindustria, 2022). The value of trade between Italy and Ukraine in 2021 amounts to 2.112.94 billion euros for Italian exports, with an increase of 24.5% compared to the previous year, and 3,288 billion euros in imports from Ukraine, marking an increase of 74.6%. As we can see from the image below (figure 11), Italy mainly exports machinery (466 million), chemical products (195 million), clothing (153 million), food products (152 million), coke and products deriving from petroleum refining (147 million), electrical equipment (122 million), tobacco (104 million), beverages (94 million) and motor vehicles (86 million). On the other hand, from Ukraine we mainly import (Figure 12) metallurgy products (2.021 million), food products (345 million), agriculture, fishery and forestry products (296 million), quarries and mines products (196 mil.), chemicals (124 million), wood and wood products (98 million) (Ministero Affari Esteri e Cooperazione Internazionale, 2022).

Figure 11: Italian Export to Ukraine



Source: MAECI (2022)

Figure 12: Italian Import from Ukraine



Source: MAECI (2022)

Moreover, in 2020 (latest data available) the total of Italian capital invested in Russia (FDI) amounted to 11.5 billion euros, 2.4% of the Italian stock in the world, while in Ukraine the capital stock invested by Italy is significantly lower: 347 million euros, equal to 0.1% of Italian capital invested in the world (Centro Studi Confindustria, 2022).

Very interesting is the fact that compared to the same period January-September of 2021 and 2022, Italian exports to Russia fell by 22%, while imports increased dramatically by 101%, probably the result of the extraordinary increase in commodity prices following the conflict (OEC, 2020). While as far as Ukraine is concerned, again in the January-September period, 2022 saw a 36.8% reduction in Italian exports and an

important 40.6% reduction in imports from Ukraine (OEC, 2020). Again, this appears to be a result of the ongoing conflict, and in particular the blockade of Ukrainian ports in the Black Sea and the destruction of production sites. As we will see in more detail later, these data could indicate the substitution of Ukrainian imports for the benefit of Russian ones, especially as regards raw materials. In other words, despite the difficulties linked to the sanctions against Russia, Italian industry seems to have replaced the raw materials imported in the previous year from Ukraine (now unable to do so) at least in part with Russian ones.

From the data on bilateral trade between Italy, Russia and Ukraine, a series of considerations emerge: first, Italy's trade with Russia is obviously greater than that with Ukraine. Second, Italy suffers a trade deficit with both countries, albeit a far greater one with Russia. Third, neither country can be considered a major trading partner of Italy in absolute terms. However, as previously underlined, Italy suffers from a great dependence in some sectors on imports from both countries. In particular, the data shows how Italy imported from Russia almost 8.5 billion euros in products of mineral extraction from quarries and mines and more than 3 billion of base metals and metal products, representing by far the most important import item and reaching almost 83% of the total. On the other hand, Italy imported more than 2 billion metallurgical products from Ukraine, representing 66% of the total imports from that country.

After having outlined the most important aspects of bilateral trade between Italy, Russia and Ukraine, in the next paragraph we will restrict the focus to a single sector: the Italian cast iron foundries. As we will see, the considerations just reported on bilateral trade between the two conflicting countries and Italy apply perfectly to the foundry sector and have had serious consequences.

2.3. Italian Cast Iron Foundries Sector

As we saw in the first paragraph of this chapter, both countries engaged in the conflict are major exporters of raw materials and metals. Furthermore, in the second paragraph we examined how Italy suffers from a heavy dependence on the import of these metals from Russia and Ukraine.

Narrowing the topic more specifically, there is a fact that stands out in the eyes of anyone who analyses the topic and that struck me to the point of providing the inspiration for this thesis, namely that in 2021 as many as 81%[4] of Italian pig iron imports came from Ukraine and Russia. From this point of view, pig iron represents for Italy an emblematic case of dependence on foreign supplies and therefore of strong exposure to supply risk in the event of disruptions along the supply chain. This is, in fact, the basic product to produce foundry castings, which have many applications and find use in various industrial sectors.

The Foundry industry is a diversified sector, made up of a very wide range of companies, ranging in

[4] (Assofond, 2022)

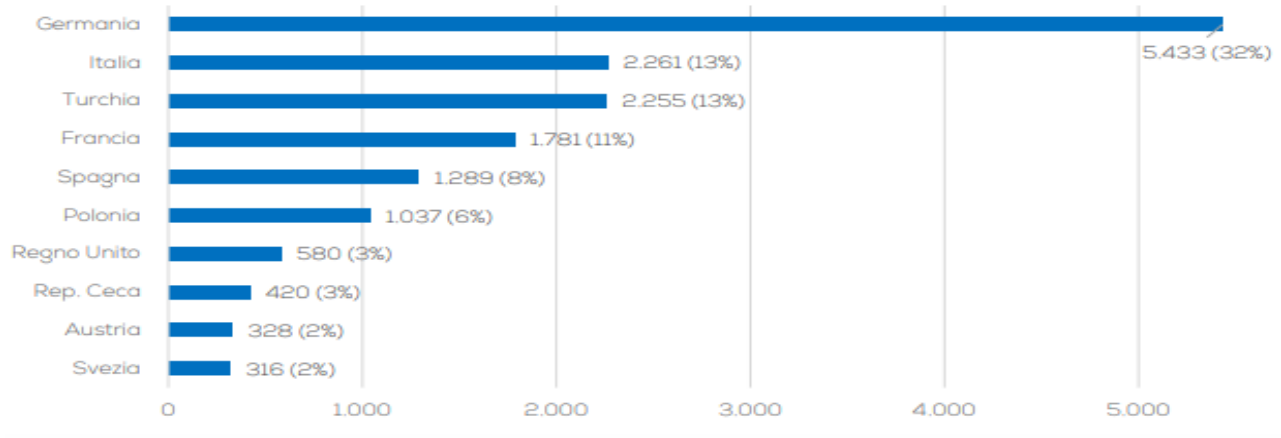
size from small to very large, each of which presents a combination of technologies, plants and processes defined according to the type of alloy processed, the size of the series and type of castings that the specific Foundry produces (Porru, Arici, & Corelli, 2017). Foundries produce industrial artefacts or artistic castings with well-defined physical, metallurgical and dimensional characteristics, melting ferrous and non-ferrous metals, casting them in forms of refractory material or in metal molds and letting them cool so that they acquire the desired shape (Assofond, 2022).

Foundry products play a role of fundamental importance within the economy and society, in fact, they are destined for a very broad market that ranges from a variety of sectors including automotive, various mechanics, construction, street furniture, aerospace, electricity production, household appliances, art and design. This vast application of foundry castings means that we all use every day (often unknowingly) objects produced by foundries, for example belt buckles, cars, bicycles, urban and household furnishings such as lamps, streetlamps, fountains and much more. For instance, since Foundry's products are the heart of all energy production plants, without the Foundry we would not be able to enjoy the advantages deriving from the use of electricity, both the one produced in thermoelectric plants and the "green" one produced from renewable sources (Porru, Arici, & Corelli, 2017).

In Italy, the sector has always developed mainly in the northern regions and, in line with the typical trend of Italian industry, is mostly made up of SMEs which, in most cases, are characterized by family governance (only 1% of foundries exceed 250 employees). A peculiar characteristic compared to what happens in other European countries, which however has shown in recent years a great capacity for adaptation and resilience, decisive for allowing Italian foundries to overcome the difficult economic situation of the last decade (Porru, Arici, & Corelli, 2017).

Within the Italian territory there are about 1044 foundries, of which 82% produce non-ferrous metals (859), while the remaining part is made up of cast iron foundries (14% -147) and steel foundries (4%). The entire sector employs around 27,569 people, of which about a third is employed in ferrous metal foundries (which are on average larger), while the overall turnover of the sector amounts to about 7 billion euros a year (0.5% of GDP). The territorial distribution reproduces somewhat that of the national industry, being 57% of the foundries located in North-West Italy, 25% in the North-East, 12% in the center and 6% between the islands and South Italy. Furthermore, the foundry sector is mainly devoted to exports, with 69% of products exported abroad. However, about 80% of these are exported within the borders of the EU, while 13% of the products go to America (Porru, Arici, & Corelli, 2017). This internationalization is explained by the fact that the Italian foundry sector represents excellence at a European level, both from a qualitative and quantitative point of view. In the top 10 European producers, Italy occupies the second position (Figure 13), immediately after Germany, with 13% of the European production of castings, ahead of Turkey, France and Spain (Centro Studi Assofond, 2019).

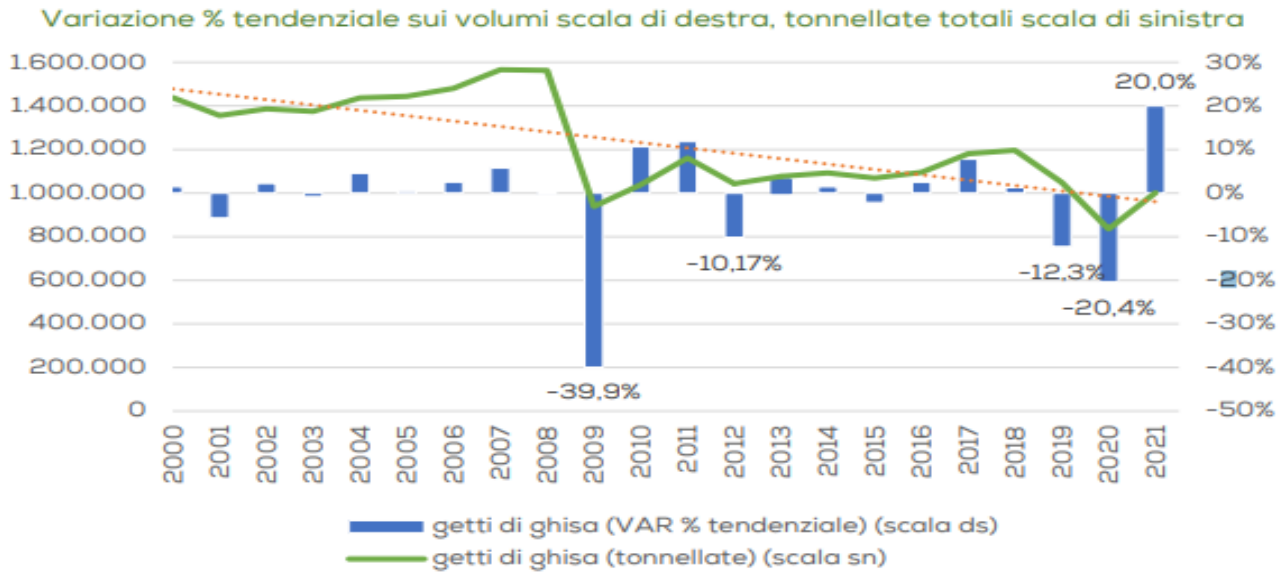
Figure 13: European foundries ranking by production.



Source: (Centro Studi Assofond, 2019)

In 2021, the contribution of exports to the recovery of the Italian ferrous castings sector was favourable, expressing a growth of +22% in volumes against a slightly higher increase in values (+24%). On the other hand, ISTAT foreign trade statistics show a growth rate of iron casting imports in Italy of +31% in volumes and in value (Assofond, 2022). As already illustrate, the Foundry Sector include companies that use ferrous metals, such as cast iron and steel, but also non-ferrous ones such as aluminium, zinc, magnesium, brass and others. For the purpose of this thesis, given the focus on the cast iron supply chain, we will analyse the sector of foundries that deal with this specific type of metal. The cast iron foundries constitute an important sub-sector, deeply rooted in the territory, with an ultra-centennial industrial tradition. According to Assofond, in 2021 the total production of cast iron foundries was 1,002,069 tons, marking a good restart with an increase of 20% compared to the previous year where practically all sectors were affected by closures and lack of personnel due to the covid pandemic -19 (Figure 14).

Figure 14: Production of iron castings annual series.



Source: (Assofond, 2022)

In fact, in 2021 production capacity rose to 81% against a measly 65% in 2020, among the all-time lows of the sector. In the same year, the total turnover (revenues) was 1.8 billion, marking a +39.1% compared to the previous year. It should be noted that the discrepancy between the increase in production and turnover hides a significant increase in prices which began their ascent in that year. Indeed, 2021, the year of recovery from the covid, has unfortunately brought with it a price increase of +60% for cast-iron and steel scrap and from +50% to +110% for the various types of ferroalloys. To this must be added the increases in energy costs (over +200% for electricity and +300% for gas) and transport (Assofond, 2022). Therefore, in the light of the increases documented above, the rise in revenues appears to be "a modest and insufficient response to safeguard margins, which have undergone a sudden compression given the difficulty of passing on all the increases to customers" (Assofond, 2022, p. 7).

As we can see from the graph below (Figure 15), the good demand in 2021 was driven by a surge in the construction sector (+23% compared to 2020), which after years of penalties experienced a good restart, followed by mechanics (+20%) and the steel industry (+20%). On the other hand, the lack of chips and the uncertainty related to the ecological transition has curbed the demand for iron castings by the automotive sector (+16%) (Assofond, 2022). In absolute value (Figure 16), however, the mechanical sector confirms itself as the main destination market, absorbing 54% of pig-iron castings alone, followed by the automotive sector, which absorbs 29.5% of foundry products. On the other hand, construction (7%) and steel (3.5%) have a smaller weight.

Figure 15: % change in production by destination market

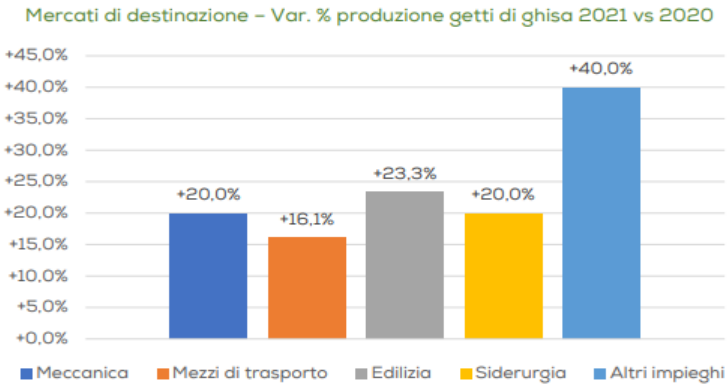
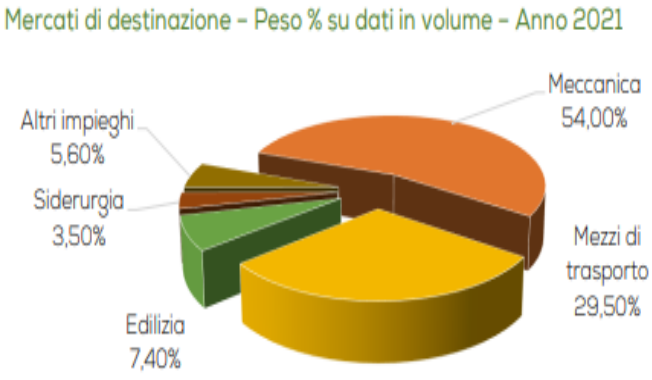


Figure 16: Destination Market



Source: (Assofond, 2022)

This paragraph has been dedicated to the analysis of the Italian foundry sector and its role within the national and European economy. Furthermore, I have tried to summarize the strategic importance covered by the sector for the whole country. Particular attention was dedicated to the sub-sector of cast iron foundries, which, as we will see, by virtue of their excessive dependence on the import of raw materials from countries

engaged in the conflict, have suffered the greatest financial and operational setback. This last topic will be the subject of the next paragraph.

2.4. The Vulnerabilities of the Italian Cast-Iron Foundry Sector in the Face of the Conflict

Before delving into the paragraph, I would like to clarify that the concrete consequences the Russian-Ukrainian conflict have generated on the cast iron supply chain at a micro-level (individual foundries) will be the subject of the empirical part of this thesis, which will be carried out through a qualitative analysis of the interviews released individually by the foundries. In this paragraph I will limit myself to the factual description of which are possible critical points (vulnerabilities) in the cast-iron supply chain to which the cast iron foundry sector is exposed at the macro level and that could materialize in what we have defined supply risk. If these sectoral vulnerabilities, then have actually materialized into a real supply risk for individual foundries and whether they have been able to mitigate such risk by building resilience, this will be verified through empirical analysis. The description of the data regarding the exposure of the Italian cast iron foundry sector to the risks of price and raw material volatility is useful to further clarify the rationale behind the research question and the objective of this thesis.

As illustrated in the previous paragraphs, Russia and Ukraine, countries currently at war at the time of this writing, despite their reduced presence in global trade, are major exporters of raw materials and metals. On the other hand, the country's most dependent on imports for these materials from the two countries are the geographically closest countries as well as some countries of the European Union. Among the latter, as mentioned above, there is Italy, for which 82% of imports from Russia are products of mineral extraction and base metals for a total of over 11,500 million euros. Furthermore, by analysing bilateral trade with Ukraine, we have deduced that 66% of Italian imports from this country is made up of metallurgical products for a total of over 2 billion euros. To these considerations must be added the fact that another variable to take into consideration when it comes to analysing the economic repercussions of a conflict on trade and a country's supply chains is power relations, meaning that while some global supply chains are made up of many competing suppliers globally (e.g. apparel), other global suppliers have large market power which can almost be assimilated to a monopoly market power (Wuester & Winkler, 2022).

Among the latter, I recall that pig iron exports are globally dominated by three countries (Russia, Brazil, and Ukraine), which together account for over three-quarters of global exports. Hence, replacing pig iron imports from Russia and Ukraine will be much more difficult than products for which the global market is less concentrated. Therefore, while a country's GVC risk depends largely on its direct trade links with Russia, GVCs reliant on products that have fewer substitutes will be affected more severely.

Having concluded this necessary premise, we could say that the positive trend in 2021 had an excellent carry-over effect also on the production results of the first two months of 2022: an excellent legacy which also

reflected favourably on the economic situation at the beginning of the year, to the point to bode well for 2022 for a return on the numbers of 2018, which stood out for a much better situation than in 2019 in which the first signs of an economic deterioration had already emerged (Assofond, 2022).

Although the forecasts for 2022 formulated at the beginning of the year were therefore positive, the Russian-Ukrainian military crisis has completely changed the scenario and threatens to have a heavy impact on the global and specific economy of the foundry sector (Assofond, 2022). As mentioned above, the conflict has spread to the economy and especially to the foundry sector through several channels: inflationary dynamics, the explosion in energy costs and the supply difficulties of pig iron and other raw materials from conflict zones. These critical issues put a heavy burden on the expansionary phase at the beginning of the year, heavily reducing the profitability of companies in the short term (Assofond, 2022).

The turbulence and volatility of the raw material markets had already heavily conditioned the economic management of companies in the second half of 2021, a situation which gradually worsened in the first two months of 2022 when electricity prices recorded a real surge: +70% compared to the 2021 average and even over +400% compared to 2020. The outbreak of war exacerbated a market situation already under severe tension, in fact, the reaction of the markets was severe and very rapid: the prices of pig iron showed significant growth, while those of electricity doubled reaching 700 euro/MWh (about 6 times the prices of 2021 and 18 times those of 2020) on 8 March 2022 (Assofond, 2022).

In addition to the tsunami in prices and in the light of the above premise, the other consequence, perhaps even more tragic for the cast iron foundry sector given the very strong dependence on the procurement of raw materials, was the cancellation of supplies of pig iron from Ukraine and Russia which, until last February, covered more than 80% of the pig iron needs of the entire sector (Assofond, 2022).

The entire annual requirement of pig iron for Italian foundries, equal to approximately 400,000 tons / year, is entirely satisfied with imports given that the only domestic production site in Servola, which fed 15% of the entire national consumption, closed almost twenty years ago. Furthermore, the situation of production deficit is also serious in the rest of Western Europe. Indeed, in Germany, the first producer of castings on the continent, there is only one producer of pig iron, which however produces a very particular product: a hematite cast iron called DK, from the name of the producer, made using a technology that exploits the powders of the iron and steel sector (Assofond, 2022).

Moreover, as already said, the offer of pig iron is characterized by a very strong concentration (Figure 17-18): the shortage of pig iron on the European market is compensated mainly by imports from Russia, Ukraine, Brazil and South Africa. The iron and steel sector, which can also use material of lower quality than foundry requests, also partly procures from India and other Asian countries.

Figure 17: Italian imports of pig iron.

Paese	2020	2021
Ucraina	14%	51%
Russia	69%	30%
Sud Africa	11%	9%
Brasile	1%	0%
Germania	3%	2%
India	0%	3%
Altri Paesi	2%	4%

Fonte: Elaborazioni CSA su dati Istat

Source: (Centro Studi Assofond, 2019)

Figure 18: Percentage weight of Italian imports of pig iron by area of origin.

Paese	2020	2021	Var.% 2021 vs 2020
Ucraina	149.028	716.560	381%
Russia	748.912	417.448	-44%
Sud Africa	123.467	121.101	-2%
Brasile	14.936	648	-96%
Germania	28.109	33.624	20%
India		48.000	
Altri Paesi	18.167	55.103	203%
Totale importazioni ghisa in pani	1.082.620	1.392.485	29%

Fonte: Elaborazioni CSA su dati Istat

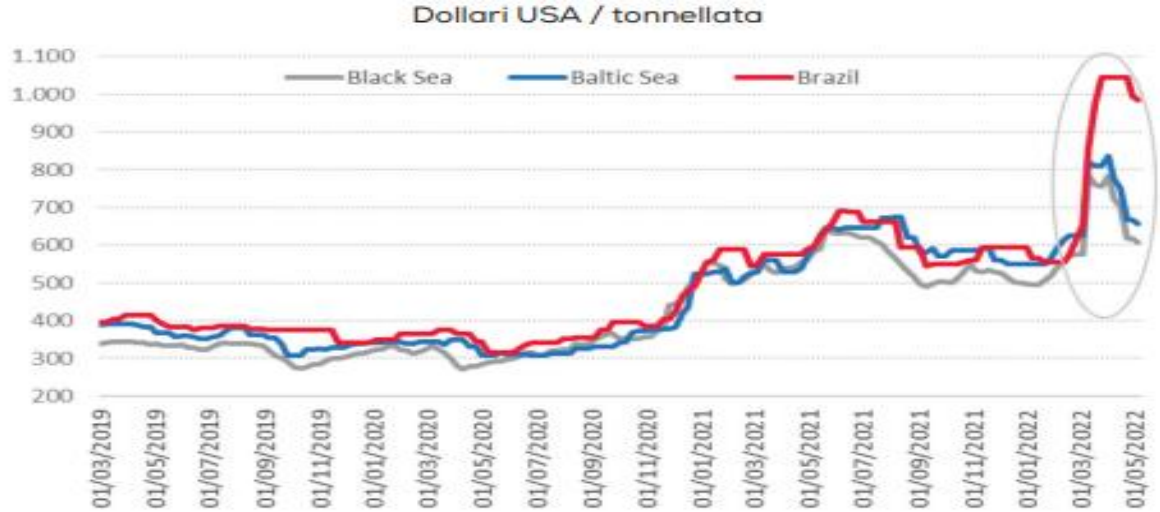
Source: (Centro Studi Assofond, 2019)

As evident from the tables drawn up by the Assofond Study Center and shown above (Figure 17-18), the total imports of cast iron in Italy (foundry + steel plant) in 2021 amounted to approximately 1.4 million tonnes (Istat data), of which 81 % coming from Russia and Ukraine (respectively 30% and 51%) while only 9% from South Africa. Germany, the only producer of cast iron in EU, accounted for only 2% of Italian imports, for a total of 33,624 tons, against 716,560 tons from Ukraine and 417,448 from Russia. Interestingly, from the comparison with the 2020 data it clearly emerges that Italy's dependence on Ukrainian cast iron imports more than tripled in 2021, going from 14% to 51%. At the same time, dependence on Russia has more than halved, passing from 69% to 30%. Therefore, it seems that in 2021 there was a preference by Italian foundries in choosing Ukrainian raw materials over Russian ones, which were largely replaced during the year (Assofond, 2022).

The outbreak of the Russia-Ukraine conflict initially made these supply channels (especially the Ukrainian ones) unviable, thus pouring the entire demand for pig iron towards Brazil (Figure 19), South Africa

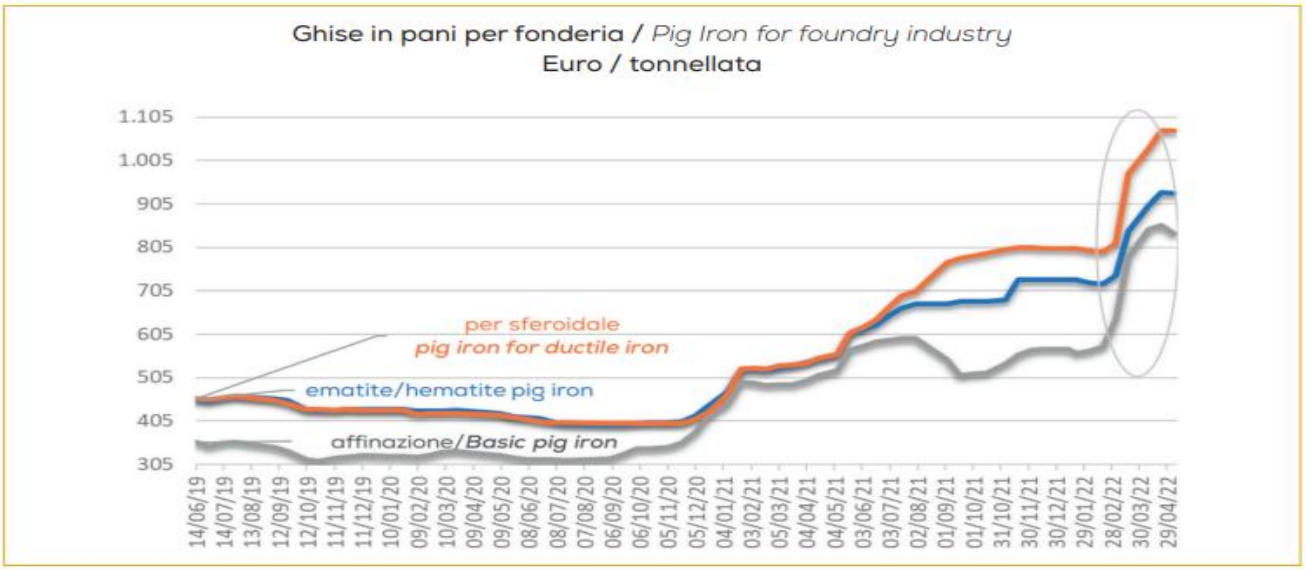
and Germany, causing a further heavy increase in the prices of these raw materials (Figure 20), which jumped between +40% and 50% depending on the categories: a growth that added up to the already strongly bullish dynamics of the first two months of 2022 and 2021 (Assofond, 2022). The graph clearly indicates that from the outbreak of war on February 24 until May of the same year, there has been an explosion in pig iron prices at the same time as an increase in imports from Brazil. However, starting from May, both the quantities imported from Brazil and the general average price appear to be decreasing, which seems to suggest some kind of adjustment within the pig iron market, and which will be further explored in the empirical part.

Figure 19: Price and origin of pig iron.



Source: (Martinelli & Pisanu, 2022)

Figure 20: Price of different types of pig iron euro/tonne.

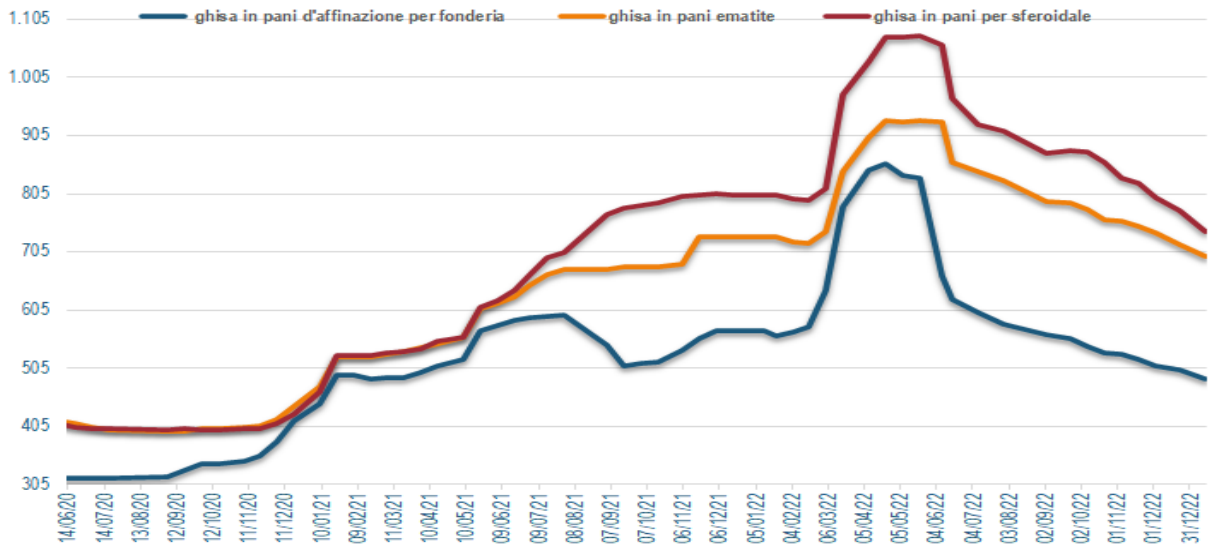


Fonte: elaborazioni CSA su rilevazioni bimensili C.C.I.A.A. di Milano.
Source: CSA elaborations on bimonthly surveys of the Milan Chamber of Commerce.

Source: (Martinelli & Pisanu, 2022)

Going into more detail, the graph below (Figure 21) clearly shows the phenomenon mentioned above, i.e. a "bell-shaped" effect in the price/tons trend of imported pig iron with a sudden and significant rise in prices in conjunction with the outbreak of war and then starting a more linear but rather constant descent. From the graph it is also possible to deduce how the general trend in the price of cast iron was in any case increasing starting from the covid period, however the surge caused by the outbreak of war is more than evident.

Figure 21: price/ton trend for three types of cast iron.



Source: (Assofond, 2023)

In fact, the bimonthly surveys of the Chamber of Commerce, Industry, Crafts and Agriculture (C.C.I.A.A.)[5] indicate a variation (increase) in the maximum prices between 18/02/22 and 04/03/22 for refining pig iron, hematite and spheroidal respectively of +68 euro/tons, +33 and again +33.

However, the real boom in the prices of cast iron imported into Italy occurred in the following 15 days, around mid-March. This time, in the period between 04/03/2022 and 18/03/2022 the bimonthly survey of the C.C.I.A.A[6] indicated a variation in the maximum prices of the three types of pig iron on the market of +205 euro/tons for refining pig iron, +165 for hematite and +214 for spheroidal cast iron (Assofond, 2023).

The drastic increases of this period are clearly visible graphically in the image above, in fact they correspond to the beginning of the upward surge of the curve. It is interesting to note that the surveys conducted by the Chamber of Commerce, which began in the 1980s, have never marked such an important three-digit increase, such as to record the unprecedented prices of 865 euro/tons for refining cast iron, 935 for hematite cast iron and even 1.067 euro/tons for spheroidal cast iron. To account for the escalation of this period,

[5] C.C.I.A.A. Survey of 04/03/22. Source: (Assofond, 2023)
[6] C.C.I.A.A. Survey of 18/03/22. Source: (Assofond, 2023)

variations ranging from a minimum of +20% for hematite to a maximum of +36% for refining cast iron are highlighted. In one year, the growth varies between +70% and +90% according to the categories (Assofond, 2023).

A further note reported by Assofond is that "From the comparison between the commissioners present it emerged that from the conflict zones the only channel out of the question at the moment is Ukraine, while supplies from Russia continue to arrive from at least two of the main producers of this market: Tula and NLMK" (Assofond, 2023). The association of foundries also goes on to point out that this is material already sold in the month of December and that it is discounting a delay in arriving at the Italian ports. The Assofond report relating to these particularly dramatic 15 days in March also shows that "At the moment there is no new material available. The new purchases are for deliveries between the end of May and the beginning of June. Relating to these producers at the moment there are no sanctions or embargoes, while for Metalloinvest, another Russian producer of reference in the cast iron market, there have been episodes of ships blocked in some Italian ports" (Assofond, 2023). Therefore, it seems that the material arriving in this period is mostly made up of orders already in transit from Russia, Brazil and South Africa. Assofond also points out that the above prices represent an average, and that therefore some prices of material from Brazil have already reached highs of 1200-1300 euro/tons.

Continuing with the analysis, according to the findings of the C.C.I.A.A[7]., in the period between 18/03/2022 and 08/04/2022 the market continues to have supply problems keeping prices high for all types of cast iron. The increases continue even if in a more limited way, marking +13 euro/tons for refining cast iron (878 euro/tons), +18 for hematite (953 euro) and +96 for spheroidal cast iron (1.163 euro). Assofond also points out that "at the moment the contracts with two of the Russian pig iron producers Tulachermet and NLMK, relating to orders issued before the conflict, are being performed even with some delays on the agreed delivery terms. Traders are also signing new contracts, but it seems that the greater requests do not find total satisfaction with the producers who are choosing to cut a certain percentage of the volumes of new orders; partly due to the difficulties in satisfying the impressive growth in demand that has poured onto their market with the coming less than the Ukrainian channel, but probably also to be able to seize other more attractive business opportunities" (Assofond, 2023) .

Moreover, the calm that was observed on the scrap market up to three weeks ago, attributable to less pressure on demand from steel mills forced to stop production due to expensive energy, is now a distant memory. The excess demand over supply produced an immediate reaction in prices which, especially in this last week, shot up, with increases of up to +100 euro/tons (Assofond, 2023).

Arriving in the period between 08/04/22 and 22/04/22, the Chamber of Commerce reports further

[7] C.C.I.A.A Survey of 08/04/2022. Source: (Assofond, 2023)

increases even if to a lesser extent[8]. The increases in the maximum prices on the market are between 2 euro/tons for hematite cast iron and +40 for spheroidal cast iron (1.203 euro/tons). Also noteworthy is a rise in scrap prices, albeit to a slight extent. With regard to this period, through a note Assofond points out that "the panorama of the pig iron market in the last two weeks has been further clouded by the international sanctions which hit the co-owner of the Russian steel-producing plant in Tulachermet on 8 April, which after the outbreak of the conflict in Ukraine remained the main possible supply channel for the import of pig iron from Russia" (Assofond, 2023). The production of NLMK is in fact a type of refining cast iron that is not very usable by foundries due to the high content of manganese, considered a polluting element. Furthermore, the association points out the very critical situation of supplies from Russia as, due to the sanctions, there are many factors of uncertainty and concern: possible blockages of ships, including those not flying under the Russian flag, possible bans on customs clearance of the material in port, difficulties with payments, etc (Assofond, 2023). It should also be noted that this period reflects a maximum point also at a graphic level in Figure 21.

Arriving in May, the surveys of the C.C.I.A.A.[9] between 22/04/22 and 06/05/22 mark a drop in the maximum prices of cast iron for the first time since the outbreak of war. The marked reduction is contained, ranging from -18 euro/tons for refining pig iron, to -2 euro for hematite. After the peak in April, the foundry scrap market also saw a drop in prices in the first week of May (Assofond, 2023). This decrease can also be seen graphically, since May represents the first step of the downward price curve.

As regards the surveys[10] from the previous period up to 20/05/22, they indicate -11 euro/tons for refining cast iron, +1 euro/tons for hematite and +5 for spheroidal cast iron. In fact, for quality cast iron (hematite and spheroidal) the offer continues to be limited and the prices always very high. Assofond also points out that "Despite the total uncertainty about the market conditions for cast iron of Russian origin, for the sanctions on producers and for those of a financial nature for payments, the risks associated with blockages of ships and the unpredictable outcomes of customs clearance operations, purchases by traders continue, but few of them at the moment dare to resell the material without having acquired the certainty of its real availability" (Assofond, 2023).

In the period between 20/05/22 and 08/06/22 we note[11] the first real fall in the maximum prices of cast iron especially in relation to refining cast iron, also graphically confirmed by the sharp drop in the line. Refining cast iron registers -151 euro/tons (713 euro/tons), hematite a small -3, while spheroidal cast iron registers -33 euro per ton. The two types of refining and quality cast iron (hematite and spheroidal) seem to travel on different tracks. As regards the former, Assofond points out that "on the one hand, arrivals from Russia continue regularly, fed by the two producers not reached by the latest package of sanctions and on the

[8] C.C.I.A.A Survey of 22/04/2022. Source: (Assofond, 2023)
[9] C.C.I.A.A Survey of 06/05/2022. Source: (Assofond, 2023)
[10] C.C.I.A.A Survey of 20/05/2022. Source: (Assofond, 2023)
[11] C.C.I.A.A Survey of 08/06/2022. Source: (Assofond, 2023)

other, supplies from Brazil have made up for the supply gap caused by the disappearance of Ukrainian cast iron, bringing the market back into balance at values slightly above those of 2021" (Assofond, 2023). The normalization of the market appears to be the result of reduced demand for pig iron generated by "panic buying", i.e. purchases fuelled by emotional tensions triggered by the worsening Russia-Ukraine conflict and fears of running out of material. As regards quality cast irons, however, the same trend was not recorded in the period in question.

In the period between the previous one and 17/06/22, the survey by the Chamber of Commerce[12] finally signalled a significant drop in the maximum prices of spheroidal cast iron (-150 euro/tons), returning to just over one thousand euro per ton. Hematite pig iron continues its decline (-61) settling at 828 euros per ton, while refining cast iron, which has already dropped significantly, marks a further -10 euros/tons, settling at around 703 euros per ton (Assofond, 2023). In this case, the Assofond note states that "The flows of cast iron from Russia, also in Italy, continue calmly even with some bureaucratic jams linked to the customs clearance process. Thanks to this important influx of material, the levels of supply have pretty much normalized, and prices have continued to fall" (Assofond, 2023).

In the following twenty days, from the previous period until 08/07/22[13], a further drop of around 50 euro/tons was recorded for both refining and spheroidal pig iron, settling respectively at 655 euro/tons and 977 euro/tons. Instead, hematite cast iron decreases the price by only 7 euro/tons. According to Assofond, the smaller reductions reinforce the idea of an end to the drop in the price of cast iron. The association also reiterates that " currently, from the objective point of view of the operation, the pig iron product is not in itself subject to sanctions if imported from the Russian Federation, while it is subject to an embargo if imported (or transiting) from Donetsk , Lugansk, Crimea, just as imports from occupied areas of Ukraine, such as Donbass, are absolutely prohibited" (Assofond, 2023). However, the necessary assessments remain on the subjective aspects of the operation, i.e. the legitimacy of the supplier (and possibly of the producer, if different from the first). Therefore, it seems that the legitimacy or otherwise of the raw material from Russia depends on the supplier and the producer, not on the material itself. Moreover, at the date in question, although some producers are sanctioned like Tulachermet, there are others like NLMK and Urasteel from which pig iron can be purchased without incurring penalties. For this reason, in June "the flow of imports from Russia increased significatively enough to produce an immediate impact on the offer and on the quotations that have suffered a real collapse" (Assofond, 2023).

I will not dwell on the analysis of the price trend in the remaining part of the year as it was simply marked by a progressive but linear fall in prices. I believe that the most fertile part from an analytical point of

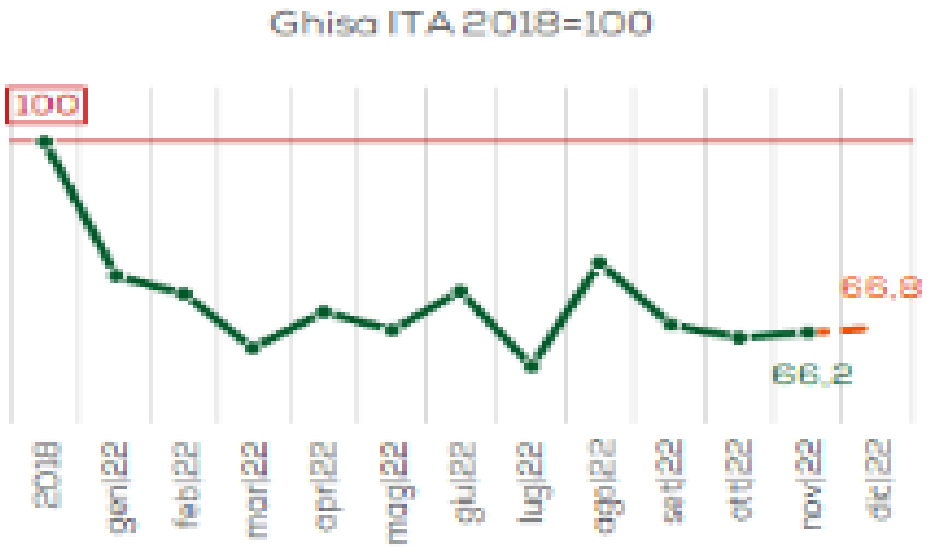
[12] C.C.I.A.A Survey of 17/06/2022. Source: (Assofond, 2023)
[13] C.C.I.A.A Survey of 08/07/2022. Source: (Assofond, 2023)

view are the months described so far, where we have seen the dizzying rise in prices up to the April peak for all types of cast iron, which remained high until at least half of May, followed by a rapid fall in prices first for refining pig iron between the end of May and the beginning of June, and then also for the other two types of quality pig iron around mid-June. The remaining part of the year, on the other hand, saw a slow but constant drop in prices for all types of cast iron.

It should be noted that although the drop in prices reached all 3 types of cast iron, it was not completely homogeneous. In fact, from the graph (Figure 21) it is possible to note that where refining pig iron has returned almost to pre-war levels, probably thanks to the continued availability of Russian refining material, the two highest quality pig irons have benefited from a sharp decline but however remained at higher price levels than pre-war, especially the spheroidal one. In fact, According to Assofond "on average for 2022, refining cast iron closes the year with higher values around +20% (+100 €/t) compared to 2021, while for hematite cast iron +30% (+ 190 €/t) and for the spheroidal one +40% (+250 €/t)" (Assofond, 2023).

The graph below (Figure 22) instead summarizes the data on industrial production in 2022 in the cast iron foundry sector through an index that uses the production values of the year 2018 as a basis.

Figure 22: Industrial production index 2022-Italian cast iron foundries



Source: (Assofond, 2023)

As we can see from the graph above, industrial production in the sector fluctuated greatly during 2022, also due to the difficult economic situation. In general, the values are very distant from those of 2018, however, what interests us most for the purposes of this thesis is the production trend during the months surrounding the outbreak of the conflict. Despite a small rebound in production in January compared to December 2021, the cast iron sector confirms a drop in production in February 2022, followed by a sharper drop in March.

However, in April, even though production levels remain low, there is a recovery of +5.1% on the March levels. Despite a small decline in May, production levels nearly returned to pre-war levels in June. Thereafter, we notice a sharp decline in July followed by a surge in August. After the drop in September, the end of the year is marked by a more constant trend, possibly the result of the stabilization of cast iron prices. Therefore, from the production levels it seems that there was a drop when the war broke out and in the following month, however, given the multiplicity of variables that may have influenced the production trend (energy prices, scrap prices, pig iron prices, material availability, state subsidies etc), it is not possible to deduce a clear relationship.

In the light of what has been said so far, the rationale of the research question that informs this thesis and of the three hypotheses set out in the previous chapter appear to be clearer. The excessive dependence of Italy and more so of the Italian cast iron foundries on the import of raw materials from Russia and Ukraine, the outbreak of the conflict, the operational and logistical problems deriving from it as well as the tsunami of prices, are all considerations (vulnerabilities) that point towards a possible disruption in the supply chain of cast iron foundries with consequent supply risk. As reiterated by Assofond President Fabio Zanardi on 3 March 2022: "The invasion of Ukraine acted as an accelerator, if necessary, to the race in the prices of raw materials, gas and electricity which form the backbone to our production system. And now the real risk for foundries is that they will soon run out of supplies, especially of pig iron" (Zanardi, 2022). As stated before, and beyond the description of these data, whether these macro risk factors then materialize in a real disruption of the supply chain network at a micro level (individually), therefore representing a procurement risk for Italian cast iron foundries, will be a matter analysed in the empirical chapter. Furthermore, through the interviews at selected foundries, I will also try to evaluate the state of information received by the companies during the war period in order to validate the second hypothesis (H2). Lastly, I will try to figure out if following the alleged disruption of the supply network, the Italian foundries have managed to build resilience by re-adapting their supply network and mitigating the supply risk.

The next chapter will therefore be devoted to the exposition of the methodology and research design that informs the analysis of this thesis.

Third Chapter: Research Method

3.1. The Case Study Research Method

The literature over the years has provided several different research methods. Each method is a different way of collecting and analysing empirical evidence, following its own logic. Similarly, each method has its own advantages and disadvantages, for this reason it is wise to question which is the most appropriate based on the research question underlying the inquiry.

According to Robert K. Yin (2009), there are three important conditions when asking which research method to use, they are: (a) the type of research question posed, (b) the extent of control an investigator has over actual behavioral events, and (c) the degree of focus on contemporary as opposed to historical events (Yin, 2009).

The first condition regards what type of research question is placed at the foundation of the inquiry. Research questions are important “to determine the expected outcomes of the research since they guide researchers toward the avenue to pursue” (Budiyanto & Prananto, 2019). Here, the most basic categorization for the types of questions is the familiar series: "who," "what," "where," "how," and "why" questions. According to Yin (2009), the latter two are the most appropriate types of questions to underlie a case study research, and this is because such questions deal with operational links needing to be traced over time, rather than mere frequencies or incidence (Yin, 2009).

As far as the second condition is concerned, this has to do with the extent of the investigator's control over and access to actual behavioural events. While for example experiments are done when an investigator can manipulate behaviours directly, precisely, and systematically, most of the time within the laboratory, the case study is preferred when the relevant behaviours cannot be manipulated (little or no control). The third and final condition concerns the degree of focus on contemporary as opposed to historical events. Again, while for example the distinctive contribution of the historical method is in dealing with the “dead” past—that is, when no relevant persons are alive to report what occurred and therefore the investigator must rely on primary documents, secondary documents, and cultural and physical artifacts as the main sources of evidence, the case study is preferred in examining contemporary events. Moreover, according to the author, “the case study relies on many of the same techniques as history, but it adds two sources of evidence not usually included in the historian's repertoire: direct observation of the events being studied and interviews of the persons involved in the events” (Yin, 2009, p. 38).

Indeed, as Robert Yin argues, one of the advantages of using the case study methodology is that of being able to combine multiple sources of evidence, among which interviews represent one of the most important sources of information. Interviews are more guided conversations rather than structured queries, meaning that while pursuing a consistent line of inquiry, the actual stream of questions in a case study interview

is likely to be fluid rather than rigid (Yin, 2009).

Evidently, here the author was referring to a specific typology of interviews which also corresponds to the one used in this thesis, i.e., the semi-structured interviews. However, for the sake of clarity, there are at least three types of interviews, unstructured, semi-structured and structured. The first typology is characterized by the complete absence of a guide or a structure of any kind. The goal is to have a broad overview of a given topic. The interviewer may have thought of some related questions or topics but does not prepare any documents in advance to be used as an aid in carrying out the interview. Semi-structured interviews are, as the name suggests, more structured than free-form interviews but more flexible than structured ones.

Semi-structured interviews are governed by an interview guide, which serves as the structure of the interview. The interviewer can refer to it to contribute to the discussion with the interviewee and ensure that the conversation goes in the desired direction defined by the project. This type of interview is the most used in qualitative research, as it combines rigor in the topics covered and flexibility in the exchange.

Structured interviews, on the other hand, are carried out in a much more rigorous way than the previous ones. The unique feature of the structured interview is that it can be conducted by several interviewers ensuring that the answers are all organized and stated in the same form. These interviews are guided by a predefined and very rigorous set of questions to which the interviewers must limit themselves in order to collect a maximum number of standardized answers which are often expressed through closed questions (Schwab, 2020).

As previously stated, the use of multiple sources of evidence in case studies allows an investigator to address a broader range of behavioural issues. However, as Robert Yin pointed out, "the most important advantage presented by using multiple sources of evidence is the development of converging lines of inquiry, a process of triangulation and corroboration" (Yin, 2009, p. 184).

According to Stake (1995), there are four main types of triangulations: a) of data sources (data triangulation), b) among different evaluators (investigator triangulation), c) of perspectives to the same data set (theory triangulation), and d) of methods (methodological triangulation). The first typology is the most relevant for the purposes of this thesis and consists in collecting information from multiple sources but aimed at corroborating the same fact or phenomenon (Stake, 1995). In fact, through data triangulation, the events or facts of the case study are supported by more than a single source of evidence; also addressing the problem of construct validity by providing multiple measures of the same phenomenon. In other words, as Einsenhardt (1989) stated: “the triangulation made possible by multiple data collection methods provides stronger substantiation of constructs and hypotheses” (Eisenhardt, 1989, p. 538). In this thesis, the evidence provided through the interviews by the unit of analysis will be triangulated with the data present in the Assofond database and partially described in the second chapter.

For the purpose of this thesis, the case study methodology seems to be the most appropriate as the

research questions underlying the thesis is: How did the Italian foundry pig iron supply chain respond to the shock of the Russian-Ukrainian conflict? How and through what strategies did they resist the supply chain shock? Thus, the research question is primarily a "how" question, which fits well within a case study research design. Indeed, Yin claims that: “there’s no formula, but your choice depends in large part on your research question(s). The more that your questions seek to explain some present circumstance (e.g., “how” or “why” some social phenomenon works), the more that the case study method will be relevant. The method also is relevant the more that your questions require an extensive and “in-depth” description of some social phenomenon” (Yin, 2009, p. 30). Furthermore, the writer has no degree of control over the events and behaviours analysed, as a large number of variables are involved. Finally, the thesis has a time space limited to a period ranging from 24 February 2022 to the end of the year, with a particular focus on the first part of the year, as it is characterized by the major upheavals in the supply chain of the cast iron foundry sector. However, since the conflict is still fervently active at the time of writing, the phenomenon considered cannot be considered historical and therefore qualifies for the case study methodology.

Provided that the thesis fully fits within the research design of the case study, it is necessary to define what is meant by this methodology of inquiry. According to Robert Yin, the definition of case study inquiry can be divided into two parts, where the first begins with the scope of a case study: "A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real- life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009, p. 47).

Therefore, in other words, the case study method is more appropriate when the researcher wants to understand a real-life phenomenon in depth, but such understanding encompassed important contextual conditions because they are highly pertinent to the phenomenon of study. On the contrary, an experiment, for instance, deliberately divorces a phenomenon from its context, attending to only a few variables because typically, the context is “controlled” by the laboratory environment (Yin, 2009). This first part of the definition also serves to characterize this methodology and therefore to distinguish it from other research methods. Given that often phenomenon and context are not always distinguishable in real-life situations, the second part of the definition is stated as follows: "the case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converges in a triangulating fashion, and as another result benefits from the prior development of theoretical hypotheses to guide data collection and analysis" (Yin, 2009, p. 47-48).

On the other hand, adopting a constructivist perspective, Robert Stake (1995) has defined the qualitative case study as "study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (Stake, 1995). In Stakian's view, qualitative case studies have four main characteristics: they are “holistic”, “empirical”, “interpretive” and “emphatic”. With the first term, the author alludes to the concept, already formulated by Yin, of the close interrelationship between the

phenomenon and its contexts. Empirical means that researchers base the study on their observations in the field, while interpretive means that researchers rest upon their intuition and see research basically as a researcher subject interaction (constructivist). Lastly, "empathic means that researchers reflect the vicarious experiences of the subjects in an emic perspective" (Yazan, 2015).

A further definition of case study has been provided by Merriam (1998), who presents her definition as follows: "an intensive, holistic description and analysis of a bounded phenomenon such as a program, an institution, a person, a process, or a social unit" (Merriam, 1998, p. 13). This definition is broader than the previous ones and provides flexibility in utilizing qualitative case study strategy to research a much wider array of cases (Yazan, 2015).

Much debated in the literature has been whether case study research includes both single- and multiple-case studies. In Robert Yin's comprehensive view, although some disciplines such as political science have tried to distinguish the two approaches, single-and multiple-case studies are in reality two variants of case study designs. Furthermore, the author claims that since some case study research has gone beyond qualitative research using a mix of qualitative and quantitative evidence, case study method is not just a form of "qualitative research," even though it may be recognized among the array of qualitative research choices.

The typology of research method used in this thesis (multiple case study), according to Robert Yin has at least four different applications: the first and most important one is to explain the presumed causal links in real-life interventions that are too complex for the survey or experimental strategies. The case study also finds a second application in the description of an intervention and the real-life context in which it occurred. The third application instead consists in the illustration of certain topics within an evaluation, again in a descriptive mode. The fourth and final application is to enlighten those situations in which the intervention being evaluated has no clear, single set of outcomes (Yin, 2009).

3.2. The Research Design

Research Design is the logic that links the data to be collected (and the conclusions to be drawn) to the initial questions of study. In other words, the design is the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions. Therefore, we could define research design as a "blueprint" for the inquiry which deals at least with four main issues: what questions to study, what data are relevant, what data to collect, and how to analyse the results (Yin, 2009).

Proceeding more schematically, according to Robert Yin there are five main components of a research design:

1. a study's questions;
2. its hypotheses, if any;
3. its unit(s) of analysis;

4. the logic linking the data to the hypotheses; and
5. the criteria for interpreting the findings (Yin, 2009).

Starting from the first component, we have already anticipated that the form of the question provides an important clue regarding the most relevant research method to be used and that the case study method is most likely to be appropriate for "how" and "why" questions. In this regard, the research questions underlying this inquiry has already been explained in the previous paragraph and are the following: *How did the Italian foundry pig iron supply chain respond to the shock of the Russian-Ukrainian conflict? How and through what strategies did they resist the supply chain disruption?* These research questions fits well in the context of the case study as they does not presuppose the quantification or frequency of a specific phenomenon, but rather requires an in-depth analysis of the operational links traced over time within a complex contemporary phenomenon. Moreover, what the researcher wants to understand in depth is a real-life phenomenon that encompasses important contextual conditions that are highly pertinent to the phenomenon of study, which therefore requires the provision of a comprehensive view avoiding unilateral visions or reductions that refer to the deepening of a single or few variables.

As regards the second component, study hypotheses play the role of directing the researcher's attention towards what should be examined within the scope of study (Yin, 2009). While the research question vaguely directs the researcher's attention towards a certain field of study, in our case that of the analysis of supply chains and their reconfiguration following a disruption, the stating of hypotheses helps us to narrow the focus of the research and point us in the right direction. Our hypotheses have already been explained in the first chapter of the thesis, but given the relative length of the thesis they will be grouped as follows:

- **(H1)**: *the Russian-Ukrainian conflict has generated an upstream disruption within the cast iron supply chain, which in turn has represented a supply risk for the Italian cast iron foundries.*
- **(H2)**: *Due to the Russian-Ukrainian conflict, Italian cast iron foundries are operating in an ambiguous environment.*
- **(H3)**: *In the face of the supply disruption caused by the Russian-Ukrainian conflict, foundries have adapted by restructuring connections and building resilience.*

These hypotheses, besides reflecting the important theoretical issues from which they arose, also tell us where to look for relevant evidence. More specifically, hypothesis H1 requires us to evaluate whether the disruption in the cast iron supply chain has actually occurred and what impact it has generated on companies. This will take place through the triangulation of the data reported in the Assofond database and the interviews released by the purchasing managers of the various foundries to which the important insights provided by an

Italian trader of cast iron are added. Furthermore, to operationalize the two concepts of "upstream disruption" and "supply risk" we will take into account the parameters provided by Chopra & Sodhi (2004). According to the authors, a supply disruption can be operationalized through two main parameters: 1) "Supplier of a key part shuts down plant for a month or at a key part of the production cycle, 2) “Supplier capacity drops by 20% overnight” (Chopra & Sodhi, 2004, p. 57). As regards the concept of supply risk, referred to by the authors as procurement risk, in order to be realized it must meet at least one of three conditions: 1)”Supplier delays in processing returns by twice as long” 2)”Supplier forced to increase price of key components by 20% “ 3)”Transportation costs go up 20% overnight” (Chopra & Sodhi, 2004, p. 57).

The second hypothesis directly addresses the question of the state of the information received by the units of analysis since the outbreak of the war, in order to evaluate whether and what type of ambiguity has been encountered by the foundries in the period in question. This feedback will take place thanks to a series of questions formulated to the interviewees aimed at assessing the awareness of the situation that the Italian foundries have developed over the period.

The third and last hypothesis instead requires the analysis of the strategies adopted by foundries in the face of the conflict and the assessment of their impact on company performance. This will again take place through a series of questions posed to the interviewees aimed at identifying the practices implemented and also through the triangulation of the data provided by the Assofond database. The ultimate goal is to find out whether Italian cast iron foundries have built and shown resilience during the period in question.

Moving on to the third component of Research Design, this "is related to the fundamental problem of defining what the “case” is" (Yin, 2009). Indeed, according to Budiyanto & Prananto (2019): “It is imperative for a case study researcher to determine their unit of analysis” (Budiyanto & Prananto, 2019, p. 4). Regarding this thesis, the research question directly indicates the Italian cast iron foundries as the unit of analysis. Moreover, “the phenomenon is bound within certain boundaries that have to be specified beforehand in order to help the inquiry over the phenomenon” (Budiyanto & Prananto, 2019, p. 4). Given that the case study has real-life phenomenon as a unit of analysis and not abstractions, the Italian cast-iron foundries must be distinguished from other types of foundries present on the Italian territory, such as those that melt steel or aluminium, and also from other subjects that are part of the reference context, such as for example the traders of cast iron or the producers themselves. Time boundaries are also defined, since the unit of analysis does not represent the entire life cycle of the foundries, but a specific time frame that goes from the outbreak of the conflict on February 24th until the end of the year 2022.

Therefore, having multiple subjects as a unit of analysis, the empirical part of this thesis fully falls within that type of case study called "Multiple Case Study Design" in the literature. As with all research methodologies, multiple-case designs have distinct advantages and disadvantages, especially in comparison to single-case designs. According to Robert Yin: "The evidence from multiple cases is often considered more

compelling, and the overall study is therefore regarded as being more robust " (Yin, 2009, p. 94). On the other hand, however, the rationale for single-case designs sometimes cannot be satisfied by multiple cases since, by definition, the unusual or rare case are likely to involve only single cases, but this is not our concern. Since criticisms about single-case studies usually reflect fears about the uniqueness or artefactual conditions surrounding the case, there is a risk that the criticism may turn into skepticism about the empirical work. For this reason, I decided to proceed to the development of the multiple-case study.

According to the author, “Each case must be carefully selected so that it either (a) predicts similar results (a literal replication) or (b) predicts contrasting results but for anticipatable reasons (a theoretical replication)” (Yin, 2009).

Again, according to the author, between 6 and 10 cases fit effectively within a multiple-case design. Furthermore: "if all cases turn out as predicted, these 6 to 10 cases, in the aggregate, would have provided compelling support for the initial set of hypotheses. If the cases are in some way contradictory, the initial hypotheses must be revised and retested with another set of cases" (Yin, 2009).

Although I have taken account of the author's considerations, to determine the sample size in this thesis I have carried out the interviews in a sufficient number to guarantee the qualitative criterion of saturation. The concept of saturation is defined by Corbin and Strauss (2008) as: the point in analysis when all categories are well developed in terms of properties, dimensions and variations. Further data gathering and analysis add little new to the conceptualization, though variations can always be discovered" (Corbin & Strauss, 2008, p. 61).

For the purpose of this thesis, six managers of Italian cast iron foundries were identified as units of analysis. Since two of the six managers spoke on behalf of the entire industrial group to which they belong, and given that these include several foundries, there are actually nine foundries included in the analysis units. The foundries are located in different Italian regions among Veneto, Toscana, Friuli-Venezia Giulia, Lombardy, Marche and Puglia. In addition to being geographically differentiated, they also vary in production capacity, ranging from 8 thousand tons/year to 100 thousand tons/year. Moreover, all units of analysis make use of both "gray" refining cast iron and spherodal or “ductile” cast iron.

As previously mentioned, the data collection method chosen consisted of semi-structured interviews (about 60 min.) carried out directly with the Purchasing Managers or Managing Directors of the cast iron foundries. The protocol of the questions was structured on the basis of the three hypotheses and is available in the appendix. Respondents were only sent an introduction to the interview where the reasons and objectives of the research were explained. The questions themselves were not made available to the interviewees before the interview in order to guarantee the spontaneity of the answers. Furthermore, as far as possible, the questions asked have been grouped according to the hypothesis to which they refer. However, as usual in the conduct of semi-structured interviews, the question protocol was unique, but the interviewer chose the sequence of questions each time based on the flow of the conversation. The appendix also contains the summary table of

the interviews carried out and lists the characteristics of the various foundries interviewed. The interviews were recorded with the informed consent of the interviewees and transcribed to facilitate the subsequent phase of content analysis.

The first foundry interviewed is Zanardi Fonderie S.p.A., located in Minerbe (VR), with a production capacity of 18,500 tons/year and which employs around 240 people. The actor interviewed is the company's CEO and president of Assofond Fabio Zanardi.

The second unit of analysis interviewed is represented by ZML Industries S.p.A. Located in Maniago (PN), it is the cast-iron division of the large industrial group "Gruppo Cividiale", which have varied economic interests in the iron and steel industry. Its production capacity is approximately 50 thousand tons/year, employing 500 employees. For ZML industries, the Energy & Raw Material Purchasing Manager Alberto Valduga was interviewed.

The third foundry taken as unit of analysis is Fonderie Guido Glisenti S.p.A., located in Villa Carcina (BS) and also owner of the Lead Time S.p.A foundry in Caldarola (Macerata). The two foundries have a capacity of around 30,000 tons/year jointly. Purchasing manager Marco Vangi spoke for them.

Moving on to the fourth cast iron foundry interviewed, this is the large Fonderia di Torbole S.r.l. located in Torbole Casaglia (BS). The Torbole foundry is part of the EF group, which also owns the Pilenga-Baldassarre S.r.l foundry and the Fond-Stamp S.p.A. foundry. The purchasing manager Maurizio Nicolosi was interviewed for them, who explained that the Torbole foundry has a production capacity of around 100,000 tons/year and employs 450 people, representing the largest unit of analysis in terms of production, while Pilenga Baldassarre employs around 100 people and produce 25.000 tons/year. Fond-Stamp employs around 80 people and do no specify the production capacity.

The fifth foundry interviewed is Fonderia De Riccardis S.r.l., located in Soleto (LE). For them, the director of the financial area Stefanizzi was interviewed, who stated that their production capacity is around 8 thousand tons/year and employing 90 employees, is the smallest unit of analysis.

The sixth and last foundry interviewed is Fonderie Palmieri S.p.A., located in Calenzano (FI). It is a medium-sized foundry, with a production capacity of around 16,700 tons/year and employing around 150 people. The person interviewed is the Managing Director Jens Hartmann.

In addition to the cast iron foundries, an important cast iron trader operating in Italy was also interviewed. His name is Francesco Carpaneto, head of Compagnia delle Ghise S.r.l. This source was heard as a great expert and connoisseur of the Italian cast iron market, in fact, being in direct contact with the major producers of cast iron at an international level, he has a detailed knowledge of the mechanisms and trade exchanges basically in real time.

The fourth and fifth components of research design, linking data to hypotheses and criteria for interpreting the findings, refer to the part devoted to data analysis. In this case, the perspective given by the

Research Design of this thesis reflects more the flexible one proposed by Stake and Merriam than the more rigorous one of Yin. In a Stakian view, researchers' impressions are the main source of data and helps making sense of them as the analysis (Yazan, 2015). In this sense, although he acknowledges the validity of an analysis protocol, "he gives precedence to intuition and impression rather than guidance of the protocol" (Yazan, 2015).

On the other hand, Merriam (1998) defines data analysis as “the process of making sense out of the data. And making sense out of data involves consolidating, reducing, and interpreting what people have said and what the researcher has seen and read – it is the process of making meaning” (Merriam, 1998, p. 178).

Moreover, Stake suggests that researchers should conduct data collection and analysis process simultaneously, therefore there is no exact point in the research process to start analysis because there is no exact point to start data collection (Stake, 1995). Indeed, the data collection and analysis in this thesis was done simultaneously. Likewise, in contrast to Robert Yin’s prescription, there was no exact moment of data collection as it was done throughout the writing of the thesis and based on the availability of the interviewees. Indeed, according to Merriam (1998): "advocating for a recursive and dynamic data collection and analysis is not to say that the analysis is finished when all the data have been collected. Quite the opposite. Analysis becomes more intensive as the study progresses, and once all the data are in" (Merriam, 1998).

Going back to the stricter framework developed by Yin, linking data to hypotheses require the combination of the case study data as a direct reflection of the initial study hypotheses. According to the author, the analysis of evidence must follow an analytical strategy in order to treat the evidence fairly, produce compelling analytic conclusions, and rule out alternative interpretations. The author's favourite analytical strategy, as well as the most used, consists in relying on theoretical hypotheses set forth previously. In fact, they arise from the research question and guide the research objective. Furthermore, they shaped the data collection and the overall research design by helping to focus attention on certain data and to ignore others, generating a criterion for interpreting the relevant study's findings. The theoretical framework exposed in the first chapter stated the conditions under which the phenomenon described by the hypotheses is likely to be found. In addition to an analytic strategy, in our case that of relying on theoretical hypotheses, Yin suggests that it is also necessary to make explicit an analytic technique (Yin, 2009). One of the more desirable techniques used herein is to use a pattern-matching logic. In the words of the author, "such a logic compares an empirically based pattern with a predicted one (or with several alternative predictions). If the patterns coincide, the results can help a case study to strengthen its internal validity" (Yin, 2009, p. 214). Again, in our case, the predicted pattern is outlined and consists of our three hypotheses. Following the logic behind these three, it becomes clear that they provide a pattern in which an initial shock occurs, a description of the environment in which the shock is occurring, and a response from the units of analysis to address that initial shock. In particular, the reference shock is represented by the disruption of the cast iron supply chain for the Italian cast iron foundries, which would therefore find themselves in a state permeated by ambiguity, and to

which they would have responded by reconfiguring the connections within the network and by building resilience. In this sense, pattern matching represents the way of linking data to hypotheses.

Finally, the repetition of the predicted pattern within all the units of analysis should guarantee the validity of the conclusions and the at least partial generalization of the evidence. The next section will be devoted to the analysis the limitations of multiple case study design.

3.3. Limitations of the Case Study Design

As previously stated, case studies provide a mean to investigate complex situations with multiple variables under analysis. Although in Yin's vision within the case study both qualitative and quantitative research methods can coexist and reinforce each other, the case study is generally included among the techniques of qualitative analysis. In other words, as Creswell (2007) stated, the case study method is not just a form of “qualitative research,” even though it may be recognized among the array of qualitative research choices (Creswell, 2007).

Therefore, case studies, like all research methodologies, are affected by limitations, and in particular, by those typical of qualitative methodologies. According to Simon & Goes (2013): " limitations are matters and occurrences that arise in a study which are out of the researcher's control. They limit the extent to which a study can go, and sometimes affect the end result and conclusions that can be drawn. Every study, no matter how well it is conducted and constructed, has limitations" (Simon & Goes, 2013).

One of the main limitations of qualitative research affecting the case study methodology is related to validity and reliability. In fact, "because qualitative research occurs in the natural setting it is extremely difficult to replicate studies" (Wiersma, 2000, p. 211).

Someone argue that another limitation, this time specific to the case study, is represented by the fact that we cannot make causal inferences from case studies because we cannot rule out alternative explanations. This limitation, combined with the previous one and the limited number of cases involved, has raised perplexity in the debate on the case study methodology regarding the generalization of the result obtained. In fact, since case studies involve the behaviour of one person, group or organisation, the behaviour of this unit of analysis may or may not reflect that of similar entities. In this sense, case studies may be suggestive of what may be found in similar organisations, but additional research would be needed to verify whether such findings can be generalized elsewhere (Simon & Goes, 2013).

To overcome this limitations, Robert Yin (2009) has provided a distinction between an analytical and a statistical generalization. Using his words, the "short answer is that case studies, like experiments, are generalizable to theoretical hypotheses and not to populations or universes. In this sense, the case study, like the experiment, does not represent a “sample,” and in doing a case study, your goal will be to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization)” (Yin,

2009, p. 43).

In addition to the differentiation between the rationale behind statistical sampling and the choice of units of analysis in the case study, it is necessary to remember that researchers must be careful to point out that they seek only contingent generalizations that apply to cases that are similar to those under study. In this sense, the problem would be an overgeneralization that arises if case study researchers or their readers extend research findings to types of cases unlike those actually studied. Therefore, it is necessary to specify that the evidence provided by this case study can be generalized only to the extent that we are considering Italian cast iron foundries that work gray or spheroidal cast-iron. In this way, case studies involve a trade-off between generalizability and specificity. Rich generalizations in the social sciences often apply only to small and well-defined populations or subtypes, whereas theories that apply to broader populations are usually not very specific (Bennet, 2004).

Moreover, someone could argue that the choice of a survey would have been more appropriate and generalizable for the purpose of this thesis. However, a survey can be readily designed to enumerate the "what," such as within research questions starting with "how many" or "how much", or research questions starting with "who" and " where", whose ultimate aim is to describe the incidence or prevalence of a phenomenon or when it is to be predictive about certain outcomes. But they are not suitable for in-depth analysis that seek the "how" of complex phenomena (Yin, 2009).

A further drawback associated with qualitative analysis is that it requires a labour-intensive analysis process such as categorization, recoding, transcription etc. While these processes are time-consuming, they provide the ability to probe for underlying values, beliefs, and assumptions. Nevertheless, qualitative studies have the capacity to gain a full appreciation of the phenomenon analysed by understanding what is driving that behaviour and yielding more in-depth information than data derived from surveys (Choy, 2014).

Moreover, another complaint concerning research using qualitative methods is the widespread practice of redefining the original research problem, question, and/or hypotheses during the research process. Clearly, adopting a quantitative research perspective, such changes are seen as catastrophic for analytical rigour. Anyhow, from a qualitative research perspective, a more flexible design can be viewed differently. This happens because quite often at the beginning of the research, neither the units of investigation, nor the precise objects of reasoning, circumstances and core problems are really known. In fact, as happened in this case, researchers do have some questions in mind when they begin their qualitative investigation, but what to ask exactly becomes clear(er) only after a while of investigating. (Diefenbach, 2009) Often new questions emerge during and because of the investigation, therefore "In this sense, the (re-)formulation of the research question (or adding new ones) is a sign for progress, for an increasingly better and deeper knowledge and understanding of the objects of reasoning and recognition of emerging patterns" (Diefenbach, 2009, p. 877).

Another major criticism brought to discredit the case study methodology is that they do not state

explicitly on which theory they are based on. This criticism derives from the fact that often the case studies do not explain on which theoretical basis the investigation was carried out, questions were asked, data gathered, and conclusions formulated. To overcome the problem, in the first chapter of this thesis the rationale of the research was deeply rooted in a solid theoretical basis, which subsequently informed all the steps carried out. As previously stated, the theoretical framework on which the thesis is based guided both the questions asked in the interviews and the collection and analysis of the data.

In addition, one of the most fundamental criticisms of qualitative research and case studies is that the entire qualitative research process is biased by implicit assumptions, interests, worldviews, prejudices, and one-sightedness of the researcher. This happen because researchers are humans and thus they have opinions not only about what they investigate but also how these things should be. While it is impossible to ignore the researcher's own subjective view, this is also true for science and quantitative research, although less addressed and more hidden. For instance, random sampling and statistical testing are not immune to manipulation by an unscrupulous researcher. This is because "Science in general is a human endeavor and one cannot have ideas, assumptions, theories, and formulas without the human factor" (Diefenbach, 2009, p. 876). Besides, as Patton (1990) argues “the human factor is the great strength and the fundamental weakness of qualitative inquiry and analysis”. Creativity and invention, science and social science are not possible without subjectivity” (Diefenbach, 2009, p. 876).

Lastly, a further criticism linked to the one mentioned above concerns the choice of analysis units and the semi-structured interviews. In particular, for gathering empirical data, units of investigation have to be selected. The implicit criticism is that this process reflects more convenience than purposive sampling, perhaps due to already established links, because they are famous or because of personal interests. As for the problem of sample representativeness and generalization, we have already dealt with the question of the difference between quantitative and qualitative generalization. In fact, what is needed is assurance that the unit of investigation are suitable for the type(s) of problem(s) that shall be investigated, and this happens if "they can provide the objects of reasoning as well as all relevant criteria and circumstances (e.g. cultural background, institutions) that are needed to be taken into account in order to investigate the research problem appropriately. It is the unit of investigation that counts, not the way how it was identified" (Diefenbach, 2009, p. 879).

On top of that, the same argument of representativeness is put forward concerning the selection of interviewees. Criticism arose because in the case of research primarily based on interview data, the selection of interviewees decides whose worldviews, opinions, and interests will be taken into account, and who's will be ignored. Someone argues that in organizations the selection of interviewees depends to a great extent on the goodwill of powerful and influential people within the organisation. In this sense, the selection of interviewees would be part of organizational politics. In the case of cast iron foundries, given that most of the foundries interviewed are small and medium-sized enterprises, the interviews were carried out with the

purchasing managers or directly with the Managing Directors. Therefore, what has been done is to limit the findings and conclusions to these particular worldviews and put them into perspective through the triangulation of the data present in the Assofond database, i.e. the wider picture.

In addition, it is not only the interviewer but also the interviewees who spoils the data. This can happen unconsciously because interviewees follow "cultural scripts about how one should normally express oneself on particular topics" and, hence, the interview is "better viewed as the scene for a social interaction rather than a simple tool for collection of data" (Alvesson, 2003, p. 169). The interviewee may also deliberately lie for personal or business interests or may be forced in some way by the interviewer to give a certain answer. To begin with, we should say that there is no such things like a neutral, non-intervening and non-existent interviewer. Interview data are through social interaction motivated statements, the interviewer is an active part of the social interaction and he or she must intervene making statements and guiding the interviewee through the questions. If one wishes to eliminate the personal influence that the interviewer can exercise on the interviewee, one should resort to surveys, returning to the previous discussion. To limit the preparation of the answers as much as possible and preserve the spontaneity, the interviewees were not given the questions previously, but only a generic introduction to the case study.

In conclusion, the next paragraph will be dedicated to the presentation of the evidence and the discussion of the findings, trying to pull the strings of the discussion to finally reach a conclusion.

Fourth Chapter: Results and Discussion

4.1. (H1): the Russian-Ukrainian conflict has generated an upstream disruption within the cast iron supply chain, which in turn has represented a supply risk for the Italian cast iron foundries.

The first hypothesis presupposes the reiteration of three fundamental concepts analysed in the first chapter of this thesis. Such concepts are necessary to understand the rationale behind the hypothesis and its operationalization. As stated in the literature review, according to Craighead et al. (2007) "supply chain disruptions are unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain and, as a consequence, expose firms within the supply chain to operational and financial risks" (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007, p. 1). On the other hand, we have defined the concept of Supply Chain Risks as follows: "the likelihood and impact of unexpected macro and/or micro level events or conditions that adversely influence any part of a supply chain leading to operational, tactical, or strategic level failures or irregularities" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4-5).

According to the framework developed by Ho, Zheng, Yildiz, & Talluri (2015), "Macro risks refer to adverse and relatively rare external events or situations which might have negative impact on companies" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4). They are divided into natural risks and man-made risks. This last type of risks includes and is driven by one of the most relevant risk factors for the purposes of this thesis: the risk generated by war. Although the war has not affected the Italian territory directly, as we described in the second chapter, it had a heavy impact on the supply chain of Italian cast-iron. In particular, given the extreme Italian dependence on the two warring countries, in the first part of the hypothesis (H1) I argued that the Russian-Ukrainian conflict has created an upstream disruption within the cast iron supply chain.

The SCRM framework developed by the authors has been useful also for identifying the specific type of risk to which the supply chain of Italian foundries would have been exposed to and therefore relevant for the purpose of this thesis, namely the supply risk. It refers to "adverse events at the upstream partners of a firm" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 4). According to the table of risk factors attached in the appendix, this type of risk is driven by a series of factors such as the impossibility to provide competitive pricing, single supply sourcing, small supply base, supplier dependency, global outsourcing, narrow number of immediate suppliers, lack of supplier visibility, transit time variability, sudden hike in costs and more.

To validate this first hypothesis (H1), as demonstrated by the interview framework in the appendix, the first set of questions has been devoted to the identification of which of the risk factors that drives supply risks has affected the Italian cast iron foundries.

Furthermore, to operationalize the two concepts of "upstream disruption" and "supply risk" we will make use of the parameters provided by Chopra & Sodhi (2004). According to the authors, a supply disruption can be operationalized through two main parameters: 1) "Supplier of a key part shuts down plant for a month

or at a key part of the production cycle, 2) “Supplier capacity drops by 20% overnight” (Chopra & Sodhi, 2004, p. 57).

As regards the concept of supply risk, referred to by the authors as procurement risk, in order to be realized it must meet at least one of three conditions: 1)”Supplier delays in processing returns by twice as long” 2)”Supplier forced to increase price of key components by 20% “ 3)”Transportation costs go up 20% overnight” (Chopra & Sodhi, 2004, p. 57).

Before starting, it is necessary to specify that from the interviews emerged that no foundry used to supply cast iron directly from foreign producers. On the contrary, all of them affirmed that they procure from some intermediaries defined as "traders", who are responsible for buying the pig iron from the foreign producers, getting it by ship to the port of Marghera and then to redistribute it to the various foundries.

The second evidence resulting from the semi-structured interviews with the managers of the Italian cast iron foundries is that, as described by the Assofond data, the foundries before the war used to procure largely from Russia and Ukraine, while only a small part of the cast iron came from South Africa (Brazil) and South America.

For instance, the first of the managers interviewed explained that although in the past his foundry used to buy (trough traders) the nodular (Spheroidal) cast iron from Brazil and the refining cast iron from Russia, in recent years two Ukrainian steel mills has supplied around 90% of the cast iron used in the foundry process.

What has been reported by the first manager was also confirmed by two other purchasing managers, who claimed to buy cast iron, before the war, basically all from Ukraine, in particular from a range of traders who used to procure the material from the Azovstal and Zaporizhzhia steelworks. For them too, Brazil accounted for only a small fraction of the purchases, mostly for the sole purpose of keeping the supply channel open.

On the other hand, one of the managers interviewed stated that it requests about ten monthly offers from as many European traders, with the addition of a single direct producer in Germany (the only case). This time, most of the pig iron came from Russia, while the remainder from the Ukraine and a tiny fraction of the ductile iron was purchased from Brazil. The last two managers instead argue that before the war they used to procure cast iron of both Russian and Ukrainian origin depending on the offers received. In fact, these evidence are confirmed by the Assofond data described in the second chapter, according to which in 2021, 51% of the cast iron imported into Italy came from Ukraine, while 30% from Russia.

Moving forward with the evidence, as the manager of Fonderia De Riccardis stated: “on the 24th of February everything stopped”. Indeed, all the managers interviewed claimed that at the time of the official outbreak of the conflict on February 24, the problem has been the "disappearance" of pig iron from the market for about two months, creating a supply panic which in turn has generated an exponential increase in pig iron prices. However, four out of six managers argued that "the initial panic over the lack of availability of pig iron

was fuelled in part by speculative aspects of the market and the excessive power of some suppliers". In fact, since one the manager usually passes near the port of Marghera, he claims to have seen the cast iron stored in the warehouses. Indeed, as confirmed by another one, "the truth is that everything didn't disappear immediately, there was an initial slowdown but not in one day, it was speculation, prices tripled in 15 days". Therefore, according to most of them, the pig iron actually did not arrive for about two months, however what was already stored in the port warehouses in some cases was not sold at all, while in other cases an attempt was made to feed foundries with the bare minimum specifically to generate panic on the market and encourage price increases.

Moreover, some managers argued to have seen some impropriety in the sector, for example in the case of some colleagues who were waiting for loads of cast iron, which disappeared for a few days and then reappeared later at much higher prices. Therefore, according to them, the lack of new arrivals of pig iron was joined by an excessive market power of the intermediaries, who, being a small number, would have deliberately "carteled" by creating a monopoly type power to make the foundries dry up the reserves and generating a climate of anxiety which led to a dramatic rise in the prices of cast iron.

The majority of the managers interviewed indicated the difficulty of obtaining material as the main problem at the outbreak of the conflict. In fact, as one of them claimed: "at the outbreak of war, I only had cast iron from Ukraine, so I shivered. In the most dramatic moments, in the first place, the fear was to stop the foundry, at the time we were consuming 4.500 tons of cast iron per month, we could have gone on for a little more than a month". On the other hand, the CEO of Fonderie Zanardi, who claims to have had good stock reserves, indicated the increase in prices (financial exposition) of cast iron as the main problem, while for the other managers this was only the second problem encountered in order of seriousness. Some of them also indicated the ambiguity in delivery times and their lengthening as problems.

Moreover, some of the managers interviewed indicated that they know personally either cases of foundries that have found themselves forced to stop production due to lack of raw materials or in any case at risk of closure.

As indicated by the interviewees, the price increases caused by the disruption of the cast iron supply chain have created an excessive financial exposure for the foundries because traders, affected by the ambiguous climate generated by the sanctions and by the uncertainty about the arrivals of the loads, stopped advancing cargo payments. Therefore, assuming the function of aggregating buyers, the traders have asked the foundries themselves to advance the money for the shipments of the loads, severely exposing them in financial terms, given that the loads are usually calculated for a period of a few months. On top of that, foundry customers usually pay a few months after the production and delivery of the castings, further exacerbating the liquidity problem for the foundries.

Furthermore, all the foundries reported the complete disappearance, even in the remaining months of

the year, of the material originating from Ukraine. In fact, as confirmed by Assofond data but also by public domain news, the destruction of the main producers of Ukrainian pig iron and the naval blockade of Ukrainian ports in the Black Sea implemented by Russia has caused the complete destruction of the supply chain of pig iron coming from Ukraine.

However, while there was a complete absence of Ukrainian raw material throughout the year, all the managers interviewed reported the reappearance of Russian pig iron starting around the end of May/beginning of June, purchasable but with irregular arrivals and at high prices. Therefore, despite the increase in prices if compared to previous years is a constant and given that cast iron as a material was not sanctioned but only a few Russian producers defined as "oligarchs" and men close to President Putin, even if with difficulty the Russian cast iron became available again after about 3 months.

An interesting detail that emerged from the interviews is that the great dependence on warring countries and the small supply base is because Russian and Ukrainian cast iron, unlike Chinese and Indian for example, has an intrinsic quality due to low quantities of waste materials. Thanks to this intrinsic mineral quality, Russia and the Ukraine are able to produce pig iron not as a product but as a by-product of steel mill waste, reducing costs but still guaranteeing an excellent product for Italian cast iron foundries. On the contrary, other global suppliers, to achieve this quality, would have to subject the mineral to various processes to make it suitable for the foundry process, which requires more or less quality material depending on the type of production. Pig iron from other global suppliers is more suitable for steel mills, which have less stringent requirements for input ore.

Another issue that informs the excessive dependence of the Italian cast iron supply chain on imports from Russia and Ukraine is the geographical distance between Italy and the other cast iron producing countries. In fact, although some foundries have declared that they source the cast iron partly from Brazil, South Africa or Australia, naval cargoes in transit from these countries take several months to arrive in Italy, also representing a problem of transport costs. For this reason, they are more attractive for the US market, especially cast iron from South America. This intrinsic quality, combined with the distance that separates Italy from the other world producers of cast iron, underlies Italy's dependence on these two countries and the difficulty of replacing this cast iron ore.

Referring to the first hypothesis (H1), which mentions the disruption of the cast iron supply chain and the consequent procurement risk for foundries, it is interesting to report a note provided some managers regarding the link between the extreme dependence of the EU on foreign raw materials and the ecological transition. As one of them stated: "The problem is that I had a production with materials of certain qualities, coming from certain industrial plants, which now half is bombed, the other half sanctioned and that I cannot move to the West because it is against the ecological transition for too much co2 emission". Likewise, others expressed concern about the availability of cast iron in the future also because, as they reiterated, "cast iron is

a fossil material extracted from coal and iron, incompatible in Europe due to the pollution generated by extraction and production. Therefore, it can't be done in Europe, but we have left the dirty work to others, we don't do it but then we buy it. These processes are incompatible here but nevertheless they are necessary; therefore, we depend on foreign countries. We made ourselves clean but then there was no structural and technological change in production, there is no green process from the base to the end and therefore we need that foreign cast iron". However, this topic, despite also informing the first hypothesis (H1) by relating to it through the excessive dependence on foreign suppliers, will be explored later.

The last piece of evidence that emerged from the semi-structured interviews and closely connected to the excessive dependence on Russian-Ukrainian suppliers, thus further exposing the companies to an important supply risk, is the reduced flexibility that foundries discount towards suppliers. Therefore, the supply risk is generated not only by the supply side due to the factors listed above, but is also magnified by the stringent requirements necessarily imposed by the foundries (demand-side). In fact, even if to different extents, all the managers interviewed declared that they have stringent requirements in terms of the quality of the input materials. The reasons for this are purely of a technical nature, since not only do the raw materials used as input by foundries have higher quality requirements than in other sectors of the steel industry, but any change to this material requires an onerous modification at the level of chemical analysis in production. In fact, to be efficient, foundries need a certain quality but above all stability and homogeneity of the raw materials, vice versa from time-to-time changes will be necessary in the production process with a waste of resources.

What has just been argued by the managers seems to be confirmed and strengthened by the Assofond data described in the second chapter. In addition to confirming the extreme dependence of Italian foundries on cast iron from Russian-Ukrainian materials, which in 2021 supplied respectively 30% and 51% of the cast iron imported into Italy, in the notes released by the association in the period of March 2022, we read "at the moment there is no new material available. The new purchases are for deliveries between the end of May and the beginning of June" (Assofond, 2023). In the same period, as reported by the managers interviewed, there was also a price boom, where the bimonthly survey of the C.C.I.A.A[14] indicated a variation in the maximum prices of the three types of pig iron on the market of +205 euro/tons for refining pig iron, +165 for hematite and +214 for spheroidal cast iron (Assofond, 2023).

The contribution to supply chain destruction provided by excessive market power of traders (speculation) and described by the managers interviewed can also be confirmed by the Assofond reports. In particular, again from the report dated 03/18/22[15], it is clear that there is no availability of <u>new</u> material, however the one already ordered previously, even if discounting delays and difficulties, was arriving. In addition to what has just been reported, Assofond also stated: "from the conflict zones the only channel out of

[14] C.C.I.A.A. Survey of 18/03/22. Source: (Assofond, 2023)
[15] C.C.I.A.A. Survey of 18/03/22. Source: (Assofond, 2023)

the question at the moment is Ukraine, while supplies from Russia continue to arrive from at least two of the main producers. However, this is material already sold in the month of December and that it is discounting a delay in arriving at the Italian ports" (Assofond, 2023).

Therefore, although it is true that there has been a disruption in the supply chain due to the real impossibility of procuring new materials, this disruption would not have been so sudden if there had not been excessive market power of traders, who had interest in draining the cast iron reserves of the foundries, fomenting the climate of anxiety. Given that traders represent an upstream part with respect to foundries in the supply chain, in this case a disruption could be argued at two different levels in the chain, both that of the producers, then in turn magnified by the intermediaries.

In accordance with the economic law of supply and demand, the price boom analysed by Assofond seems to coincide with the period of greatest scarcity of raw materials. In fact, as previously highlighted and again in agreement with what was declared by the foundries, the first significant drop in prices was recorded within the survey dated 06/08/22[16]. In that period, Assofond reports that "arrivals from Russia continue regularly, fed by the two producers not reached by the latest package of sanctions and on the other, supplies from Brazil have made up for the supply gap caused by the disappearance of Ukrainian cast iron , bringing the market back into balance at values slightly above those of 2021" (Assofond, 2023). Indeed, the normalization of the market appears to be the result of reduced demand for pig iron generated by "panic buying", i.e. purchases fuelled by emotional tensions triggered by the worsening Russia-Ukraine conflict and fears of running out of material.

As regards the discussion of the evidence obtained in relation to our first hypothesis (H1), given that all the interviewees stated that they had been exposed to "unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain and, as a consequence, expose firms within the supply chain to operational and financial risks", it is possible to argue that the Russian-Ukrainian conflict has generated an upstream disruption in the cast iron supply chain (both levels). Given that, for the reasons listed above, the cast iron foundries used to procure raw materials entirely from the two warring countries, this disruption affected the entire supply chain for about two months, while later it was possible to observe a recovery in the arrivals of cast iron of Russian origin, however at irregular intervals and made difficult by sanctions. On the other hand, the blockade of Black Sea ports and the physical destruction of Ukrainian producers has completely side-lined the country in pig iron exports. In addition, as reported by one of the managers, at that moment, other global suppliers such as South Africa and Brazil, "come from a period of low demand and do not have sufficient availability to meet the entire global demand for pig iron".

This upstream destruction in the cast iron supply chain has also been magnified by a series of risk factors which in turn have exposed the Italian cast iron foundries to a supply risk. First of all, an excessive

[16] C.C.I.A.A Survey of 08/06/2022. Source: (Assofond, 2023)

dependence on suppliers has been empirically found for a series of elements that refer to both the supply and the demand side. In fact, the intrinsic quality of the Russian-Ukrainian raw material, the geographical proximity which facilitates transport, the incompatibility of a possible re-shoring of production with the ecological transition and the scarce flexibility due to technical requirements on the part of the foundries in the choice of suppliers, all have contributed to exposing foundries to excessive dependence on suppliers and therefore to supply risk. On the other hand, a series of risk factors emerged from the semi-structured interviews which further contributed to the exposure to supply risk, namely small supply base, global outsourcing, narrow number of intermediate suppliers, lack of supplier's visibility, supplier market strength, supplier opportunism, monopoly power, transit time variability, supplier fulfilment errors and sudden hike in costs.

In conclusion, a substantial coincidence emerges from the triangulation of the macro-data of Assofond with the micro-level empirical evidence obtained through the semi-structured interviews. Furthermore, all five criteria provided by Chopra & Sodhi (2004) for detecting an "upstream disruption" and "supply risk" are fully satisfied. Similarly, a series of risk factors that have magnified the supply risk of foundries have been identified through empirical evidence. Therefore, my first hypothesis would appear to be fully satisfied.

4.2. (H2): Due to the Russian-Ukrainian conflict, Italian cast iron foundries are operating in an ambiguous environment.

The second hypothesis (H2) is directly informed by the concept of ambiguity. According to Gunessee & Subramanian (2020), "ambiguity can be defined as situations or events whose outcomes and likely occurrence are unclear and cannot be coded with precision" (Gunessee & Subramanian, 2020, p. 1203). Moreover, "ambiguity corresponds to a situation where there is no sufficient information to assign objective probabilities and where even a subjective probability distribution cannot be defined uniquely" (Gunessee & Subramanian, 2020, p. 1203). As already illustrated in the first chapter, the authors have developed a typology of ambiguity applied to the context of supply chains. In particular, the authors provide four different types of ambiguity:

1. Interpretative ambiguity
2. Causal ambiguity
3. Evaluative ambiguity
4. Probabilistic ambiguity

The first type of ambiguity "implies a situation being open to more than one interpretation, with an unambiguous situation described as having clear understanding as it has one meaning" (Gunessee & Subramanian, 2020, p. 1205). Causal ambiguity, on the other hand, concerns the unclear nature of causal connections between factors. Evaluative ambiguity is about decision-makers' assessment of situations

including impact and outcomes. Lastly, probabilistic ambiguity is the classical type of ambiguity which encapsulates “uncertainty about probabilities” and extreme ambiguity. Probabilistic ambiguity relates to decision-makers being unsure about the exact likelihood of potential outcomes and unaware of what future scenarios are possible (Gunessee & Subramanian, 2020, p. 1205).

In addition, according to Gunessee & Subramanian (2020), what demarcates an unambiguous situation from an ambiguous one is "two set of factors, information and cognitive factors and supply chain complexity factors. The former are individual or behavioural factors, while the latter are organizational factors" (Gunessee & Subramanian, 2020, p. 1206). Indeed, at the heart of the concept of ambiguity lies information. The ambiguity of a situation, in fact, is directly proportional to the amount of information available, whether missing or incomplete, to its lack of clarity due to possible multiple and sometimes conflicting meanings that can be attributed to the data or to the novelty of the situation due to lack of signals. Therefore, the status and availability of information in a situational context can be a source of ambiguity. Moving on, another source of ambiguity can be represented by human cognition, or rather by its limits, namely by the concept of “bounded rationality”.

While, on the organizational side, according to the authors what generates ambiguity is the complexity of the supply chains. In particular, two factors drive complexity: change in an organisation's external environment and global sourcing. The validation of the first hypothesis (H1) in the previous paragraph presupposes and implies in itself the supply chain complexity factors described by Gunessee & Subramanian (2020). In fact, the Russian - Ukrainian conflict and the consequent supply chain disruption (H1), first hypothesized and then empirically confirmed, are sufficient to configure the two organizational elements that drive supply chain complexity, namely the change in an organisation's external environment and global sourcing, therefore not I will focus on these conditions.

The necessary element to configure the ambiguous environment, empirically investigated through the interviews, is represented by the state of the information riceived by the foundries in the periods surrounding the outbreak of the conflict. Indeed, as can be seen from the interview framework, the set of questions posed to foundry managers relating to the second hypothesis (H2) focused on the state of information received from foundries.

The first piece of evidence, which can be generalized for all the foundries interviewed, is that the information in the moments surrounding the outbreak of war and also subsequently came mainly from the traders themselves. In fact, as pointed out by one of the managers, "the information arrived first from the traders, who promptly raised the problem and raised their hands declaring a state of calamity for war, in such a way as not to incur penalties and sanctions for breach of contracts".

Secondly, as indicated by others, the information regarding the state of supplies and the availability of cast iron came from the associative comparison through Assofond, which took care to organize Webinars and

discussions with the legal parties. Lastly, another source of information indicated by the interviewees was news in the public domain, i.e. newspapers, television, etc.

As regards the status of the information received, however, in this case the evidence was multiple and not always consistent. In fact, some managers interviewed reported different degrees and types of ambiguity related to different issues, while for others the situation was rather clear.

For example, one of the manager reported an uncertain and limited information status, above all due to the dynamism and confusion generated by sanctions. Indeed, given the numerous packages of sanctions imposed in various rounds by Western countries on Russia, the problem would have been to understand eventually whether the transiting cast iron cargo would have been affected by the sanctions or not (evaluative and probabilistic ambiguity). Since it could happen that a producer of pig iron was placed under sanction while the cargo of pig iron is in transit, the ambiguity would have been in understanding whether that cargo was actually legitimate or not. However, in line with the trend outlined in the previous paragraph, the manager further stated that the uncertainty regarding the availability and legitimacy of the pig iron shipments would have diminished after the first few months. At that time, the uncertainty would have concerned more the long term, also in connection with what was previously argued regarding the ecological transition.

A second manager, on the other hand, stated that "the channels stopped immediately" on February 24, and it was precisely in that period that he would have suffered the most from the lack of information intended as a difficulty in assessing the impact and duration that the war may have had on his foundry (probabilistic and evaluative ambiguity). Similarly, also a third and fourth manager stated to have found a high degree of ambiguity regarding both the duration and impact of the conflict, the availability and quality of the material, and the timing of delivery. Indeed, they claimed that "the information was confusing, unreliable and to be taken with a grain of salt".

Furthermore, a widespread fear among foundry managers derives from the ambiguity surrounding the future of sanctions and relations with Russia, given that any sanction imposed directly on the cast iron material or even on the triangulation of loads would have a destructive impact on the foundries Italian. Therefore, also in this case, once they took note of the situation, they would have passed from an evaluative and probabilistic ambiguity regarding the present to one regarding the future (aggravated by the background of the ecological transition).

Conversely, someone stated that "we had clear and clear information about who can ship and who cannot". According to the Manging Director, the only ambiguity found concerns the transit time and the date of arrival of the shipments of pig iron (probabilistic). Moreover, he claimed to have received sufficient information to be able to act accordingly, therefore not being affected by evaluative and causal ambiguity.

Likewise, the same evidence has been confirmed by another manager who stated to have received rather reliable information, furthermore he did not find a lack of information or poor quality. He argued that

the problem was more on the institutional side, generated by the dynamism with which the sanctions packages are released and not due to a lack of information. Furthermore, he stated that the information received allowed him to act accordingly in a rather clear manner, thus not even finding an ambiguity in the assessments.

In conclusion, although there were most of the elements indicated by the literature to define a situation of ambiguity, this cannot be generalized in the case of foundries. Although most of the managers have indicated some kind of ambiguity, generally evaluative or probabilistic in nature and concerning both the impact of sanctions and the conflict itself, my second hypothesis is only partially verified since the evidence are mixed. Indeed, it was not possible to identify one type of ambiguity found by all the foundries, even though most of them suffered from a lack of information.

In this case it could be argued that in the assessment of the ambiguity in which the foundries found themselves at the outbreak of the war, some variables intervene that were not taken into consideration by the study, such as for example the minor or major inclusion of the foundry in a system of relationships that guaranteed the reliability of the information. In fact, depending on the various traders to which the foundries have entrusted themselves and the relationship system in which the foundries are inserted, it seems that the various information has been passed on in a different way.

Therefore, although from the organizational point of view the complexity of the supply chain was confirmed, the evidence provided by the foundries are not consistent and thus sufficient to guarantee the validation of the hypothesis (H2). Furthermore, the difficulty in validating the hypothesis (H2) could derive from a deficit in the interview framework, which was not rigorous in identifying ambiguity through the questions posed. In addition, investigating ambiguity with precision probably requires a greater depth in the questions and in the explanation of the same to the interviewee. Lastly, although it is outside the field of study of this thesis, it would be interesting to analyse the relationship that exists between the relational system in which the various foundries are inserted and the degree of ambiguity to which they are subject.

4.3. (H3): In the face of the supply disruption caused by the Russian-Ukrainian conflict, foundries have adapted by restructuring connections and building resilience.

Given the relative length of the thesis, even the discussion of the third hypothesis (H3) requires a brief recap of the literature presented in the first chapter.

As we have seen above, supply chain risks can become real supply chain problems, causing unexpected changes in the flow of goods due to disruptions. Most companies develop plans to protect against low-impact, recurring risks in their supply chains. Many, however, are all but ignorant of high-impact, low-probability risks (Chopra & Sodhi, 2004). As a result, managers will continue to face the critical challenge of recovering from supply chain disruptions and attempting to minimize their impact. Thus, beyond understanding how managers

might work to prevent disruptions through risk planning, it must be better understood how managers respond to and recover from the supply chain disruptions they experience (Macdonald & Corsi, 2013).

Therefore, in relation to the hypothesis (H3), the aim of the thesis was to add a further piece of knowledge on how interconnected companies behave within a complex network in the face of a supply disruption. As suggested by the literature, most of the leading companies deal with this range of supply-chain risks by holding reserves, which usually includes excess inventory, excess capacity and redundant suppliers (Chopra & Sodhi, 2004).

Overcoming the "classic" prescriptions mentioned above and by adopting a vision of the supply chain as a complex adaptive system (CAS), in the face of a supply disruption companies connected in a complex network can adapt and restructure their connections. In this case, the CAS framework provides a useful theoretical foundation as firms in a supply chain operate as an interconnected network in a dynamic environment. Positing that firms in a supply chain constitute self-organizing networks, several authors have argued that some supply chains can be adaptive or resilient. This means that when hit with a disruption, they can adapt or restructure themselves to reach a desirable state which can be back to the original state, an equivalent state, or a better state (Zhao, Zuo, & Blackhurs, 2019).

Therefore, from CASs perspective, when facing a disruption, the ability to adapt and restructure the supply chain in the face of changing conditions is critical to maintain continuity of supply chain performance and minimizing the losses. Flows of materials within the supply chain network need to be redirected and structures need to be adapted to allow for continuity in operations (Zhao, Zuo, & Blackhurs, 2019).

Dabhilkar, Birkie, & Kaulio (2016) claim to have shifted the focus of resilience in supply chains from redundant capacity and inventory to dynamic capabilities. The latter are defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing circumstances" (Dabhilkar, Birkie, & Kaulio, 2016, p. 950). The dynamic capabilities are formed from intentional practices undertaken in the business firm and help to deploy the resources and infrastructure to align with prevailing circumstances upon disruption. Therefore, for assessing resilience, the key issue is the level of operations performance after recovery.

The authors frame these capabilities along two main dimensions: the first is the “proactive or reactive” dimension, while the second is called “internal or external” according to the capability's location, i.e. internal to the boundaries of the company or external to them (Dabhilkar, Birkie, & Kaulio, 2016).

This suggests four bundles of possible resilience practices, namely, proactive-internal, proactive-external, reactive-internal and reactive-external. Precisely these last bundles of resilience practices have been the focus of the questions relating to the third hypothesis (H3) and exposed in the interview framework.

First, it is necessary to point out that, given the singularity and specificity of the event that caused the disruption, a clear division between reactive and proactive practices based on the position of suppliers within

the supply chain has proved difficult. In fact, given that the managers interviewed stated that they received information on the status of the pig iron supply chain directly from their traders, this created a difficulty for foundries in preparing for upcoming issues related to direct producers. Indeed, when foundries learned from the traders the problems caused by the conflict, these were probably already in place at the level of direct producers. Therefore, in the reference period of this thesis, it was difficult to create a clear division between the practices adopted to mitigate the risk coming from a first-tier supplier and those beyond them (upstream). Nonetheless, I was able to identify some practices implemented by managers clearly as a preventive hedge against the disruption of primary producers.

For the sake of simplicity, I will divide the bundles of resilience practices along the reactive/proactive dimension as follows: reactive if these practices are aimed at mitigating the risk related to the failure or non-delivery of a trader or intermediary (first-tier supplier), proactive if the risk mitigation is related to the failure of a direct producer (beyond first-tier supplier).

The first evidence provided by the interviews with the managers was that the cast iron foundries actually operate as an interconnected network in a dynamic environment made up of producers, a series of primary and secondary intermediaries, connections between the various foundries and all the related industries that source from them. This evidence also resulted in the practices that characterized foundries in an attempt to hedge against the disruption.

The second piece of evidence highlighted in the interviews is that all the managers stated that they usually have a warehouse that ensures the continuity of production ranging from one to four months depending on the purchasing policies and melting plants. In addition to a certain redundancy in the inventory, all the managers claimed to have a rather wide range of suppliers, between 4 and 10 traders each, however they regularly source from only half of them, thus highlighting a redundancy also in the suppliers (although the supplier often overlap for different foundries). A further sign of foresight that emerged from the interviews and classified as a preventive strategy implemented by the foundries was the fact that the majority of managers stated that they make small purchases from traders with whom they do not collaborate regularly for the sole purpose of keeping supply channels active.

An interesting detail reported by one of the managers is that until a few years earlier, when the market enjoyed a certain degree of regularity, the Italian cast iron foundries used to source trough a purchasing strategy characterized by just in time, which is a stock management policy aimed at improving the production process, trying to optimize the upstream phases and to lighten the stocks of raw materials necessary for production as much as possible. In practice, it is a question of coordinating the times of effective need for materials on the production line with their acquisition and availability in the segment of the production cycle and at the moment in which they must be used. However, this has changed over the years due to an increasingly irregular and unpredictable market that has forced companies to build a larger warehouse.

As stated by all six managers, it was precisely these stocks combined with the other resilience strategies that most safeguarded their companies when there was the outbreak of the conflict and the consequent disruption of the supply chain. In fact, for example, two of the managers stated that at the outbreak of war their foundries could count on about 2 months of supplies. On the other hand, the Managing Director of the Fonderia Palmieri was even more foresighted, in fact he declared that he had made a preventive stockpile of more than four months due to the "hint" of a possible war generated by news of the movement of military troops on the borders in the period before the conflict.

Maintaining a high level of inventories, combined with other practices, has allowed the foundries analysed to overcome the first and most dramatic moment of the supply chain disruption, shielding them in some way even from extraordinary price increases.

Going beyond what we have defined as "classic" prescriptions, i.e. redundancy of the warehouse and suppliers, the evidence of the strategies implemented by the foundries has been truly manifold.

One of the strategies implemented by all the foundries, truly significant of their resilience and which we could classify as internal reactive, was the modification of the ingredients used in the metal charge of the furnaces. This strategy, perhaps the most exemplary in this sense, requires further explanation. First of all, it is necessary to specify that the mix of ingredients of the metal charge inserted inside the furnaces is not entirely made up of cast iron. On the contrary, both for a question of circular economy and efficiency, recycled material from production cycles is added to the cast iron, such as foundry returns, scrap iron and steel, with the addition of alloys such as ferrosilicon.

The differences in the ingredients that make up the charge to be inserted into the foundry furnaces vary on the basis of both qualitative criteria and the furnace used. The most traditional and dated one is the so-called “cubilotto" or “dome furnace", i.e. a type of furnace where the smelting takes place through the combustion of coke which burns in direct contact with the material to be melted, made up of solid cast iron and scrap. As explained by the managers, this type of furnace is less flexible in the changes of the ingredients inserted in the load. In fact, the height of the sole of the bottom of the furnace determines the composition of the materials inserted in the load, giving more or less the possibility of using cast iron or scrap. The poor flexibility is due to the fact that this sole is changed every 4 months due to scheduled maintenance, only then is it possible to choose the percentage of material to insert into the furnace. This type of furnace is used, for example, in the Fonderie di Torbole.

Another type of furnace, used in the Fonderia De Riccardis, is the methane-oxygen rotary furnace. This type of smelting plant, like the "cubilotto", suffers from a lack of flexibility in the variations of the ingredients of the charge. In fact, as explained by the manager, if in normal periods the load is represented by approximately 70% of cast iron and 30% of scrap, this percentage of scrap can only be increased by approximately 10% and no more, vice versa there is the risk of a significant loss of quality.

The third type of smelting plant is the so-called electric induction furnace, which is present in the majority of the foundries interviewed. Contrary to the other two types, after the necessary chemical analyses, the quantities of ingredients inserted in the furnace can be varied at any time, even to the point of eliminating the charge of cast iron. As can be understood, this represents an enormous advantage for the foundries, being able to change the ingredients introduced into the furnace at any time according to the various market quotations of the ingredients, thus optimizing production costs.

Therefore, depending on the different typology of smelting plant, all the managers interviewed stated that the first reactive-internal strategy was to reduce the percentage of cast iron in charge, in such a way as to lengthen the duration of stocks in the warehouse. For example, the manager of Fonderia De Riccardis (methane-oxygen rotary furnace) stated that he has reduced the pig iron charge in his dome furnace by 10%, while the Managing Director of Fonderia Palmieri stated that he has reduced the pig iron charge in his electric furnace by at least 50% (electric furnace). The case of ZML Industries is significant, where the purchasing manager stated that he had brought the production philosophy of the steelworks present in his group into the cast iron foundry, implementing a production mainly from scrap. Therefore, they usually load only 10% of cast iron, a percentage that varies according to the market quotations of the materials.

In this sense, the strategy of ZML Industries can be categorized as both a reactive and a proactive internal strategy. Furthermore and very surprisingly, the purchasing manager stated that in the most intense months of the disruption, when no pig iron seemed to be available, the foundry was able to completely eliminate the pig iron inserted in the charge.

On the other hand, the purchasing manager of the EF Group stated that in all their three foundries, first in the two with an electric furnace and then also in the one in Torbole, they passed from 730 kg of cast iron inserted in the charge to just 170 kg, lengthening considerably the duration of their warehouse and ensuring continuity in production until the summer. In these cases, the objective of their strategy was to lengthen the duration of stocks, so as to reduce the need to purchase cast iron at tripled market prices with the hope of a "cooling" of the market.

Therefore, the adaptability and resilience of foundries in this respect has been mind-blowing, but that's not all. Interestingly, while the manager of ZML Industries stated that he switched from the electric to the dome furnace a few years ago due to the above advantages, the manager of Fonderia De Riccardis stated that his foundry, starting with the methane gas increase in 2021, has implemented a series of huge investments aimed at overcoming the natural gas furnace and switching to the electric furnace (proactive internal strategy). In fact, driven by the increases in raw materials, primarily methane gas and cast iron which began their ascent in 2021, the foundry is currently investing heavily (8 million on a turnover of around 20) to free itself from dependence on Russia and Ukraine. In this case, the goal is to implement an electric smelting plant to minimize the dependence on pig iron and increase the use of scrap, and at the same time to implement a local logistics

chain that allows to find scrap on the national market. This long-term strategy represents a particular form of "reshoring" and highlights a notable foresight on the part of the foundry.

In addition, a number of external strategies have been implemented through collaboration with external entities. First of all, according to the concept of dynamic capabilities, all the managers interviewed stated that at the outbreak of the conflict, the first action was to look for alternative cast irons, generally investigating the Brazilian and South American markets both through the traders with whom they already collaborated, and through new traders. Therefore, an attempt was promptly made to reconfigure the network's channels, although often with poor results due to the excessive demand that has poured into these two countries and the very rapid increase in prices.

However, at this point the foundries' choices have varied according to the conditions of their warehouses and the smelting plant. For example, Fonderia Zanardi claims to have explored new channels from Brazil and South Africa which however have mostly turned out to be "dead ends". Therefore, they purchased very small loads from these two countries only to supply the little that was enough for the warehouse. ZML Industries, on the other hand, despite having claimed to have explored all the alternatives, even those suggested by some American customers, thanks to his smelting plant he has decided not to buy cast iron from other channels at all. Conversely, three of them claimed to have purchased pig iron even at very high prices from the new supply channels with the ultimate aim of not stopping the foundry. Indeed, as one of them stated: "I have worked with large warehouses, always trying to supply them as much as possible with even small purchases at high prices, the goal was to keep the warehouse as high as possible".

Another one argued: “the first thing I did was to rake all the material available, even financially exposing the foundry due to the high prices. The main goal was not to stop. I tried to buy stock for 4 months by opening a range of traders and new suppliers, I didn't succeed, but I still found something lying in the ports. Furthermore, I have undertaken greater relations with Brazil through traders, trying to make ship loads more efficient and pushing for the goods to arrive in Europe as well”.

Some managers have stated that a strategy used to get the goods to Europe and overcome the fact that traders often did not want to expose themselves financially, was to create purchasing groups among the foundries. In this way, the foundries managed to purchase small loads from the most disparate locations in an attempt to replenish the warehouse.

Furthermore, as some managers pointed out, the foundries have also demonstrated a degree of solidarity by helping each other through small exchanges of pig iron to make up for the material shortages.

Despite some failed attempts due to the problems set out above, the managers words once again highlight the resilience shown by Italian foundries, which have been effectively able to redirect the flows of materials within the supply chain network.

The strategies outlined above mostly represent practices implemented at the single foundry level.

However, in parallel to these, the foundries have also tried to mitigate the supply risk through the association Assofond. Indeed, as explained by President Zanardi, Assofond, at the time of the outbreak of the Russian-Ukrainian conflict, tried to leverage the government to restore part of the cast iron production of the former Ilva of Taranto, in such a way as to guarantee supplies of cast iron to foundries through domestic production. According to Zanardi, the blast furnaces of the former Ilva in Taranto would have a production capacity such as to guarantee supplies for the whole of Europe. However, despite some progress, this reshoring of production runs counter to the goals of the ecological transition and therefore has not been implemented.

In addition, a further proposal by Assofond to overcome the cast iron shortage was to purchase strategic stocks of cast iron from Brazil at the government level to fill the shortages of the foundries. However, this proposal was also declined by the government. Furthermore, adopting a long-term perspective, President Zanardi declared that through the association of Assofond many resources have been invested in research and development to try to overcome the current polluting cast iron production technology. Despite the resources invested and some experiments implemented, we are still far from this technology, which would have the ability to bring the production of cast iron back to Europe.

Thanks to the strategies implemented by the managers, mainly to the reduction of cast iron in the metal charge and to the purchases made from the new promptly configured supply channels, combined with the additional mitigation practices mentioned, the Italian foundries have managed to keep the production levels high until the arrival of the summer. Period in which, as previously reiterated, supplies from Russia started to reappear.

Indeed, around the beginning of summer, the supply channels from Russia appear to have been reconfigured, however at higher prices than in the pre-war period and not without logistical difficulties.

All the managers interviewed stated that they returned to purchasing Russian pig iron as soon as the channel became available again. For example, President Zanardi stated that in the second half of the year he mainly purchased cast iron of Russian and Brazilian origin, thus managing to actually replace the old main channel represented by Ukraine with the current one of Russian origin. Even the manager of Fonderie De Riccardis, who had necessarily moved to the Brazilian channel in the moments following the outbreak of the conflict, declared that he returned to Russian cast iron during the summer period. While for ZML Industries, a more singular case since by eliminating the cast iron used in the metallic charge he did not have the need to reconfigure new channels, once the disruption of the Russian channel had been overcome, he simply returned to purchase it from the Federation. At that point, production was also reconfigured by returning to insert cast iron in the charge using the old percentages. What has been said for Zanardi also applies to Fonderie Glisenti, who used to obtain supplies mainly from Ukraine before the war, while in the second half of the year he declared that he had switched to cast iron from Russia ("not excellent but of sufficient quality)". The same argument also applies to the rest of them.

Therefore, in conclusion, the disruption of the cast iron supply chain generated by the Russian-Ukrainian conflict has caused unexpected changes in the flow of goods. In these cases, the ability to restructure the supply chain in the face of changing conditions (disruptions and supply risks) is critical to maintain continuity of supply chain and foundry performance. Through the interview of foundries's managers, it has been possible to examine their company resilience and the effect of their adaptive behaviour. Following Zhao, Zuo, & Blackhurs (2019), flows of materials within the supply chain network need to be redirected and structures need to be adapted to allow for continuity in operations, and this was just what the Italian cast iron foundries did. Indeed, in the face of a supply disruption, the foundries connected in a complex network were readily able to adapt and restructure their connections according to the availability of material. As we have seen, the production structures and techniques were also promptly reconfigured. When they were hit by the Russian-Ukrainian disruption, they adapt or restructure themselves to reach a desirable state which is for most of them an equivalent or better state to the previous one. Through the mitigation strategies described above and the reconfiguration of both the structures and the supply channels, all the managers interviewed declared that they had concluded an overall satisfactory year from the point of view of corporate performance.

If, According to Dabhilkar, Birkie, & Kaulio (2016), supply-side resilience can be defined as "the capability of a buying firm to prepare for, respond to and recover from unexpected upstream supply chain disruptions by returning to, or maintaining continuity of, operations at the desired level of connectedness and control over structure and function" (Dabhilkar, Birkie, & Kaulio, 2016, p. 949), it is possible to argue that the Italian cast iron foundries have been exemplary in this sense. Therefore, my third hypothesis (H3) seems to be fully validated.

CONCLUSION

5.1. Main Findings and Key Takeaways

Starting from February 24th, the invasion of the Ukrainian territory by the Russian Federation has threatened to generate a new supply-chain disruption. This time, unfortunately, the terrible consequences in terms of human lives add up to the economic ones. Since both countries are major suppliers of raw materials, the destruction of Ukraine, combined with the economic sanctions imposed by most Western countries on Russia and the naval blockade of the Black Sea, have severely affected global markets.

The disruptions of Russian and Ukrainian exports have especially affected regional economies that are highly dependent on these specific supplies. Among the latter, the Italian cast iron supply chain deserves special consideration since its supply of cast iron comes almost entirely from the two warring countries, which in 2021 jointly represented the 81% of the Italian cast-iron imports (Assofond, 2022).

Indeed, cast iron exports are dominated by three countries (Russia, Brazil, and Ukraine), together accounting for over three-quarters of global exports. From this point of view, pig iron represents for Italy an emblematic case of dependence on foreign supplies and therefore of strong exposure to supply risk in the event of disruptions along the supply chain.

Among the categories most exposed is certainly the sector of Italian foundries, and in particular those that produce cast iron since this is the basic material to produce their castings. The Russian-Ukrainian military crisis has completely changed the scenario and threatens to have a heavy impact on the economy of the cast-iron foundries (Assofond, 2022). In addition to the tsunami in prices, the other consequence, perhaps even more tragic for the cast iron foundry sector given the very strong dependence on the procurement of raw materials, was the cancellation of supplies of cast iron from Ukraine and Russia (Assofond, 2022).

Therefore, this thesis aimed to answer the following research questions*: How did the Italian foundry pig iron supply chain respond to the shock of the Russian-Ukrainian conflict? How and through what strategies did they resist the supply chain disruption?* By using a multiple-case study methodology, the focus of this thesis has been mainly on the disruption and restructuring of the supply chain of Italian cast iron foundries, both trying to understand how the industry has moved overall at a macro level, which solutions they have adopted as a category, and analysing their effects at a micro level through semi-structured interviews with six managers who run the supplies of nine cast iron foundries.

The semi-structured interviews aimed at verifying the following three hypotheses:

- ***(H1)****: the Russian-Ukrainian conflict has generated an upstream disruption within the cast iron supply chain, which in turn has represented a supply risk for the Italian cast iron foundries.*
- ***(H2)****: Due to the Russian-Ukrainian conflict, Italian cast iron foundries are operating in an ambiguous environment.*

- ***(H3)**: In the face of the supply disruption caused by the Russian-Ukrainian conflict, foundries have adapted by restructuring connections and building resilience.*

Thanks to the methodological flexibility guaranteed by the case study design, the evidence provided by the semi-structured interviews have also been triangulated with the data present in the database of Assofond, the association of Italian foundries.

In relation to our first hypothesis (H1), the evidence gathered through the semi-structured interviews confirmed that the Russian-Ukrainian conflict has generated an upstream disruption in the cast iron supply chain. Since the cast iron foundries used to procure raw materials entirely from the two warring countries, this disruption affected the entire supply chain for about two months, while later it was possible to observe a recovery in the arrivals of cast iron of Russian origin, however at irregular intervals and made difficult by sanctions. On the other hand, the blockade of Black Sea ports and the physical destruction of Ukrainian producers has completely side-lined the country in pig iron exports. In addition, South Africa and Brazil come from a period of low demand and do not have sufficient availability to meet the entire global demand for pig iron.

This upstream destruction in the cast iron supply chain has also been magnified by a series of risk factors which in turn have exposed the Italian cast iron foundries to a supply risk. First of all, an excessive dependence on suppliers has been empirically found for a series of elements that refer to both the supply and the demand side. On the other hand, a series of risk factors emerged from the semi-structured interviews which further contributed to the exposure to supply risk, namely small supply base, global outsourcing, narrow number of intermediate suppliers, lack of supplier's visibility, supplier market strength, supplier opportunism, monopoly power, transit time variability, supplier fulfilment errors and sudden hike in costs. Therefore, my first hypothesis has been fully verified.

Moving on to the second hypothesis, according to Gunessee & Subramanian (2020) what generates ambiguity on the organizational side is the complexity of the supply chains. In this case, the validation of the first hypothesis (H1) presupposes and implies in itself the supply chain complexity factors described by Gunessee & Subramanian (2020). However, according to the authors, the necessary element to configure the ambiguous environment, empirically investigated through the interviews, is represented by the state of the information received by the foundries in the periods surrounding the outbreak of the conflict.

In this case the evidence was multiple and not always consistent. In fact, some managers interviewed reported different degrees and types of ambiguity related to different issues, while for others the situation was rather clear. In conclusion, although most of the managers have indicated some kind of ambiguity, generally evaluative or probabilistic in nature and concerning both the impact of sanctions and the conflict itself, my second hypothesis is only partially verified since the evidence is mixed. Indeed, it was not possible to identify one type of ambiguity found by all the foundries, even though most of them suffered from a lack of

information. Therefore, although from the organizational point of view the complexity of the supply chain was confirmed, the evidence provided by the foundries are not consistent and thus sufficient to guarantee the validation of the hypothesis (H2).

The evidence gathered through the semi-structured interviews confirm my third and last hypothesis (H3). Indeed, thanks to the strategies implemented by the managers, mainly to the reduction of cast iron in the metal charge and to the purchases made from the new promptly configured supply channels, combined with the additional mitigation practices mentioned, the Italian foundries have managed to keep the production levels high until the arrival of the summer, period in which the supply channels from Russia appear to have been reconfigured. Following Zhao, Zuo, & Blackhurs (2019), flows of materials within the supply chain network need to be redirected and structures need to be adapted to allow for continuity in operations, and this was just what the Italian cast iron foundries did. In fact, in the face of a supply disruption, the foundries connected in a complex network were readily able to adapt and restructure their connections according to the availability of material. As we have seen, the production structures and techniques were also promptly reconfigured. When they were hit by the Russian-Ukrainian disruption, they adapt or restructure themselves to reach a desirable state which is for most of them an equivalent or better state to the previous one. Therefore, it is possible to argue that the Italian cast iron foundries have been exemplary in showing and building resilience, validating my third hypothesis (H3).

5.2. Main Contributions, Limitations and Suggestions for further Research

This thesis aims to provide a double contribution, both to the literature on SCRM, integrating the concept of Complex Adaptive Systems to understand how the structure of the network may play a role in the propagation of disruptions along the supply chain, and to the business community, examining the resilience of the Italian foundry sector and the effect of adaptive behaviours in real-world supply chain networks.

In fact, from a purely theoretical point of view, within an increasingly interconnected world, but also increasingly subject to market disruptions and volatility, this thesis demonstrates the importance of conceptualizing the business community and the surrounding environment as a Complex Adaptive System and no longer through a linear representation of the concept of Supply Chain. As highlighted by the thesis, companies are immersed and interact in a dynamic and interconnected environment, which can undergo sudden changes also due to stimuli external to the environment. Within this ecosystem, and hence the practical contribution of this thesis, the ability of companies to interact with each other and with the external environment is of fundamental importance for their success. This ability to act required by today's market goes through not only a simple reactive ability to adapt to adverse changes in the surrounding environment, but above all requires foresight, scouting and continuous monitoring of the system in which they are immersed in

order to identify such critical issues and exploit them to gain a competitive advantage.

As demonstrated by Italian foundries, within today's market, characterized by strong competition but also volatility and rapid changes, resilience has become a necessary quality for companies. By building resilience, companies faced with a negative shock are able to identify the critical point within the network and more or less quickly reconfigure their connections, overcoming the difficulty and returning to a state that can be the same, similar or even better than the previous one. However, without an adequate theoretical conceptualization of the ecosystem in which productive activities are inserted, the practical contribution of this thesis would have been meaningless.

Furthermore, it was thanks to the case study design that it was possible to highlight the importance of the concept of resilience and adaptability of companies, once again confirming the usefulness and practicality of the methodology. In fact, given the multiplicity of variables involved, in this case the writer had no degree of control over the events and behaviours analysed. However, thanks to the long semi-structured face-to-face interviews with the managers of the foundries and the triangulation with Assofond data, I managed to deepen the details that characterize a complex social phenomenon whose understanding required the analysis of important contextual conditions highly pertinent to the phenomenon of study, which in turn require a comprehensive but flexible methodology.

Despite the practical and theoretical contribution of this thesis, like all empirical research, it is not without limitations. As reported in the third chapter, some limitations derive from the methodology employed. In addition to those highlighted by the methodological debate in the literature and reported previously, a specific limitation of this research was found in the collection of evidence related to my second hypothesis (H2). In this case it could be argued that in the assessment of the ambiguity in which the foundries found themselves at the outbreak of the war, some variables intervene that were not taken into consideration by the study, such as for example the minor or major inclusion of the foundry in a system of relationships that guaranteed the reliability of the information. In fact, depending on the various traders to which the foundries have entrusted themselves and the relationship system in which the foundries are inserted, it seems that the various information has been passed on in a different way.

Furthermore, the difficulty in validating the hypothesis (H2) could derive from a deficit in the interview framework, which was not rigorous in identifying ambiguity through the questions posed. In addition, investigating ambiguity with precision probably requires a greater depth in the questions and in the explanation of the same to the interviewee. Therefore, although it is outside the field of study of this thesis, it would be interesting to analyse the relationship that exists between the relational system in which the various foundries are inserted and the degree of ambiguity to which they are subject.

Someone can argue that another limitation, this time typical of the case study but heuristically relevant, is represented by the fact that we cannot make causal inferences from case studies because we cannot rule out

alternative explanations. This limitation has raised perplexity in the debate on the case study methodology regarding the generalization of the result obtained. In this sense, case studies may be suggestive of what may be found in similar organisations, but additional research would be needed to verify whether such findings can be generalized elsewhere. This limitation necessarily afflicts this thesis as well, in the sense that the evidence gathered can be generalized only to the Italian cast iron foundry sector.

For this reason, it would be interesting to extend the study also to foundries that process non-ferrous metals such as aluminium and also to steel mills, which are large users of cast iron. Further development of the research could also come from the use of questionnaires, aimed at the quantification and greater generalization of the evidence reported here. Through the use of the questionnaire, the research could be extended to the majority of foundries, dividing them by territory of origin, type of metal used, type of smelting plant and size of the company, in order to compare the results and deepen the resilience strategies adopted. Indeed, it would be scientifically relevant to use this thesis for the purpose of probing research fertility within an under researched field. This thesis could be exploited as pilot research to provide the "how" of a complex phenomenon, while subsequent questionnaires could investigate the "who", "where" and "how many".

In conclusion, it would be interesting to further investigate a detail that emerged recurrently in the background of the interviews. Although all foundry managers declared that they have overcome the disruption of the pig iron supply chain following the Russian-Ukrainian conflict, all of them expressed concern about the long-term future due to the ambiguous link between their sector and the ecological transition. In other words, the concern of the foundries derives from the incompatibility of the processes that are upstream of the supply chain with the objectives of the ecological transition imposed by the European Union. In fact, the European production of cast iron has been practically eliminated due to the excessive polluting emissions resulting from the process of extraction and production of cast iron. This factor, combined with the distance from the other world producers of cast iron and the poor quality of their minerals, places a sword of Damocles on the head of the foundries, which in the event of an indefinite stop of Russian supplies would find themselves in serious difficulty. In fact, given the incompatibility of the current cast iron production process with the objectives of the ecological transition, if there were no disruptive technological developments in the production process aimed at reducing emissions and Russia ordered a stop to supply, the foundries would find themselves totally without raw material. In this sense, it would be useful to investigate which solutions are being explored within the steel sector to overcome this long-term problem which is nonetheless so strategic for the economy.

Appendix

Macro-risk factors	Micro-risk factors					
	Demand risk factor	Manufactoring risk factors	Supply risk factors	Infrastructural risk factors		
				Information risk factors	Transportation risk factors	Financial Risk Factors
•Natural disaster •War and terrorism •Fire accidents •Political instability •Economic downturns •External legal issues •Sovereign risk •Regional instability •Government regulations •Social and cultural grievance	•Inaccurate demand forecasts •Serious forecasting errors •Bullwhip effect or information distortion •Demand uncertainty •Sudden shoot-up demand •Demand variability •Customer fragmentation •High level of service required by customers •Customer dependency •Deficient or missing customer relation management function •Short lead times •Short products' life cycle •Competitor moves •Competition changes •Market changes •High competition in the market •Low in-house production •Order fulfilment error	•Labor disputes/strikes •Employee accidents •Operator absence •Lack of experience or training •Working conditions •Product obsolescence •Inventory holding cost •Inventory ownership •Lean inventory •Production flexibility •Production capabilities/capacity •Technical/knowledge resources •Engineering and innovation •Shorter lifetime products •Warehouse and production disruption •Insufficient maintenance •Instable manufacturing process •Centralized storage of finished products •Design changes •Technological change	•Inability to handle volume demand changes •Failures to make delivery requirements •Cannot provide competitive pricing •Technologically behind competitors •Inability to meet quality requirements •Supplier bankruptcy •Single supply sourcing •Small supply base •Suppliers' dependency •Supply responsiveness •High-capacity utilization ay supply source •Global outsourcing •Narrow number of intermediate suppliers •Lack of integration with suppliers •Lack of suppliers' visibility •Supplier management •Supplier market strength •Supplier opportunism •Monopoly •Selection of wrong partner •Transit time variability •Contractual agreements •Low technical reliability •Supplier fulfilment errors •Sudden hike in costs	•Information infrastructure breakdown •System integration or extensive systems networking •E-commerce •Information delays •Lack of information transparency between logistics and marketing •Internet security •Lack of compatibility in IT platforms among supply chain partners	•Excessive handling due to border crossings or change in transportation modes •Lack of outbound effectiveness •Transport providers' fragmentation •No transport solution alternatives •On-time/on-budget delivery •Damages in transport •Accidents in transportation •Maritime pirate attack •Remote high-way theft •Stress on crew •Lack of training •Long working times •Negligently maintenance •Old technology •Transportation breakdowns •Port strikes •Global sourcing network •Supply chain complexity •Port capacity and congestion •Custom clearances at ports •Paperwork and scheduling •Higher costs of transportation	•Exchange rate •Currency fluctuations •Interest rate level •Wage rate shifts •Financial strength of customers •Price fluctuations •Product cost •Financial and insurance issues •Loss of contract •Low profit margin •Market growth •Market size •Lead time for internal processing and the timing of its related cash outflows •Credit periods for accounts receivable to its customers and the pattern of early collection of accounts receivable •Credit periods for accounts payable from its suppliers and the pattern of early payment of accounts payable

Source: (Ho, Zheng, Yildiz, & Talluri, 2015)

INTERVIEW SUMMARY TABLE 1/2

	Zanardi Fonderie S.p.A.	ZML Industries S.p.A.	EF Group: Fonderia di Torbole S.r.l. + Pilenga Baldassarre S.r.l. + Fond Stamp S.p.A	Fonderie Guido Glisenti S.p.A. + Fonderia Lead Time S.p.A.
Interviewed	Fabio Zanardi: CEO of Fonderia Zanardi and President of Assofond	Alberto Valduga: Energy & Raw Material Purchasing Manager	Maurizio Nicolosi: Purchasing Manager	Marco Vangi: Purchasing Manager
Interview Date	19/01/2023	20/01/2023	24/01/2023	24/01/2023
Headquarter	Minerbe (VR), Italy	Maniago (PN)	Torbole Casaglia (BS)+ Lallio (BG) + Rocca De Baldi (CN)	Villa Carcina (BS) + Caldarola (Macerata)
Type of Production	Ductile iron + Austempered ductile iron between 1-120 kg	Grey or ductile iron castings from 0.3kg to 21kg	Grey iron castings – raw, machined and coated	Ductile Iron + High Silicon Ductile Iron + Austempered Ductile Iron between 0.3 e 75 kg.
Production/Year	Medium size, about 18.500 tons.	50.000 tons only for pig-iron.	100.000 Tons (Torbole) + 25.000 tons (Pilenga)	30.000 tons.
N. Employees	About 240	About 500	About 450 (Torbole) + 100 + 80	
Product	Agriculture, energy, railways, forestry, industrial, earthmoving and mining, off-road vehicles, on-road vehicles.	automotive cast iron, compressor cast iron, mechanical cast iron,	Solid, vented brake discs and drums for passenger cars, Flywheels and other castings, Brake discs for light commercial and heavy industrial vehicles + transmissions, valves, agriculture + sheet metal	Automotive + Earth Moving Machinery + Agricultural Sector + Industrial Vehicles
Furnace Type	electric induction furnace	Just switched to electric induction furnace	Dome Furnace (Torbole) + electric induction furnace	electric induction furnace
Interview Time	45 min.	45 min.	60 min.	60 min.

INTERVIEW SUMMARY TABLE 2/2

	Fonderie De Riccardis S.r.l.	Compagnia delle ghise S.r.l.	Fonderie Palmieri S.p.A.
Interviewed	Stefanizzi: Financial Area	Francesco Carpaneto: cast-iron trader	Jens Hartmann: Managing Director
Interview Date	25/01/2023	24/01/2023	30/01/2023
Headquarter	Soleto (LE)		Calenzano (FI)
Type of Production	Castings in grey and ductile iron		Gray Iron, Nodular Iron, Vermicular Iron, SiMo, Silicon Iron, Austempered Iron (ADI) and more.
Production/Year	8.000 tons/year		14.680 tons/year
N. Employees	About 90		150
Product	sectors of axles and transmissions, reducers, tractors, pumps and hydraulic cranes		Compressors, Engines, Movement of water and fluids, Construction and agricultural machinery 1-300 kg
Furnace Type	Dome Fornace, investments for switching to an electric induction furnace		electric induction furnace
Interview Time	35 min.	45 min.	30 min.

FRAMEWORK INTERVISTA

- Le volevo ricordare che la tesi pone 3 principali ipotesi, pertanto, l'intervista verterà sui riscontri empirici che lei potrebbe fornire riguardo a queste 3 ipotesi:

-H1: il conflitto Russo-Ucraino ha generato uno sconvolgimento a monte della filiera della ghisa, che a sua volta ha rappresentato un rischio di approvvigionamento per le fonderie italiane di ghisa.

Per quanto riguarda lo sconvolgimento (detta anche disruption) a monte della filiera della ghisa, essa viene definita nella letteratura come "eventi non pianificati e imprevisti che interrompono il normale flusso di merci e materiali all'interno di una catena di approvvigionamento e, di conseguenza, espongono le imprese all'interno della catena di approvvigionamento a rischi operativi e finanziari".

- Pertanto, le volevo chiedere innanzitutto: posso registrare la videochiamata? Ovviamente non verrà pubblicata da nessuna parte e verrà utilizzata unicamente ai fini didattici di questa tesi.
- Inoltre, sempre per la privacy, preferirebbe che non citassi il suo nome e quello della sua azienda in modo tale da rimanere anonimi?
- Passando invece alle domande, vorrei gentilmente chiederle anzitutto la sua fonderia cosa produce nello specifico, di quanti dipendenti disponete e più o meno quanto producete in media?
- Di quanti fornitori disponete per la ghisa? Sono produttori o trader? Qual è la loro provenienza e dimensione? E che tipo di ghisa utilizzate?
- Attraverso quale canale principale arrivano le vostre merci?
- Quali problematiche di approvvigionamento della ghisa ha riscontrato a partire dal 24 febbraio? Vi è stato un cambiamento avverso nell'ambiente esterno all'azienda? (utile per H2)
- Ha pesato maggiormente l'allungamento dei tempi di consegna, il rialzo dei prezzi della materia prima, l'aumento dei costi del trasporto o la difficoltà di reperimento delle materie prime (interruzione fornitura)?
- Le faccio questa domanda solo come complemento alla precedente: Ha riscontrato alcuni di questi fattori di rischio nel suo contesto? fallimento dei fornitori, approvvigionamelo unico, piccola base di approvvigionamento, dipendenza eccessiva da fornitori, global outsourcing, numero ristretto di fornitori intermedi, mancanza di visibilità dei fornitori, eccessivo potere di mercato del fornitore, monopolio del fornitore, variabilità del tempo di transito, improvviso aumento dei costi delle materie principali, improvviso aumento dei costi di trasporto

- *H2: A causa del conflitto Russo-Ucraino, le fonderie italiane di ghisa operano in un ambiente ambiguo.*

- Quale è lo stato delle informazioni ricevute durante questo periodo e tramite quale canale le avete ricevute? Le informazioni ricevute erano assenti del tutto, incomplete, confliggenti, inaffidabili o confuse?
- Durante il periodo dallo scoppio del conflitto ad oggi, le informazioni che avete ricevuto sono state sufficienti per potervi comportare di conseguenza??
- Gliela pongo sotto una prospettiva leggermente differente, le informazioni vi hanno consentito di valutare o stimare l'impatto che il conflitto avrebbe avuto sulla vostra supply chain (evaluative)?
- Vi hanno consentito di stimare a grandi linee le probabilità di un'interruzione totale delle forniture?
- Lo stato delle informazioni ricevute possono aver generato ambiguità nella direzione della fonderia?

- *H3: La terza ipotesi necessita di una premessa, e questa premessa è che le fonderie italiane di ghisa sono collegate in un network complesso e dinamico, pertanto, quando poste di fronte allo sconvolgimento della catena*

di approvvigionamento esse hanno la capacità di adattarsi e ristrutturare le connessioni, mostrando quella che viene definita resilienza.

Dunque, l'ipotesi H3 è che: di fronte allo sconvolgimento della catena di 'approvvigionamento causata dal conflitto Russo-Ucraino, le fonderie italiane si sono adattate ristrutturando le connessioni e costruendo resilienza.

- Alla luce di questo, quali strategie avete implementato in risposta al contesto ambiguo nel quale vi siete trovati ad operare?
- Inoltre, supponendo di poter dividere le strategie di mitigazione del rischio di approvvigionamento lungo le due dimensioni attivo/reattivo e interno/esterno, la domanda che vorrei porle è: quali strategie avete implementato in risposta al contesto ambiguo nel quale vi siete trovati ad operare? Per Interno ed esterno intendo relativamente ai confini dell'azienda, ovvero pratiche implementate per mitigare il rischio di approvvigionamento all'interno dell'azienda oppure esterne ai confini di essa, magari integrando o beneficiando di azioni o aziende esterne alla vostra. Mentre per strategie reattive intendo quelle mirate alla ristrutturazione del network di approvvigionamento in risposta all'interruzione o sconvolgimento da parte di un fornitore diretto, quindi ex post, mentre per strategie proattive intendo quelle mirate alla salvaguardia o ristrutturazione del network di approvvigionamento dopo aver osservato un interruzione distante dalla vostra ma che potrebbe interessarvi in futuro. In poche parole, le prime sono strategie usate dopo il fallimento di un fornitore primario mentre queste ultime riguardano le strategie per l'anticipazione di una possibile disruption nella catena di approvvigionamento.
- Siete stati in grado di sostituire i fornitori?
- Se si, qual'e la loro provenienza e la qualità delle forniture?
- Se si, in quanto tempo?
- È stata necessaria la chiusura dell'attività durante il periodo più difficile dello shock?
- Eravate in qualche modo preparati ad un tale shock? Avevate delle strategie preventive in risposta agli shock da parte dei fornitori? (magari ridondanza dei fornitori o nell'inventario oppure recovery practices, scansione dell'ambiente circostante)
- Quanto siete flessibili nella scelta dei fornitori? In altre parole, siete stati in grado di integrare, costruire e riconfigurare le competenze interne ed esterne per far fronte a circostanze in rapida evoluzione?
- Qual è lo stato operativo e finanziario attuale della fonderia?
- Qual è l'indicatore dello stato dell'azienda (performance) al quale dà priorità? Livelli di produzione, qualità della produzione, costi di produzione, tempi di consegna ai clienti
- Dato che la resilienza di un azienda viene definita come l'abilità di tornare al livello originale o desiderato delle prestazioni delle operazioni di produzione dopo l'interruzione causata da un imprevisto incidente della catena di approvvigionamento a monte, siete riusciti a ritornare ai livelli "normali" di produzione nell'indicatore/dimensione che ha indicato precedentemente?
- Inoltre, le volevo chiedere se quello che ci siamo detti finora è in qualche modo generalizzabile per le altre fonderie. In altre parole, il contesto nel quale vi siete trovati ad operare e le strategie implementate dalla sua azienda per farvi fronte, sono specifiche della sua azienda oppure in qualche modo rappresentano la categoria in generale?
- Sa se per caso tali dinamiche si sono verificate anche in altri settori, come per esempio quello dell'acciaio??

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Summary

As sadly confirmed by the recent covid-19 pandemic, supply chain disruptions represent a real danger for the survival of commercial activities and sometimes even of entire production categories. According to (Mentzer, et al., 2001), a supply chain is very broadly defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer (Tarver, 2022). Therefore, supply chain disruptions are unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain and, as a consequence, expose firms within the supply chain to operational and financial risks (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007).

Recent history is not new to supply chain disruptions, in fact they can be caused by a variety of factors, including natural disasters such as the 2011 earthquake in Japan, logistic delays and failures such as the blockade of the Suez Canal in 2021, pandemics such as Covid-19 and many others. But before entering into the heart of the thesis, it is necessary a brief recapitulation of the literature from which it arises and on which it is built on.

It was only 1958 when Forrester introduced a theory of distribution management that recognized the integrated nature of organizational relationships. In that year, Forrester enunciated the principle according to which companies are so intertwined that system dynamics can influence the performance of functions such as research, engineering, sales, and promotion (Mentzer, et al., 2001).

Later in his paper, the author proposed that "there will come general recognition of the advantage enjoyed by the pioneering management who have been the first to improve their under-standing of the interrelationships between separate company functions and between the company and its markets, its industry, and the national economy" (Forrester, 1958, p. 37). Through this sixty-year-old quotation, Forrester precisely identified the phenomenon that was later defined by the literature as Supply Chain Management (SCM).

Starting around the end of the century, in the wake of examples of companies that have achieved resounding successes such as Dell, Walmart and Amazon, the mentality of managers began to change, seeing the purpose of supply chain management not only as a cost driver, but as a source of competitive advantages, therefore forcing companies to always find new ways to stabilize, control and coordinate the flow of materials.

In other words, the competitiveness of international companies has increasingly been linked to their ability to deliver customized products quickly and timely all over the world. Accordingly, competition is no longer just between firms at the same level in the production process, but today we are witnessing a competition between supply chains, from raw materials to customers (Jespersen & Skjott-Larsen, 2005).

On other hand, recent history is full of examples of supply chain disruptions that have impacted the performance of companies. For example, due to a fire at a Phillips semiconductor plant in 2000, Ericsson

production was disrupted costing the company $400 million in losses. In the wake of these catastrophic events, both scholars and practitioners have undertaken a series of studies aimed at controlling and mitigating the negative effects caused by risks and disruptions in the supply chain, leading to the emergence of the field of study called Supply Chain Risk Management (SCRM).

Numerous journal articles reviewing the literature in the field of SCRM have been published in the last thirty years. Among them we can mention Tang C. S. (2006), who reviewed more than 200 journal articles published between 1964 and 2005 and classified them into four categories: supply management, demand management, product management, and information management for managing supply chain risks. On the other hand, Rao & Goldsby (2009) reviewed 55 published between 1998 and 2008, thus developing a typology of risk factors, including environmental, industrial, organizational, problem-specific, and decision-maker related factors.

Since there was no consensus on what exactly is meant by SCRM, Ho, Zheng, Yildiz, & Talluri (2015) proposed the following definition: "an inter-organizational collaborative endeavour utilizing quantitative and qualitative risk management methodologies to identify, evaluate, mitigate, and monitor unexpected macro and micro level events or conditions, which might adversely impact any part of a supply chain" (Ho, Zheng, Yildiz, & Talluri, 2015, p. 5). In addition, the literature on SCRM has provided several qualitative and quantitative methods to manage supply chain risks. Despite fundamental disagreement about the assessment and the validity of the different methods, the majority of authors in the field agree on the general framework which identifies four main phases of SCRM, namely: risk identification, risk assessment, risk mitigation, and risk monitoring.

Therefore, the ability to restructure the supply chain in the face of changing conditions (disruptions and supply risks) is critical to maintain continuity of supply chain performance. Thus, beyond understanding how managers might work to prevent disruptions through risk management, it must be better understood how managers respond to and recover from the supply chain disruptions they experience (Macdonald & Corsi, 2013). Therefore, this thesis fits fully into the wake of the SCM literature, touching on topics dear to the SCRM literature and the restructuring of Supply Chains.

Starting from February 24th, the invasion of the Ukrainian territory by the Russian Federation is threatening to generate a new supply-chain disruption. This time, unfortunately, the terrible consequences in terms of human lives add up to the economic ones. Since both countries are major suppliers of raw materials, the destruction of Ukraine, combined with the economic sanctions imposed by most Western countries on Russia and the naval blockade of the Black Sea, have severely affected global markets. According to Wuester & Winkler (2022), what makes Russia and Ukraine so important within the international economy is that they mainly export primary and intermediate goods used in other countries' exports at an early stage of production (energy, metals, chemicals, corn, wheat). Therefore, the countries are clearly marked by high forward GVC

participation or 'upstreamness' (Wuester & Winkler, 2022).

Although in absolute economic terms the two warring countries cannot be defined as great powers, disruptions of Russian and Ukrainian exports will especially affect regional economies that are highly dependent on these specific supplies. Among the latter, the Italian cast iron supply chain deserves special consideration since its supply of cast iron comes almost entirely from the two warring countries, which in 2021 jointly represented the 81% of the Italian cast-iron imports (Assofond, 2022).

Indeed, cast iron exports are dominated by three countries (Russia, Brazil, and Ukraine), together accounting for over three-quarters of global exports. Hence, replacing pig iron imports from Russia and Ukraine would be much more difficult than products for which the global market is less concentrated. From this point of view, pig iron represents for Italy an emblematic case of dependence on foreign supplies and therefore of strong exposure to supply risk in the event of disruptions along the supply chain.

Among the categories most exposed to a potential disruption of the cast iron supply chain is certainly the sector of Italian foundries, and in particular those that produce cast iron since this is the basic material to produce their castings. Foundry products play a role of fundamental importance within the economy and society, in fact, they are destined for a very broad market that ranges from a variety of sectors including automotive, various mechanics, construction, street furniture, aerospace, electricity production, household appliances, art and design (Porru, Arici, & Corelli, 2017).

The Russian-Ukrainian military crisis has completely changed the scenario and threatens to have a heavy impact on the economy of the cast-iron foundries (Assofond, 2022). The reaction of the markets to the war was indeed severe and very rapid: the prices of pig iron showed significant growth, while those of electricity doubled reaching 700 euro/MWh (about 6 times the prices of 2021 and 18 times those of 2020) on 8 March 2022 (Assofond, 2022). In addition to the tsunami in prices and in the light of the above premise, the other consequence, perhaps even more tragic for the cast iron foundry sector given the very strong dependence on the procurement of raw materials, was the cancellation of supplies of cast iron from Ukraine and Russia (Assofond, 2022).

Therefore, building on the literature on Supply Chain Management (SCM), Supply Chain Risk Management (SCRM) and Supply Chain Restructuring, the focus of this paper has been on the disruption and restructuring of the supply chain of Italian cast iron foundries following the Russian-Ukrainian conflict.

The research question at the center of this thesis directly stems from the SCM literature and the considerations above-mentioned**:** *How did the Italian foundry pig iron supply chain respond to the shock of the Russian-Ukrainian conflict? How and through what strategies did they resist the supply chain disruption?* By using a multiple case study methodology, the focus of this paper has been mainly on the disruption and restructuring of the supply chain of Italian cast iron foundries, both trying to understand how the industry is moving overall at a macro level, which solutions they are adopting as a category, and analysing their effects

at a micro level through semi-structured interviews with six managers who run the supplies of nine cast iron foundries. Thus, the research focuses both on how the industry and the supply chain are restructuring, and on the heterogeneity of the business strategies adopted by individual foundries.

Most of the leading companies deal with this range of supply-chain risks by holding reserves, which usually includes excess inventory, excess capacity and redundant suppliers. Overcoming the "classic" prescriptions mentioned above and by adopting a vision of the supply chain as a complex adaptive system (CAS), in the face of a supply disruption companies connected in a complex network can adapt and restructure their connections. In this case, the CAS framework provides a useful theoretical foundation as firms in a supply chain operate as an interconnected network in a dynamic environment. In such environment, even a small change at one node in the chain can cause a disruption to spread throughout the supply chain. Positing that firms in a supply chain constitute self-organizing networks, several authors have argued that some supply chains can be adaptive or resilient. This means that when hit with a disruption, they can adapt or restructure themselves to reach a desirable state which can be back to the original state, an equivalent state, or a better state (Zhao, Zuo, & Blackhurs, 2019).

From CASs perspective, when facing a disruption, the ability of companies to adapt and restructure is critical for minimizing the losses. As I said, in recent years the concept of resilience to supply chain disruptions has been frequently explored, however without incorporating the concept of CAS. In other words: "understanding how disruptions impact multiple tiers in a supply chain and how the structure of the network may play a role in this impact is lacking" (Zhao, Zuo, & Blackhurs, 2019, p. 191). Therefore, this thesis aims to add a further piece of knowledge on how interconnected companies behave within a complex network in the face of a supply disruption. Through the interview of supply chain managers operating within Italian cast iron foundries, it is possible to examine their resilience and the effect of adaptive behaviours in real-world supply chain networks.

According to Robert Yin: "A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2009, p. 47). Therefore, the research question will be explored using a multiple case-study design, where the units of analysis are represented by nine Italian cast iron foundries, which were first identified and then studied through semi-structured interviews aimed at verifying the following three hypotheses:

- ***(H1)**: the Russian-Ukrainian conflict has generated an upstream disruption within the cast iron supply chain, which in turn has represented a supply risk for the Italian cast iron foundries.*
- ***(H2)**: Due to the Russian-Ukrainian conflict, Italian cast iron foundries are operating in an ambiguous environment.*
- ***(H3)**: In the face of the supply disruption caused by the Russian-Ukrainian conflict, foundries have*

adapted by restructuring connections and building resilience.

Thanks to the methodological flexibility guaranteed by the case study design, the evidence gathered through the semi-structured interviews has also been triangulated with the data present in the database of Assofond, the association of Italian foundries.

These hypotheses, besides reflecting the important theoretical issues from which they arose, also told us where to look for relevant evidence. More specifically, hypothesis H1 requires to evaluate whether the disruption in the cast iron supply chain has actually occurred and what impact it has generated on companies. Furthermore, to operationalize the two concepts of "upstream disruption" and "supply risk" I've taken into account the parameters provided by Chopra & Sodhi (2004), according to which a supply disruption can be operationalized through two main parameters: 1) "Supplier of a key part shuts down plant for a month or at a key part of the production cycle, 2) "Supplier capacity drops by 20% overnight" (Chopra & Sodhi, 2004, p. 57). As regards the concept of supply risk, referred to by the authors as procurement risk, in order to be realized it must meet at least one of three conditions: 1)"Supplier delays in processing returns by twice as long" 2)"Supplier forced to increase price of key components by 20% " 3)"Transportation costs go up 20% overnight" (Chopra & Sodhi, 2004, p. 57).

According to Gunessee and Subramanian (2020) "ambiguity is the imprecision involved in situations when the decision-maker is making a judgement, assessment or forecasts. Thus, ambiguity can be defined as situations or events whose outcomes and likely occurrence are unclear and cannot be coded with precision" (Gunessee & Subramanian, 2020, p. 1203). Therefore, the second hypothesis directly addresses the question of the state of the information received by the units of analysis since the outbreak of the war, in order to evaluate whether and what type of ambiguity has been encountered by the foundries in the period in question. This feedback has taken place thanks to a series of questions formulated to the interviewees aimed at assessing the awareness of the situation that the Italian foundries have developed over the period.

The third and last hypothesis instead required the analysis of the strategies adopted by foundries in the face of the conflict and the assessment of their impact on company performance. This will again has taken place through a series of questions posed to the interviewees aimed at identifying the strategic practices implemented by the foundries and also through the triangulation of the data provided by the Assofond database. The ultimate goal here has been to find out whether Italian cast iron foundries have built and shown resilience during the period in question.

In relation to my first hypothesis (H1), the evidence gathered through the semi-structured interviews confirmed that the Russian-Ukrainian conflict has generated an upstream disruption in the cast iron supply chain. Since the cast iron foundries used to procure raw materials entirely from the two warring countries, this disruption affected the entire supply chain for about two months, while later it was possible to observe a recovery in the arrivals of cast iron of Russian origin, however at irregular intervals and made difficult by

sanctions. On the other hand, the blockade of Black Sea ports and the physical destruction of Ukrainian producers has completely side-lined the country in pig iron exports. In addition, South Africa and Brazil come from a period of low demand and do not have sufficient availability to meet the entire global demand for pig iron.

This upstream destruction in the cast iron supply chain has also been magnified by a series of risk factors which in turn have exposed the Italian cast iron foundries to a supply risk. First of all, an excessive dependence on suppliers has been empirically found for a series of elements that refer to both the supply and the demand side. On the other hand, a series of risk factors emerged from the semi-structured interviews which further contributed to the exposure to supply risk, namely small supply base, global outsourcing, narrow number of intermediate suppliers, lack of supplier's visibility, supplier market strength, supplier opportunism, monopoly power, transit time variability, supplier fulfilment errors and sudden hike in costs. Therefore, my first hypothesis has been fully verified.

Moving on to the second hypothesis, according to Gunessee & Subramanian (2020) what generates ambiguity on the organizational side is the complexity of the supply chains. In this case, the validation of the first hypothesis (H1) presupposes and implies in itself the supply chain complexity factors described by Gunessee & Subramanian (2020). However, according to the authors, the necessary element to configure the ambiguous environment, empirically investigated through the interviews, is represented by the state of the information received by the foundries in the periods surrounding the outbreak of the conflict.

In this case the evidence was multiple and not always consistent. In fact, some managers interviewed reported different degrees and types of ambiguity related to different issues, while for others the situation was rather clear. In conclusion, although most of the managers have indicated some kind of ambiguity, generally evaluative or probabilistic in nature and concerning both the impact of sanctions and the conflict itself, my second hypothesis is only partially verified since the evidence is mixed. Indeed, it was not possible to identify one type of ambiguity found by all the foundries, even though most of them suffered from a lack of information. Therefore, although from the organizational point of view the complexity of the supply chain was confirmed, the evidence provided by the foundries are not consistent and thus sufficient to guarantee the validation of the hypothesis (H2).

The evidence gathered through the semi-structured interviews confirm my third and last hypothesis (H3). Indeed, the disruption of the cast iron supply chain generated by the Russian-Ukrainian conflict has caused unexpected changes in the flow of goods (disruption) and, through the interview of foundries' managers, it has been possible to examine their company resilience and the effect of their adaptive behaviour. Moreover, I argued that thanks to the strategies implemented by the managers, mainly to the reduction of cast iron in the metal charge and to the purchases made from the new promptly configured supply channels, combined with the additional mitigation practices mentioned, the Italian foundries have managed to keep the

production levels high until the arrival of the summer, period in which the supply channels from Russia appear to have been reconfigured. Following Zhao, Zuo, & Blackhurs (2019), flows of materials within the supply chain network need to be redirected and structures need to be adapted to allow for continuity in operations, and this was just what the Italian cast iron foundries did. In fact, in the face of a supply disruption, the foundries connected in a complex network were readily able to adapt and restructure their connections according to the availability of material. As we have seen, the production structures and techniques were also promptly reconfigured. When they were hit by the Russian-Ukrainian disruption, they adapt or restructure themselves to reach a desirable state which is for most of them an equivalent or better state to the previous one. Through the mitigation strategies described above and the reconfiguration of both the structures and the supply channels, all the managers interviewed declared that they had concluded an overall satisfactory year from the point of view of corporate performance.

If, according to Dabhilkar, Birkie, & Kaulio (2016), supply-side resilience can be defined as "the capability of a buying firm to prepare for, respond to and recover from unexpected upstream supply chain disruptions by returning to, or maintaining continuity of, operations at the desired level of connectedness and control over structure and function" (Dabhilkar, Birkie, & Kaulio, 2016, p. 949), it is possible to argue the Italian cast iron foundries have been exemplary in showing and building resilience, validating my third hypothesis (H3).

The structure of the thesis has been the following: the first chapter is dedicated to the literature review, following the evolution of the concept of Supply Chain, Supply Network, and Complex Adaptive System. Furthermore, this chapter reviewed the main contributions in the field of Supply Chain Management, Supply Chain Risk Management, Supply Chain ambiguity and the concepts of Supply Chain Resilience and Supply Chain Restructuring. In this chapter, the three hypotheses arising from the literature, and which inform this thesis, has also been presented and argued.

The second chapter instead has been dedicated to the practical presentation of the Italian cast iron supply chain. Starting from the fundamentals of the Russian-Ukrainian conflict and the consequent destruction of the supply chains that referred to these two countries, I gradually tried to narrow down the focus by first analysing the Russian and Ukrainian market and trade relations, then the specific bilateral ones with Italy in order to highlight the extreme dependence that it suffers from the two warring countries. The third paragraph of the chapter instead has performed the function of underlining the social and economic importance of the Italian foundry sector. The fourth and final paragraph has dealt with the specific vulnerabilities of this sector in light of the conflict.

Moving on to the third chapter, this has been dedicated to the research methodology, highlighting the typical characteristics of the case study methodology and explaining the reasons for this choice. The second paragraph of this chapter explained in detail the research design of this thesis, while in the third the main

limitations and strengths of the case study have been exposed.

The fourth chapter has therefore been dedicated to the analysis and discussion of the evidence obtained from the semi-structured interviews. The chapter is divided into three paragraphs corresponding to the three different hypotheses raised. Lastly, in the conclusion I've tried to summarize what has been done, highlighting both the evidence obtained and the major limitations of the thesis. Particular attention has been devoted to the exploration of future analytical paths to follow in order to deepen the theme and which have not been carried out here due to space problems.

This thesis aimed to provide a double contribution, both to the literature on SCRM, integrating the concept of Complex Adaptive Systems to understand how the structure of the network may play a role in the propagation of disruptions along the supply chain, and to the business community, examining the resilience of the Italian foundry sector and the effect of adaptive behaviours in real-world supply chain networks.

In fact, from a purely theoretical point of view, within an increasingly interconnected world, but also increasingly subject to market disruptions and volatility, this thesis demonstrates the importance of conceptualizing the business community and the surrounding environment as a Complex Adaptive System and no longer through a linear representation of the concept of Supply Chain. As highlighted by the thesis, companies are immersed and interact in a dynamic and interconnected environment, which can undergo sudden changes also due to stimuli external to the environment. Within this ecosystem, and hence the practical contribution of this thesis, the ability of companies to interact with each other and with the external environment is of fundamental importance for their success. This ability to act required by today's market goes through not only a simple reactive ability to adapt to adverse changes in the surrounding environment, but above all requires foresight, scouting and continuous monitoring of the system in which they are immersed in order to identify such critical issues and exploit them to gain a competitive advantage.

As demonstrated by Italian foundries, within today's market, characterized by strong competition but also volatility and rapid changes, resilience has become a necessary quality for companies. By building resilience, companies faced with a negative shock are able to identify the critical point within the network and more or less quickly reconfigure their connections, overcoming the difficulty and returning to a state that can be the same, similar or even better than the previous one. However, without an adequate theoretical conceptualization of the ecosystem in which productive activities are inserted, the practical contribution of this thesis would have been meaningless.

Furthermore, it was thanks to the case study design that it was possible to highlight the importance of the concept of resilience and adaptability of companies, once again confirming the usefulness and practicality of the methodology. In fact, given the multiplicity of variables involved, in this case the writer had no degree of control over the events and behaviours analysed. However, thanks to the long semi-structured face-to-face interviews with the managers of the foundries and the triangulation with Assofond data, I managed to deepen

the details that characterize a complex social phenomenon whose understanding required the analysis of important contextual conditions highly pertinent to the phenomenon of study, which in turn require a comprehensive but flexible methodology.

Despite the practical and theoretical contribution of this thesis, like all empirical research, it is not without limitations. As reported in the third chapter, some limitations derive from the methodology employed. In addition to those highlighted by the methodological debate in the literature, a specific limitation of this research was found in the collection of evidence related to my second hypothesis (H2). In this case it could be argued that in the assessment of the ambiguity in which the foundries found themselves at the outbreak of the war, some variables intervene that were not taken into consideration by the study, such as for example the minor or major inclusion of the foundry in a system of relationships that guaranteed the reliability of the information. In fact, depending on the various traders to which the foundries have entrusted themselves and the relationship system in which the foundries are inserted, it seems that the various information has been passed on in a different way.

Furthermore, the difficulty in validating the hypothesis (H2) could derive from a deficit in the interview framework, which was not rigorous in identifying ambiguity through the questions posed. In addition, investigating ambiguity with precision probably requires a greater depth in the questions and in the explanation of the same to the interviewee. Therefore, although it is outside the field of study of this thesis, it would be interesting to analyse the relationship that exists between the relational system in which the various foundries are inserted and the degree of ambiguity to which they are subject.

Someone can argue that another limitation, this time typical of the case study but heuristically relevant, is represented by the fact that we cannot make causal inferences from case studies because we cannot rule out alternative explanations. This limitation has raised perplexity in the debate on the case study methodology regarding the generalization of the result obtained. In this sense, case studies may be suggestive of what may be found in similar organisations, but additional research would be needed to verify whether such findings can be generalized elsewhere. This limitation necessarily afflicts this thesis as well, in the sense that the evidence gathered can be generalized only to the Italian cast iron foundry sector.

For this reason, it would be interesting to extend the study also to foundries that process non-ferrous metals such as aluminium and also to steel mills, which are large users of cast iron. Further development of the research could also come from the use of questionnaires, aimed at the quantification and greater generalization of the evidence reported here. Through the use of the questionnaire, the research could be extended to the majority of foundries, dividing them by territory of origin, type of metal used, type of smelting plant and size of the company, in order to compare the results and deepen the resilience strategies adopted. Indeed, it would be scientifically relevant to use this thesis for the purpose of probing research fertility within an under researched field. This thesis could be exploited as pilot research to provide the "how" of a complex

phenomenon, while subsequent questionnaires could investigate the "who", "where" and "how many".

In conclusion, it would be interesting to further investigate a detail that emerged recurrently in the background of the interviews. Although all foundry managers declared that they have overcome the disruption of the pig iron supply chain following the Russian-Ukrainian conflict, all of them expressed concern about the long-term future due to the ambiguous link between their sector and the ecological transition. In other words, the concern of the foundries derives from the incompatibility of the processes that are upstream of the supply chain with the objectives of the ecological transition imposed by the European Union. In fact, the European production of cast iron has been practically eliminated due to the excessive polluting emissions resulting from the process of extraction and production of cast iron. This factor, combined with the distance from the other world producers of cast iron and the poor quality of their minerals, places a sword of Damocles on the head of the foundries, which in the event of an indefinite stop of Russian supplies would find themselves in serious difficulty. In fact, given the incompatibility of the current cast iron production process with the objectives of the ecological transition, if there were no disruptive technological developments in the production process aimed at reducing emissions and Russia ordered a stop to supply, the foundries would find themselves totally without raw material. In this sense, it would be useful to investigate which solutions are being explored within the steel sector to overcome this long-term problem which is nonetheless so strategic for the economy.