The Impact of International Sanctions on Supply Chains in the Portuguese Metalworking Industry

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Universidade do Minho
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Declaration of Integrity

I declare that I have acted with integrity in the preparation of this academic work and confirm that I have not engaged in plagiarism or any form of misuse or falsification of information or results at any stage of its development. I further declare that I am aware of and have complied with the Code of Ethical Conduct of the University of Minho.

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The Impact of International Sanctions on Supply Chains in the Portuguese Metalworking Industry

Abstract

Increasingly complex and globalised environments present significant challenges for organisations operating within interconnected supply chains. This is particularly relevant for firms exposed to international sanctions, which can act as major sources of disruption. While existing research has predominantly focused on the macroeconomic effects of sanctions, limited attention has been given to firm-level operational experiences and responses. Addressing this gap, this study examines the impact of international sanctions on supply chain dynamics and operational performance in the Portuguese metalworking industry.

Grounded in Resource Dependence Theory and Institutional Theory, the study proposes a conceptual model in which exposure to international sanctions, dependency on external suppliers, and institutional pressure act as antecedents of supply chain disruption. Supply chain disruption is further analysed in relation to operational performance and the adoption of mitigation strategies.

A quantitative research design was employed, based on primary data collected through a structured questionnaire administered to firms in the Portuguese metalworking industry, resulting in 46 valid responses. The data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) to assess both measurement and structural relationships in an exploratory context.

The results indicate that exposure to international sanctions has a positive and statistically significant effect on supply chain disruption. In turn, supply chain disruption significantly influences both the adoption of mitigation strategies and operational performance. Additionally, mitigation strategies were found to have a positive and significant effect on operational performance. In contrast, dependency on external suppliers and institutional pressure were not found to have statistically significant effects on supply chain disruption.

This study contributes to the literature by providing firm-level empirical evidence within a highly internationalised and externally dependent industry. It highlights the role of supply chain disruption as a key mechanism through which external shocks affect organisational outcomes and underscores the importance of proactive mitigation strategies in enhancing operational stability. The findings also offer practical implications for managers operating in geopolitically uncertain environments, emphasising the need for effective supply chain risk management and diversification strategies.

Keywords: International sanctions; Supply chain disruption; Operational performance; Mitigation strategies; PLS-SEM; Portuguese metalworking industry

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List of Abbreviations

AICEP – Agência para o Investimento e Comércio Externo de Portugal

AIMMAP – Associação dos Industriais Metalúrgicos, Metalomecânicos e Afins de Portugal

B2B – Business-to-Business

CAE – Classificação das Atividades Económicas

CBAM – Carbon Border Adjustment Mechanism

CRM Act – Critical Raw Materials Act

DPP – Digital Product Passport

ETS – Emissions Trading System

EU – European Union

FDI – Foreign Direct Investment

GDP – Gross Domestic Product

PLS-SEM – Partial Least Squares Structural Equation Modelling

RDT – Resource Dependence Theory

SCM – Supply Chain Management

SMEs – Small and Medium-sized Enterprises

REPowerEU – European Union Energy Transition Initiative

1. Introduction

1.1. Research Framework and Relevance

In the contemporary global landscape, international sanctions have emerged as key tools of economic diplomacy, used by political actors seeking to bring about behavioural changes in foreign jurisdictions (Meyer et al., 2023; Omokaro et al., 2025). Although traditionally perceived as macroeconomic instruments, these measures operate by causing structural shocks with persistent effects that fundamentally impact private companies, reverberating through value chains dispersed internationally (Fan et al., 2024; Imbs & Pauwels, 2024; Meyer et al., 2023).

For manufacturing sectors, sanctions represent a source of heightened uncertainty, as they can cause abrupt disruptions in the flows of materials, financial resources and information, whether firms are directly located in countries targeted by sanctions or indirectly affected through their integration in international supply chains (Roscoe et al., 2022; Shakeri et al., 2016; Shalpegin et al., 2023; Tang & Nurmaya Musa, 2011).

The Portuguese metallurgical and metalworking industry is particularly relevant in this context as it occupies a vulnerable position in this commercial climate, as Portugal has a limited upstream production capacity and is highly dependent on international trade, which may increase exposure to disruptions in an environment of trade restrictions (DN/Lusa, 2025; ECO, 2026).

Sector-specific sanctions often target this industry specifically, through bans on the export and import of iron, steel and high-tech production equipment (Belik et al., 2022; Cooper, 2024; Tavrikov & Yashalova, 2024). Furthermore, the industry faces dual pressure resulting from institutional mandates, including European Union regulations such as the Carbon Border Adjustment Mechanism (CBAM) and REPowerEU, which act as material constraints, potentially forcing companies to realign their logistics and supply strategies (Belik et al., 2022; Jiang et al., 2023; Liagkouras & Metaxiotis, 2023; Omokaro et al., 2025).

In this context, exploring the development of supply chain resilience and structural ambidexterity becomes particularly relevant, especially given the increasingly volatile and fragmented business environment (Moradlou et al., 2025). However, there remains limited empirical understanding of how firms develop and implement these capabilities.

By examining organisational preparedness and mitigation strategies, this research provides relevant insights for practitioners seeking to maintain competitiveness amidst constantly shifting geopolitical alliances (Bastani et al., 2021; Johnson & Haug, 2021; Roscoe et al., 2022; Shakeri et al., 2016).

In particular, it remains unclear whether Portuguese firms, operating in a peripheral and highly export-oriented economy, respond differently to international sanctions when compared to firms based in more central European economies, which may benefit from stronger industrial bases and more diversified supply networks. Prior studies have shown that there is an increased demand for more clearly defined methods to handle unexpected results caused by commercial pressure to third parties in the global supply chain (Shalpegin et al., 2023). This research therefore adopts an exploratory perspective in order to examine how these dynamics unfold in the context of the Portuguese metalworking industry.

1.2. Research Problem and Objectives

The significance of this study lies in the fact that much of the existing research focuses on aggregate macroeconomic indicators rather than on the micro-level mechanisms of impact at the firm level (Meyer et al., 2023; Omokaro et al., 2025; Shakeri et al., 2016).

Understanding how the Portuguese metalworking industry copes with these shocks is crucial. Prior research shows that supply chain disruptions can lead to increased production costs, delivery delays, and a significant erosion of operational performance (Ali et al., 2024; Qiao, 2024).

Given this gap, the study aims to examine the relationship between exposure to international sanctions, supply chain disruption, and its effects on operational performance in the Portuguese metalworking industry, while resilience is addressed from a theoretical perspective.

In this context, the research is guided by the following question**: To what extent does exposure to international sanctions lead to supply chain disruption and influence operational performance in the Portuguese metalworking industry?**

1.3. Structure of the Dissertation

The dissertation is organized into eight chapters, starting with the Introduction, which presents the research framework, outlines the relevance of the study, and defines the main objectives and research question.

The second chapter presents a review of the literature, addressing the key concepts related to international sanctions, supply chain disruptions, operational performance, institutional pressure and resilience, as well as the theoretical foundations of the study.

Then the third chapter focuses on the Portuguese metallurgical industry, providing an overview of the sector's context, its importance to the national economy and its exposure to international trade.

The fourth chapter develops the conceptual model, including the definition of constructs and the formulation of research hypotheses. Followed by the fifth chapter details the methodology adopted, including the research design, the population and the sample, as well as data collection and analysis techniques. Then the results obtained from the empirical analysis are presented at the sixth chapter.

At the seventh chapter, the results were discussed, relating them to the existing literature and highlighting their implications.

Finally, in the eighth chapter, the main conclusions and contributions of this research work are outlined, the limitations of the study and suggestions for future research.

2. Literature Review

This chapter presents the theoretical basis for this study by outlining the global context for imposing international sanctions and their effects on supply chain management. This chapter addresses international sanctions, supply chain management at risk from geopolitical factors, supply chain resilience, as well as the Resource Dependence and Institutional Theory that support the research framework.

It further considers how firms operate under geopolitical risk and the impact of European legislation on supply chain dynamics. The chapter concludes by outlining the theoretical links between the main constructs, which support the development of the research hypotheses.

2.1. International Sanctions and Economic Impact

International sanctions are defined as nonmilitary coercive measures imposed by a country, group of countries, or international organizations against a target, with the explicit aim of changing a specific behaviour or political policy (Ellis, 2021; Meyer et al., 2023). The target can take various forms, including countries, political entities, individuals, decision-makers, industries, and organizations (Meyer et al., 2023). These measures represent barriers to cross-border economic activities and impose costs on both the sender and the target (Gutmann et al., 2023; Wang et al., 2025). Nevertheless, the literature reveals significant divergence in how it defines both the scope and intent of sanctions, which can be organised into three main debates.

First, a fundamental divide exists between normative, ethical and strategic, institutional framings. Sanctions are conceptualized as distinct from war, defining them through the refusal to trade rather than through violence, with the rejection of the application of Just War Theory (Ellis, 2021). In contrast, sanctions can also be understood from a strategic institutional perspective rooted in international business, treating sanctions as deliberate disruptions to global business environments that reshape incentives, rules, and dependencies (Early & Peterson, 2023; Meyer et al., 2023).

The classification of sanctions is generally based on the sphere of economic activity that they restrict. Sanctions may take various forms, ranging from broad technological, economic, financial, and commercial measures to more specific actions such as arms embargoes, travel bans, and the suspension of digital services (Meyer et al., 2023; Wang et al., 2025). Furthermore, sanctions can be categorised according to their scope, typically distinguished as either comprehensive or “smart.” While

comprehensive sanctions target the economy as a whole, smart sanctions target specific persons, entities, or sectors (Ellis, 2021; Fu et al., 2022; Meyer et al., 2023; Shalpegin et al., 2023). Second, the literature diverges on whether sanctions are intended primarily to induce behavioural change or to impose material constraints. Bargaining models view sanctions as instruments designed to alter cost–benefit calculations and compel compliance (Fu et al., 2022; Kavaklı et al., 2020), whereas degradation-based approaches emphasize the direct weakening of economic or military capacity through restricted access to finance, technology, and industrial inputs (Meyer et al., 2023; Omokaro et al., 2025). The signalling role of sanctions, particularly towards domestic or third-party audiences, has also been emphasised (Özdamar & Shahin, 2021).

Trade sanctions involve the suspension of normal trading relations. These include export embargoes that restrict the export of certain goods, such as Russia's energy sales to Europe, as well as import bans that restrict the importation of specific goods, such as European products entering Russia (Ellis, 2021; Imbs & Pauwels, 2024). Product-based trade sanctions may affect the global activity of organizations by constraining productivity levels, while commodity trade sanctions may take the form of permanent bans or price ceilings set below marginal costs (Ghironi et al., 2025). Trade sanctions are also often identified as a contributing factor behind the negative influence on innovation in sender countries (Wang et al., 2025).

Financial sanctions include the withdrawal of normal financial business and the reduction of banking transactions (Ellis, 2021; Shakeri et al., 2016). These sanctions often target specific actors through asset freezes and denial of access to global bond markets and are considered damaging due to the difficulty of bypassing (Ellis, 2021; Ghironi et al., 2025; Gutmann et al., 2023; Meyer et al., 2023). Technological sanctions restrict access to critical technologies and related critical resources, for example, bans on technology transfer and the export of related equipment in sectors such as metallurgy and dual-use goods (Cooper, 2024; Meyer et al., 2023; Tavrikov & Yashalova, 2024). Sanctions are generally found to negatively affect technological advancement and innovative capabilities in target nations due to constraints on financial resources and international collaboration (Fu et al., 2022; Meyer et al., 2023; Omokaro et al., 2025; Wang et al., 2025). At the same time, these constraints may act as a catalyst for domestic innovation and increased technological self-reliance (Meyer et al., 2023; Omokaro et al., 2025).

Sanctions have far-reaching economic impacts that affect not only the sanctioned nation but also the sanctioning nation and third-party countries (Meyer et al., 2023; Omokaro et al., 2025). In sanctioned states, sanctions are associated with effects on macroeconomic stability and business performance, often

translating into severe economic hardship (Omokaro et al., 2025; Qiao, 2024). These effects include decreases in GDP per capita, heightened financial risk, and reductions in foreign direct investment (Gutmann et al., 2023; Özdamar & Shahin, 2021; Qiao, 2024; Shakeri et al., 2016)

Third, the debate over smart versus comprehensive sanctions remains unresolved. Targeted sanctions are often undermined by bypassing practices and domestic lobbying (Meyer et al., 2023), while strict enforcement mechanisms may trigger widespread corporate de-risking, effectively broadening their impact (Early & Peterson, 2023). At the same time, the humanitarian justification of smart sanctions has been challenged, with arguments that they may indirectly expose civilians to repression (Ellis, 2021), a claim that has received empirical support (Özdamar & Shahin, 2021). Finally, several authors point to structural transformations in the global system, including parallel markets and alternative financial infrastructures, which increasingly constrain the effective reach of sanctions and suggests that their success may depend on control over key financial nodes (Omokaro et al., 2025; Özdamar & Shahin, 2021).

Sanctions also alter global competitiveness by disrupting trading patterns and forcing countries to modify market policies (Ghironi et al., 2025; Y. Li & Han, 2025). They are often found to be more successful when they exploit a country's structural disadvantages, requiring the redistribution of resources to less efficient sectors and increasing overall costs (Ghironi et al., 2025). In response, sanctioned countries often redirect their trade towards other markets (Meyer et al., 2023). Exchange rate volatility is also likely to be heightened under sanctions, depending on their intensity (Ghironi et al., 2025; Razek et al., 2025; Shalpegin et al., 2023). Engagement in global value chains, however, remains a key mechanism for potentially mitigating some of the negative effects associated with sanctioned trade (Le, 2022).

Despite the breadth of existing literature, several gaps remain. The economic costs sustained by sender states and third-party countries, as well as anticipatory effects prior to sanction implementation, remain under-quantified (Gutmann et al., 2023). Moreover, microeconomic analyses of firm-level strategies under sanctions are scarce, leaving questions unanswered regarding divestment, avoidance mechanisms, and multinational operational strategies (Meyer et al., 2023).

Contradictions in the literature concern both the severity and the extent of economic harm. Case-study evidence highlights sharp declines in foreign direct investment and technological stagnation in sanctioned economies (Özdamar & Shahin, 2021). In contrast, quantitative studies often identify smaller average effects, partly due to low baseline Foreign Direct Investment (FDI) levels and compensatory investments by non-sanctioning countries (Early & Peterson, 2023; Gutmann et al., 2023; Meyer et al., 2023;

Özdamar & Shahin, 2021). While economic decline is commonly associated with sanctions, some studies suggest that sanctions may enhance internal cohesion or generate "siege morality," potentially stimulating domestic productive capacity (Özdamar & Shahin, 2021).

Overall, sanctions can be understood as effective instruments of economic coercion, but their outcomes remain heterogeneous, difficult to predict, and associated with significant trade-offs for all actors involved (Omokaro et al., 2025).

2.2. Supply Chain Management under Geopolitical Risk

The literature identifies geopolitical risk as a fundamental shift in the landscape of global supply chain management, moving away from equilibrium-based assumptions toward strategies that prioritise resilience. Contemporary supply chains appear to operate within a destabilised environment shaped by heightened geopolitical uncertainty (Fan et al., 2024; Liagkouras & Metaxiotis, 2023; Roscoe et al., 2022). The natural orientation of firms towards globalisation and internationalised supply chains has arguably increased exposure to geopolitical tensions, thereby amplifying vulnerability to external shocks (Ali et al., 2024; Hendricks & Singhal, 2005; Moradlou et al., 2021, 2025; Shakeri et al., 2016).

Geopolitical risks are commonly described as risks associated with warfare, terrorism, and conflicts between state-level actors, disrupting the previously undisturbed flow of international business activities. These risks are categorised as man-made macro risks, originating outside the firm but exerting systemic effects across supply networks (Johnson & Haug, 2021; Narkhede et al., 2024; Roscoe et al., 2022). Geopolitical issues tend to introduce uncertainty that increases transaction costs and complicates long-term operational planning (Ali et al., 2024; Fan et al., 2024).

Trade conflict and policy represent a central dimension of geopolitical risk, encompassing the imposition of tariffs, import quotas, and economic sanctions (Johnson & Haug, 2021; Liagkouras & Metaxiotis, 2023; Narkhede et al., 2024). The openness and volatility of international trade policy are often identified as a major threat to the stability of global supply chains (W. Li et al., 2025; Liagkouras & Metaxiotis, 2023). Energy-related geopolitical risk further contributes to instability, specifically when conflicts affect major energy-exporting countries, possibly disrupting global energy trade and supply continuity (Chen et al., 2023; Shakeri et al., 2016).

Geopolitical risks may exert multidimensional effects on supply chains. At the operational and transactional level, these risks are typically associated with supply disruptions, demand shocks, and delivery delays (Ali et al., 2024; Fan et al., 2024). At the financial and macroeconomic level, sanctions

are frequently considered a major source of risk, with fluctuations in commodity prices, supplier bankruptcies, and exchange rate volatility exerting particularly strong negative effects (Liagkouras & Metaxiotis, 2023; Shakeri et al., 2016).

From a logistics and infrastructure perspective, geopolitical tensions may interrupt critical commercial corridors, including sea-lanes, roads, and railways, forcing firms to adopt alternative routes, suppliers, or more expensive transportation modes (Narkhede et al., 2024). Border-related disruptions, such as those observed following Brexit, have been shown to increase logistics costs and delay deliveries (Ali et al., 2024). Over the longer term, supply chain disruptions may have persistent reputational and performance consequences, including declines in stock performance and increases in stock risk (Hendricks & Singhal, 2005).

In response to geopolitical risk, firms appear to increasingly pursue structural adjustments aimed at enhancing resilience. Nearshoring and regionalisation strategies are often adopted to diversify production sites and sourcing locations, thereby reducing dependence on distant and geopolitically exposed regions (Johnson & Haug, 2021; Meyer et al., 2023; Moradlou et al., 2025; Roscoe et al., 2022). These strategies involve relocating production, research and development, and business operations to geographically proximate, lower-cost locations (Moradlou et al., 2025; Roscoe et al., 2022). Firms also tend to pursue dual sourcing strategies, creating parallel supply options to hedge against geopolitical disruptions and volume shocks (Moradlou et al., 2025). Diversification of energy partnerships is similarly emphasised as a potential means of mitigating exposure to potential energy sanctions (Omokaro et al., 2025).

Building on the structural adjustments, firms increasingly seek to balance efficiency and flexibility simultaneously, a capability referred to as supply chain structural ambidexterity (Moradlou et al., 2025; Roscoe & Blome, 2019). When geopolitical disruptions allow for longer adjustment periods, such as Brexit or the US–China trade war, firms have been observed to respond by developing parallel supply chains. One chain prioritises efficiency through global scale and cost minimisation, while the other emphasises flexibility through localisation and customisation (Moradlou et al., 2025; Roscoe & Blome, 2019). Reconfiguration of supplier networks through diversification and the establishment of redundant suppliers may further support business continuity across varying response time horizons. In situations requiring immediate response, firms pursue ambidexterity through internal restructuring within focused geographic areas (Moradlou et al., 2025).

Beyond structural redesign, firms are also reported to implement supply chain risk management practices aimed at proactively addressing geopolitical risk. Effective risk management generally involves assessing

the probability and impact of risks and incorporating buffers into supply chain design (Moradlou et al., 2025). Contingency planning and inventory buffers remain central mechanisms, with firms maintaining excess capacity and strategic stock to hedge against disruptions. The probability–impact matrix is commonly employed to evaluate geopolitical threats, recognising that low-probability events may generate disproportionately high impacts (Moradlou et al., 2025). Increased supplier vigilance has also become critical, particularly given the risk of sanctions propagating through indirect supplier relationships, necessitating visibility beyond tier-one suppliers (Roscoe et al., 2022).

The literature identifies resilience and agility as primary response logics to geopolitical risk (Johnson & Haug, 2021; Narkhede et al., 2024). Long-term strategies include supply base diversification, dual sourcing, localisation, and reshoring (Johnson & Haug, 2021; Moradlou et al., 2025; Narkhede et al., 2024). Recent theoretical developments suggest that supply chain structural ambidexterity and supply chain logics may function as mechanisms enabling firms to reconcile efficiency and flexibility under persistent geopolitical pressure (Moradlou et al., 2025; Roscoe et al., 2022). Awareness and preparedness for geopolitical threats have also been associated with improved supply chain resilience and overall performance, particularly among SMEs (Althaqafi, 2025).

Reshoring or onshoring represents a related strategic response, defined as the relocation of manufacturing activities back to the firm's home country (Fan et al., 2024; Roscoe et al., 2022). Reshoring is identified as a preventative strategy that mitigates disruption risk, specifically when contractual obligations involve fixed delivery schedules. Empirical findings suggest that, under many disruption scenarios, the benefits of onshoring outweigh those of offshoring, especially when market accessibility and uninterrupted product flows are prioritised (Moradlou et al., 2021; Pang et al., 2025).

Despite growing interest, empirical research on geopolitical risk in supply chain management remains limited. Existing literature has been dominated by natural disasters, with comparatively little attention paid to the distinct characteristics of geopolitical risk (Ali et al., 2024; Moradlou et al., 2021, 2025). Quantitative modelling and decision-support research is scarce, leaving a gap between emerging geopolitical uncertainties and appropriate analytical tools for risk assessment (Liagkouras & Metaxiotis, 2023; Tang & Nurmaya Musa, 2011). Research on second- and higher-order effects of sanctions and boycotts on supply chain sustainability is also limited (Shalpegin et al., 2023). Moreover, empirical studies disproportionately focus on multinational enterprises, with insufficient attention to SMEs and supplier-side perspectives, particularly in the context of international buyer–supplier contracts affected by geopolitical events (Fan et al., 2024; Johnson & Haug, 2021; Moradlou et al., 2025; Negri et al., 2021).

Contradictions emerge in the literature regarding supply chain management approaches to geopolitical risk. A central tension exists between efficiency-driven globalisation and resilience-oriented strategies required to manage geopolitical uncertainty (Moradlou et al., 2025; Negri et al., 2021). Structural ambidexterity is proposed as a means of reconciling this tension through mechanisms such as parallel supply chains and dual sourcing (Moradlou et al., 2025). External risk may further mediate the relationship between external capabilities and resilience (Pham et al., 2023).

Finally, inconsistencies persist in the implementation of supply chain risk management. Although proactive risk management is widely advocated, empirical evidence indicates that firms continue to rely on a combination of short-term reactive measures, such as inventory increases, and longer-term structural responses, such as production relocation, often implemented only after major disruptions occur (Althaqafi, 2025; Johnson & Haug, 2021; Kırılmaz & Erol, 2016; Narkhede et al., 2024). Historically, proactive responses appear to have emerged primarily following significant adverse events, underscoring persistent gaps between theoretical prescriptions and managerial practice (Kırılmaz & Erol, 2016; Tang & Nurmaya Musa, 2011).

2.3. Supply Chain Resilience

Traditional supply chain risk is commonly categorised into operational risks, which relate to supply, production, infrastructure, and demand, and disruption risks (Pham et al., 2023; Tang & Nurmaya Musa, 2011). In the contemporary context, supply chains appear to operate in an increasingly unstable environment characterised by traditional uncertainties combined with emerging sources of risk, including geopolitical instability, climate change, and global pandemics, as evidenced by COVID-19 (Cinti et al., 2025; Liagkouras & Metaxiotis, 2023).

Supply chain resilience is defined as the ability of a supply chain system to prepare for, resist, respond to, and recover from unforeseen events while sustaining operations and evolving toward a more favourable state (Bastani et al., 2021; Negri et al., 2021). Resilience typically extends beyond shock absorption or a return to pre-disruption operations, encompassing the system's capacity to enhance its own parameters and preparedness as a means of continuous improvement and structural evolution (Bastani et al., 2021; Negri et al., 2021).

Despite growing attention, supply chain resilience remains a relatively immature and weakly institutionalised concept. The literature lacks consensus on terminology, with resilience variously

conceptualised as a capability, a measure, a feature, or a managerial philosophy (Negri et al., 2021). This conceptual ambiguity is compounded by a dominance of theoretical and conceptual studies, contrasted with a relative scarcity of empirical investigations (Cinti et al., 2025). Systematic literature reviews on supply chain risk frequently emphasise terrorism, natural disasters, and financial crises, while, in many cases, overlooking the specific characteristics and implications of geopolitical disruptions (Moradlou et al., 2025). Additionally, the integration of resilience and sustainability remains underexplored, with persistent ambiguity regarding their relationship and the practices capable of advancing both simultaneously (Negri et al., 2021).

Contradictions within the resilience literature reflect inherent tensions between resilience, efficiency, and sustainability. A central conflict arises between efficiency-driven paradigms focused on cost minimisation and resilience-oriented approaches prioritising effectiveness, often at the expense of higher costs (Negri et al., 2021). Sustainability practices such as inventory minimisation may undermine resilience by reducing responsiveness to disturbances, while redundancy, a recognised resilience driver, may generate waste and resource overconsumption, thereby conflicting with sustainability objectives (Negri et al., 2021). The relative performance of offshoring versus onshoring strategies further appears to depend on disruption intensity, with evidence suggesting that offshoring may outperform onshoring under high-disruption scenarios due to lead-time dynamics (Pang et al., 2025). Although most studies confirm the negative impact of risk on performance, a minority suggest that exposure to risk may positively influence supply chain practices by strengthening coordination and integration (Pham et al., 2023)

The literature identifies a range of strategic approaches to building supply chain resilience. Traditional risk mitigation strategies include avoidance, postponement, speculation, control, risk transfer or sharing, hedging, and security (Johnson & Haug, 2021), and redundancy-based strategies, such as multiple sourcing, safety stock, and excess capacity, remain central mechanisms for enhancing resilience (Bastani et al., 2021; Kırılmaz & Erol, 2016; Negri et al., 2021; Tang & Nurmaya Musa, 2011). Recent disruptions, including COVID-19, the US–China trade war, and Brexit, have contributed to reinforcing the adoption of onshoring, reshoring, and nearshoring as both reactive and preventative strategies aimed at minimising disruption risk. Integrated approaches combining responsive and preventive initiatives have been shown to outperform isolated strategies in terms of productivity and resilience outcomes (Althaqafi, 2025; Johnson & Haug, 2021; Pang et al., 2025).

The network-based paradigm reconceptualises the supply chain as a network of interconnected nodes rather than a linear chain. This perspective is argued to enhance resilience through increased malleability

and collaborative capacity. Under this paradigm, resilience frameworks identify critical dimensions for resilient supply networks, including network structure, interdependencies, collaboration and coordination, network positioning, and temporary organising, defined as the rapid assembly and reconfiguration of resources (Cinti et al., 2025).

Another approach to addressing resilience-related tensions between flexibility and efficiency is supply chain structural ambidexterity combined with managerial logics. Structural ambidexterity involves the simultaneous pursuit of efficiency and flexibility through mechanisms such as twin supply chains, diversification and dual sourcing, or internal subunit restructuring (Moradlou et al., 2025). Managerial decision-making under compounded disruptions is shaped by supply chain logics, reflecting bounded rationality influenced by institutional pressures, asset mobility, supplier constraints, and perceived disruption severity (Roscoe et al., 2022).

Technological investment and analytics are suggested to enhance resilience by improving visibility and decision-making. Digital twin simulations, integrated enterprise resource planning systems, and technologies that enable end-to-end supply chain visibility are increasingly recognised as essential tools for resilience strategy formulation and implementation (Roscoe et al., 2022).

Although the literature broadly agrees that supply chain resilience lacks a single settled definition, a fundamental theoretical divide persists between recovery-oriented and transformational perspectives. This distinction reflects incompatible assumptions regarding how supply chains should respond to disruption rather than mere semantic disagreement (Cinti et al., 2025; Negri et al., 2021; Shakeri et al., 2016).

The recovery-oriented perspective, often described as engineering resilience, conceptualises resilience as the capacity to withstand shocks and restore the system to its pre-disruption state. Seminal contributions emphasise rapid recovery and continuity of operations, framing disruption as a temporary deviation from an otherwise stable equilibrium (Negri et al., 2021). This logic tends to assume relatively predictable environments in which returning to normal operations remains feasible (Cinti et al., 2025; Gligor et al., 2020).

In contrast, the transformational perspective, commonly associated with ecological resilience, frames resilience as a dynamic and forward-looking capability (Hendricks & Singhal, 2005). Rather than reverting to past configurations, supply chains are expected to adapt, reconfigure, and evolve toward new equilibrium. This perspective conceptualises resilience as an evolutionary process in which disruption serves as a catalyst for learning, structural change, and strategic renewal (Negri et al., 2021). Recent

contributions further emphasise the opportunity-seeking nature of resilience, highlighting the role of network flexibility in converting disruption into competitive advantage (Bastani et al., 2021; Cinti et al., 2025).

The contrast between these perspectives reveals a deeper strategic tension between efficiency and effectiveness. While recovery-oriented resilience prioritises cost efficiency and stability, transformational resilience emphasises long-term effectiveness through adaptation (Negri et al., 2021; Omokaro et al., 2025; Shalpegin et al., 2023). The literature increasingly suggests that in volatile, uncertain, complex, and ambiguous environments, resilience may not be fully captured by a return to equilibrium, as the pre-disruption "normal" may no longer represent a viable or desirable state (Ali et al., 2024; Cinti et al., 2025; Moradlou et al., 2025).

Although the construct of resilience is included in the theoretical discussion area, it is excluded from the final empirical model due to measurement and sample size limitations. Therefore, resilience is treated primarily as a conceptual construct and addressed in future research directions.

2.4. Resource Dependence Theory

Resource Dependence Theory (RDT) is a theoretical framework for examining organization–environment relations and the ways in which resource dependencies influence organizational behaviour (Drees & Heugens, 2013; Lee et al., 2014). The theory rests on three central propositions. First, organizations exhibit inherent dependence because they rely on other organizations for crucial resources and can never achieve full autonomy with respect to those resources, which are necessary for organizational survival (Drees & Heugens, 2013; Lee et al., 2014; Sarkis et al., 2011). Second, organizations operate under conditions of constraint and uncertainty arising from these dependencies, which significantly limit autonomy while remaining unpredictable and fluctuating over time (Drees & Heugens, 2013; Jiang et al., 2023; Lee et al., 2014; Pfeffer, 1997). Third, because organizational survival depends on external resource access, organizations attempt to cope with these dependencies by employing dependence management solutions aimed at reducing resource uncertainty (Drees & Heugens, 2013; Jiang et al., 2023; Lee et al., 2014).

These dependence management solutions are commonly categorized into approaches such as absorbing dependences, countervailing dependences, and avoiding dependences (Jiang et al., 2023; Lee et al., 2014; Narkhede et al., 2024). The formation of inter-organizational arrangements, including board interlocks, mergers, acquisitions, and joint ventures, is typically described as a way to counterbalance constraints that affect organizational autonomy and control over resources (Pfeffer, 1997).

Sanctions represent a significant shock to the external environment, increasing uncertainty and threatening access to vital resources. They tend to introduce immediate environmental instability by altering information and resource flows, often requiring organizations to rapidly adapt due to restricted access to raw materials, markets, capital, or distribution channels (Pfeffer, 1997). Sanctions also associated with effects on organizations' ability to obtain critical resources, thereby engaging the survival environment emphasized by RDT (Pfeffer, 1997; Sarkis et al., 2011). As supply chain configurations are disrupted, firms may be required to reassess existing dependencies, reconfigure supplier relationships, and, in some cases, accept higher operational costs as a trade-off for continuity.

Applying RDT to geopolitical disruptions further requires distinguishing between early deterministic interpretations of the theory and later dynamic, strategic ones. This distinction is considered relevant for understanding firm behaviour under sanctions and trade conflicts. Classic RDT portrays firms as largely constrained by their environments. Because organizations are not self-sufficient, they depend on external actors for critical resources, which grants power to those controlling scarce or non-substitutable inputs. In this interpretation, firms are primarily reactive, adopting inter-organizational arrangements to absorb constraints or co-opt sources of dependence within relatively stable institutional and political contexts (Pfeffer & Salancik, 2009).

Contemporary interpretations, however, tend to shift away from this environmental determinism toward a more strategic perspective (Jiang et al., 2023; Sheppard, 1995). Firms are increasingly viewed as active managers of interdependence rather than passive recipients of environmental pressures, employing firm-specific capabilities such as innovation or corporate social responsibility to shape the dependence of their partners. Dependency is therefore not fixed, but can be reshaped over time (Sarkis et al., 2011).

2.5. Institutional Theory

Institutional theory focuses on the origins of institutionalism and explains how organizations obtain legitimacy by aligning with the institutional environments surrounding them. It provides insight into why organizations within the same organizational field tend to become increasingly similar over time, a process referred to as institutional isomorphism (DiMaggio & Powell, 1983). Organizations are considered to gain advantages from this similarity because shared structures and practices facilitate transactions, employment mobility, reputational assessment, and administrative classification.

Institutional conformity does not necessarily improve operational efficiency, however, it is understood to facilitate organizational functioning and enhance legitimacy within the external environment (DiMaggio & Powell, 1983). Institutional pressures are typically manifested through coercive, mimetic, and normative mechanisms. In the context of this study, particular emphasis is placed on coercive pressures, as regulatory frameworks, such as international sanctions and EU legislation, directly influence firms' supply chain decisions and operational practices.

While these foundational mechanisms provide a consistent analytical framework, the literature reveals a divergence in how it interprets the consequences of institutional pressures. This distinction becomes particularly relevant when analysing firm responses to sanctions and regulatory constraints.

Early institutional theory largely conceptualizes institutional conformity as a symbolic action aimed at securing legitimacy rather than enhancing efficiency. From this perspective, organizations adopt structures and practices to appear appropriate to key stakeholders, even when these changes are decoupled from core operational activities. In the context of sanctions, this suggests that firms may engage in low-profile compliance measures or stakeholder-oriented signalling in their home countries while maintaining economic ties with sanctioned markets.

In contrast, more recent approaches emphasise the material impact of institutions, specifically in the case of binding regulations and enforced sanctions regimes. Rather than acting merely as symbolic constraints, these mechanisms are understood to impose tangible financial costs rather than merely reputational pressures, directly affecting firm profitability, fiscal obligations, and access to regional markets (Belik et al., 2022).

This shift from symbolic to material interpretations is critical in understanding how firms respond to contemporary regulatory environments, where compliance is increasingly tied to financial and operational consequences rather than reputational considerations alone.

Intense institutional pressure can constrain managerial discretion by imposing specific supply chain logics and forcing firms to adopt particular organizational designs, such as production localization or the maintenance of costly buffer inventories, thereby narrowing the range of viable strategic choices (Roscoe et al., 2022).

In the Portuguese metalworking industry, these pressures can be interpreted as operating within a broader European regulatory framework. As a result, companies face growing regulatory requirements in relation

to environmental standards and trade-related obligations (European Commission. Directorate General for Taxation and Customs Union., 2023).

Coercive isomorphism is particularly relevant in this context as it represents the most immediate and visible form of institutional pressure, in the European context, instruments such as the Carbon Border Adjustment Mechanism (CBAM) and the Emissions Trading System (ETS) impose mandatory compliance requirements that directly affect firms operating within energy-intensive sectors (DiMaggio & Powell, 1983). These regulations impose obligations in terms of emissions monitoring, reporting, and financial accountability. As a result, organizations are expected to engage more closely with their supply chains, particularly upstream partners, to obtain reliable data and ensure compliance. This leads to environmental monitoring and inter-organizational collaboration becoming increasingly institutionalized, not necessarily as a strategic choice, but as a legal requirement.

Alongside these coercive mechanisms, mimetic isomorphism emerges as a response to heightened environmental uncertainty (European Commission. Directorate General for Taxation and Customs Union., 2023).

Normative isomorphism further contributes to this process through mechanisms of professionalization and the diffusion of shared norms within the industry, over time, this leads to the internalization of standardized practices and contributes to the homogenization of organizational structures and behaviours across the sector (DiMaggio & Powell, 1983).

The evolution of the industry can also be interpreted through different modes of institutional change (Mahoney & Thelen, 2009). One such mode is layering, which is evident in the introduction of new regulatory instruments, rather than replacing previous rules, these additions increase the complexity of the regulatory environment and require firms to adapt their compliance systems accordingly. Displacement occurs when there is a transformation in the underlying logic of production, gradually replacing established practices with new, carbon-neutral approaches. Drift highlights the risks associated with inaction, if firms fail to respond adequately to evolving environmental and regulatory conditions (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2025).

Overall, institutional pressures are seen as shaping firm behaviour not only by constraining available choices but also by redefining what constitutes viable strategic action. In this context, compliance is no longer optional or symbolic, it becomes a central determinant of operational and supply chain decisions.

2.6. Influence of European Legislation on the Metal and Steel Industry

The regulatory framework has emerged through European legislation and the development of strategic plans governing the iron, steel and base metals sectors, which form the backbone of the metalworking industry and are, to a large extent, driven by broader environmental, energy and industrial policy objectives. These developments have contributed to introducing new constraints for businesses, whilst redefining strategic priorities, particularly in energy-intensive sectors (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2025).

The Carbon Border Adjustment Mechanism (CBAM), established under Regulation (EU) 2023/956, is widely regarded as a landmark that imposes a price on the embodied greenhouse gas emissions of certain goods, including iron and steel products, that are imported into the EU (European Commission. Directorate General for Taxation and Customs Union., 2023). The purpose of CBAM is to protect EU climate policies and promote low-carbon production outside the EU. As of October 2023, importers of goods from outside the EU are required to supply information on greenhouse gas emissions to the EU importers (European Commission. Directorate General for Taxation and Customs Union., 2023). These obligations extend beyond firm boundaries, requiring coordination with suppliers and greater visibility across the value chain.

While the mechanism is designed to prevent carbon leakage and promote fair competition, concerns have been raised regarding its impact on competitiveness. In practice, firms may face a trade-off between regulatory compliance and cost efficiency, particularly when competing with producers operating under less stringent environmental regimes.

In parallel, broader legislative initiatives associated with the European green transition, namely the policy framework often referred to as the “Clean Industrial Deal” and the Competitiveness Compass, are intended to reinforce the obligation for energy-intensive industries to transition towards cleaner energy sources and more sustainable production models. Although these policies aim to promote long-term environmental and economic sustainability, their implementation presents challenges for the industry (European Commission, 2025).

This is remarkably relevant in sectors characterised by capital-intensive production systems with long life cycles, where rapid technological adaptation can be both costly and operationally complex. As a result, firms may be required to make substantial investments in upgrading or replacing existing infrastructure, increasing financial pressure in the short to medium term.

Beyond environmental regulation, supply chain resilience and resource security have gained increasing importance. The Critical Raw Materials Act (CRM Act) (Regulation (EU) 2024/1252) introduces a framework aimed at securing access to essential inputs within the European Union. This regulation encourages firms to diversify sourcing strategies, strengthen supply security, and adopt more sustainable and circular practices.

Similarly, the REPowerEU initiative (Regulation (EU) 2023/435) seeks to reduce dependence on external energy suppliers, particularly from geopolitically sensitive regions. This policy promotes the transition towards renewable energy and improved energy efficiency across industrial processes.

From a supply chain perspective, these measures not only affect energy costs but may also reshape sourcing decisions and supplier relationships, reinforcing the need for greater flexibility and diversification.

The Digital Product Passport has a major effect on the metalworking industry in Portugal, with a large portion of products being produced and sold in the value chains originating from Portugal and containing intermediate goods. As it provides for information requirements concerning product composition, product origin and environmental performance, the DPP is likely to create an increased need for supply chain transparency and traceability. Thus, firms, especially sub-contractors, may face increasing pressure to obtain accurate and reliable data from their upstream suppliers and therefore reinforce their reliance on their supply chain (Arcipowska et al., 2026).

Additionally, since the metalworking industry is comprised primarily of small and medium-sized enterprises who cannot afford to implement DPP requirements without significant investment in operational and/or technological capabilities, the implementation of the DPP could create significant operational and technological challenges for SMEs as they will have to change their supply chain structures and competitive strategies (Arcipowska et al., 2026; Blanco Pérez et al., 2025).

It is also worth noting that these substantive changes, the administrative burden associated with regulatory compliance, remains a commonly identified concern (AICEP, 2025). Although the European Commission has introduced initiatives aimed at reducing bureaucratic complexity, such as the Competitiveness Compass, firms continue to face overlapping regulatory requirements across environmental, industrial, and energy domains (Council of the European Union, 2025).

This complexity increases operational uncertainty and requires firms to allocate additional resources to compliance-related activities, which may not directly contribute to productivity or value creation (Council of the European Union, 2025).

Finally, the European Union has developed transition pathways for the metals sector, outlining strategic directions for achieving both green and digital transformation objectives while maintaining industrial competitiveness (European Commission, n.d.). These frameworks provide guidance but also reinforce the expectation that firms align internal strategies with evolving regulatory demands.

Overall, European legislation can be seen as acting as a structural force that reshapes the operating environment of the metal and steel industry. Rather than functioning solely as an external constraint, it actively influences supply chain configuration, investment decisions, and long-term strategic orientation (Confederação Empresarial de Portugal, 2026).

While there has been significant progress in literature regarding the understanding of international sanctions and their broader implications on economies and supply chains, important limitations remain. More specifically, the literature on international sanctions, geopolitical risk, and supply chain resilience has yet to be unified with regard to the relationship between all three entities at the firm level.

The gap between literature and empirical study is most evident in Portugal's metalworking sector, where a high degree of internationalisation and high dependency levels on external resources are in contrast with increased institutional pressure from European regulatory bodies. This research provides an empirical analysis of companies at the firm level, combining exposure to sanctions, supply chain disruption, and organisational response. In doing so, it aims to address the existing gap in the literature and contributing to a clearer understanding of how firms operate within constrained structural and politically volatile environments.

3. The Portuguese Metalworking Industry

The metal and metalworking sector in Portugal, often integrated within the broader Advanced Manufacturing industry, which also includes Mechanical and Electronics segments, is widely regarded as a cornerstone of the national manufacturing sector. The Advanced Manufacturing sector is the largest exporting industry of the Portuguese economy, and the metal and metalworking sector in particular is described as a strategic pillar.

Figure 1 demonstrates the progression of total exports from Portugal and the exports from the Metalworking sector from 2018 to 2025, allowing the progress of the sector to be compared with Portugal's total export performance.

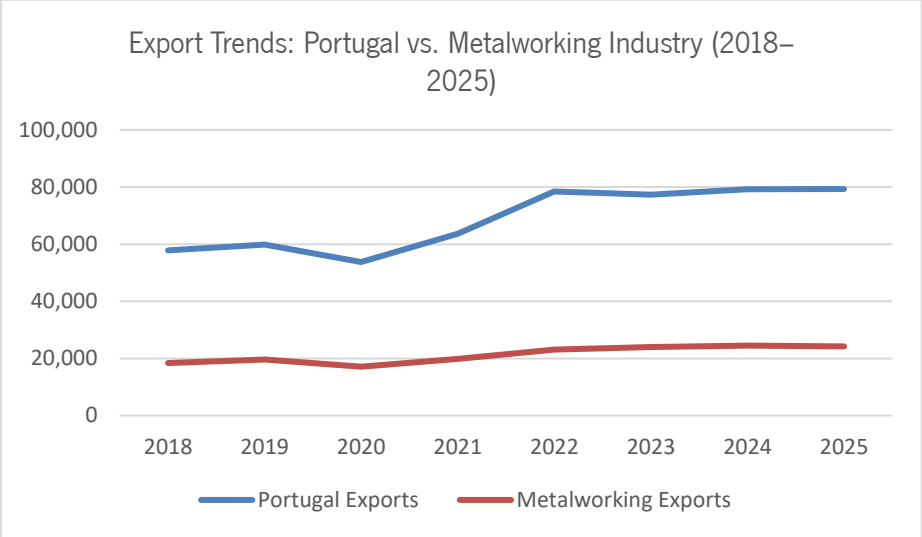


Figure 1 – Export Trends: Portugal vs. Metalworking Industry (2018–2025)

The metalworking sector has continued to play a significant part in total exports from Portugal, thus reinforcing its importance as a sector exposed to international market volatility. It represents 32% of total Portuguese exports, with annual export levels surpassing €25 billion (AICEP, 2025).

Figure 2 shows the relative contribution of the metalworking sector to total Portuguese exports during the same time period as outlined in Figure 1.

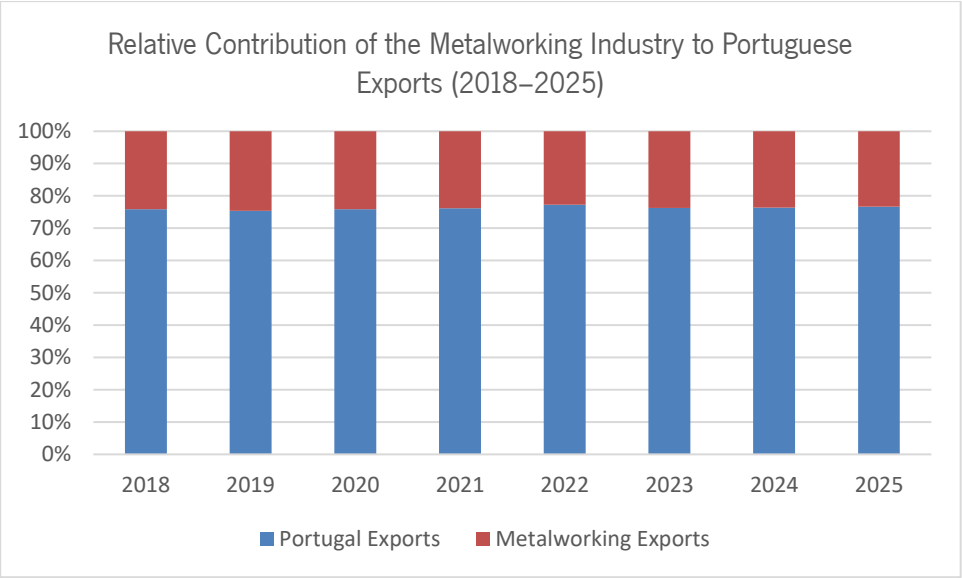


Figure 2 – Relative Contribution of the Metalworking Industry to Portuguese Exports (2018–2025)

This evidence confirms that the metalworking sector is not limited to a marginal role, but rather is an industry with structural significance for the economy in Portugal.

The Advanced Manufacturing sector broke records in export value in 2022 at over €19 billion, while in 2023, the sector reached €25.023 billion in export value. In 2021, the Advanced Manufacturing sector had contributed to the overall export of the nation's goods at 24%. The sector surpasses 15,000 companies, employing more than 200 thousand people, contributing 22% of the companies and 22% of the labour force in the total manufacturing sector in 2022 (AICEP, n.d.-a, 2025). Additionally, Portugal holds a specialized leadership, as it is a global leader in the mould industry, ranking the 3rd largest producer in Europe and 8th worldwide.

Portugal is positioned as a highly interdependent contributor to the European metalworking industry. This is not due to its gross domestic product (GDP) or primary metal production amount. Instead, Portugal's contribution to the metalworking industry relates largely to how its strategic position facilitates or detracts from integrated value-added processes.

While Portugal has a relatively modest amount of upstream production, it plays a significant role at the intermediate markets, as most companies function primarily as suppliers or contractors to produce metal parts and components which are then used in downstream industries such as building and construction, automotive manufacturing, and machinery or equipment (AICEP, 2025; AIMMAP, 2023; EY-Parthenon, 2023). This indicates that the industry operates primarily in a business-to-business (B2B) context and is highly embedded within industrial supply chains (EY-Parthenon, 2023).

Nonetheless, the metal industry is not uniform as it consists of heterogeneous activities and a wide variety of product types. In addition to those companies that are classified as intermediate, there are also companies that are closer to the final end of the value creation chain and produce finished products as well as durable goods that are sold directly to end-users (AICEP, 2025; EY-Parthenon, 2023).

Collectively, both types of operations exemplify how the structural diversity of the metal industry enables participation across multiple stages of the value chain through the combination of base metallurgical material with highly finished manufactured goods (AIMMAP, 2023).

The Portuguese metal and metalworking industry exports to markets across five continents and more than 200 markets worldwide, emphasizing the high level of internationalization. Its main destination markets are concentrated in advanced EU economies, which account for over half of the total sales value, with Spain at €5.916 billion, Germany at €3.695 billion, and France at €4.062 billion as the top markets in 2023. Other dynamic and increasingly important markets include the USA, Morocco, and Poland, which have shown expressive growth over the past five years. Exports to Morocco grew by 22.9% annually between 2019 and 2023, and the USA consistently ranks among the top five destination markets for the sector. The sector's competitive positioning is built on quality, precision, innovation, and reliability, and Portugal enjoys a strong reputation for offering an excellent balance between quality and price (AICEP, 2025). Competitiveness is reinforced by strong technical and engineering capabilities, the integration of modern design requirements, and substantial investment in innovation and research and development. Around 75% of companies are involved in innovation activities, applying advanced technologies such as digitalization, automation, robotics, collaborative robotics, Artificial Intelligence, and Additive Manufacturing (AICEP, n.d.-b).

Foreign direct investment has been driven by the talent and skills of the workforce, encouraging international companies to set up production facilities in the districts of Aveiro, Leiria, Porto and Braga. Investors frequently praise what they describe as a clear formula for success in Portugal, expressed in the phrase Invented in Portugal and made in Portugal with Portuguese talents (AICEP, n.d.-a, n.d.-b). The sector navigates a complex balance between attracting foreign capital and relying on external inputs.

Despite the many strengths in the sector, there are risks threatening it. The first and most pressing problem is the lack of skilled human resources, described by the companies themselves as the major growth deterrent and most difficult resource to find. Its remedy entails significant investment in professional development and talent retention (EY-Parthenon, 2023). Performance in export is also temporarily dampened as evidenced by the 4.3% drop in export value in the first nine months in 2024

compared to 2023 (AICEP, 2025). Although the high volume of exports, the sector remains dependent on external suppliers, predominantly for energy and raw materials, reflecting the sector's external dependence, which results in weak economic and financial performance among SMEs, as well as higher levels of debt, financial pressure and weak operating margins. Finally, the sector also faces challenges related to the changing demands for materials being lighter but more resilient. Decarbonization is also another area the industry is finding continually challenging. The industry is also pressed to focus on sustainable and circular industry flows.

4. Conceptual Model

The empirical analysis of the study developed in this chapter uses a conceptual model founded on the theoretical framework developed in the literature review. This chapter critically integrates previously identified key constructs and relationships from the literature into a coherent, structured framework used to explain how international sanctions affect supply chain dynamics and operational performance. The first part of this chapter presents the development of the model and the rationale for the proposed relationships; the second part contains the hypotheses for testing; and finally, the final section outlines how the constructs will be operationalised, by converting the abstract concepts discussed in the literature to measurable variables using the questionnaire designed for the research. The structured approach adopted in this chapter ensures that there is a logical relationship between the theoretical constructs and empirical data, which will provide a solid foundation for the subsequent testing and interpretation of the results.

4.1. Model Development

The aim of the conceptual model is to analyse the extent to which exposure to international sanctions influences supply chain dynamics and operational performance in the Portuguese metalworking industry. Given the sector's heavy reliance on international trade and external factors of production, geopolitical restrictions, such as sanctions represent a significant source of disruption.

The development of the conceptual model is primarily based on Resource Dependency Theory and Institutional Theory. Resource Dependency Theory suggests that firms are dependent on external resources controlled by other actors, and are therefore vulnerable to disruptions in their supply chains. In this sense, international sanctions can be an aggravating factor in terms of resource constraints by limiting access to suppliers, technologies or markets. At the same time, Institutional Theory highlights regulatory frameworks and external pressures, particularly those imposed by supranational bodies such as the European Union, which shape organisational behaviour and strategic responses.

According to the theoretical background outlined above, the proposed model identifies three critical antecedents of disruptions within supply chains: international sanctions; reliance on external suppliers and markets; and institutional pressure.

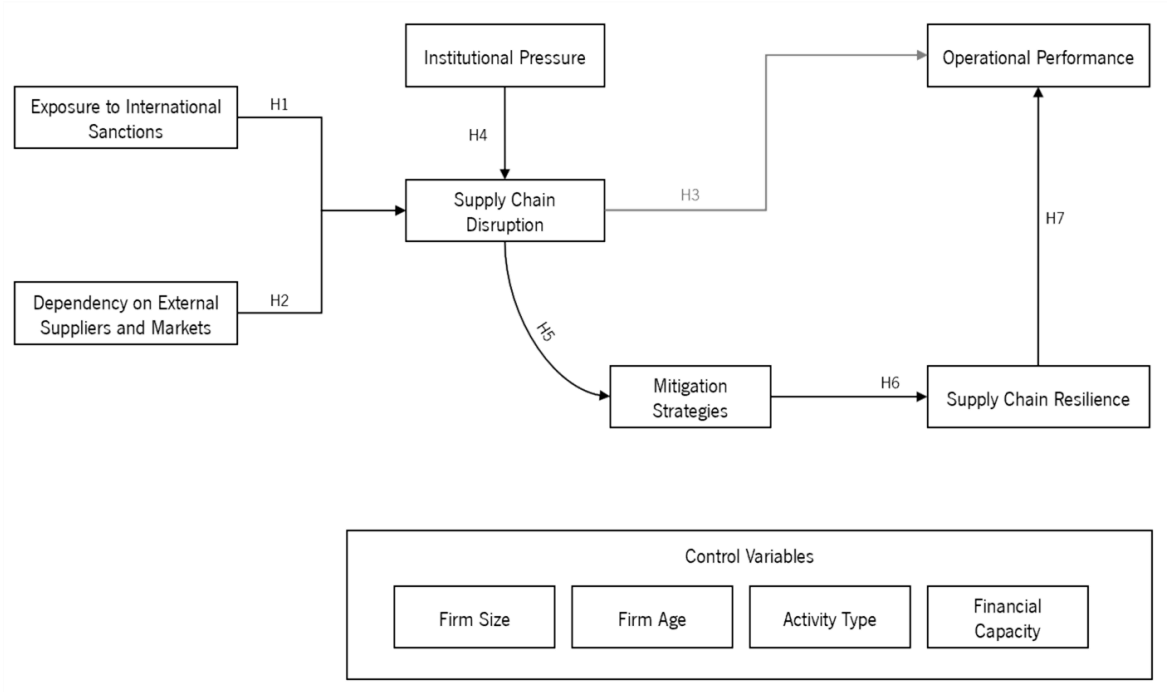


Figure 3 - Conceptual Model of the Study

Companies that are heavily dependent upon external sources are likely to face greater disruptions than companies that depend less upon outside agents because they have limited flexibility to adjust their sourcing strategies. Likewise, as companies face greater amounts of institutional pressure through regulations, compliance requirements will also likely increase the amount of disruption experienced by limiting the company's ability to procure goods or services or operate in accordance with regulations.

The supply chain disruption itself serves as the central mediator of the effects of external pressures on firm outcomes. Supply chain disruptions are expected to be associated with a deterioration in operational performance, reflected in higher costs, delays and inefficiencies.

As firms experience disruptions in their supply chains, they will engage in mitigation strategies to respond to these disruptions. Mitigation strategies are defined as any planned management action taken by a firm to reduce its exposure to risk and maintain continuity of operations. Mitigation strategies should provide a positive impact on operational performance when there is a disruption in place.

Although resilience is conceptually relevant, it is not included in the final empirical model due to measurement limitations and the exploratory nature of the study. Therefore, resilience is discussed as a theoretical implication and as a direction for future research, rather than as an empirically tested construct.

Response to these disruptions is executed through the implementation of mitigation strategies. While there is conceptual linkage between these two constructs in promoting supply chain resilience, this relationship is not empirically tested in the present study. Instead, the results indicate that mitigation strategies contribute to improving operational performance, reinforcing their role in stabilising firms' operations during periods of disruption. Although all constructs are theoretically relevant, the empirical testing of the model is constrained by data availability and measurement limitations, and some relationships are therefore explored only conceptually.

4.2. Research Hypotheses

This chapter sets out the conceptual framework of the study, establishing the theoretical relationships between the variables under analysis within the context of the Portuguese metalworking sector, and serves as the basis for the formulation of the research hypotheses presented below. The hypotheses are therefore as follows:

H1: Exposure to international sanctions is positively associated with supply chain disruption. International sanctions impose restrictions on trade flows, which can limit access to suppliers and increase uncertainty in procurement processes. Exposed firms are therefore more likely to experience disruptions in their supply chains.

H2: Resource dependency is positively associated with the severity of supply chain disruption. Companies with a higher degree of dependence on external suppliers are more vulnerable to external restrictions; under sanctions, this dependence is amplified, as flexibility in seeking alternative supply sources is reduced.

H3: Supply chain disruption is positively associated with operational performance deterioration. Higher levels of disruption are expected to be reflected in increased costs, delays and operational inefficiencies.

H4: Institutional pressure is positively associated with the severity of supply chain disruption. Regulatory frameworks, primarily those of the European Union and national legislation, impose additional restrictions on companies, which may exacerbate the effects of sanctions.

H5: Supply chain disruption is positively associated with the adoption of mitigation strategies and risk management practices. As disruptions increase, firms adopt strategies designed to reduce exposure whilst maintaining operational continuity.

H6: The adoption of mitigation strategies is positively associated with operational performance. Mitigation strategies improve the level of coordination, flexibility, and responsiveness within a supply chain, thereby reducing the adverse effects of disruptions experienced by firms. In this way, the use of mitigation strategies helps firms to stabilise their operations and provide a continuous flow of goods and/or services, even when faced with unfavourable conditions.

H7: The adoption of mitigation strategies is positively associated with supply chain resilience. Mitigation strategies strengthen the company's ability to respond to disruptions, thereby enhancing its resilience.

H8: Supply chain resilience is positively associated with operational performance. Businesses with higher levels of resilience are equipped to sustain operations in adverse conditions, thereby reducing the negative impact of disruptions.

H7 and H8 are treated as conceptual propositions. Their exclusion as methods of empirical testing is based upon the limitations of operationalising resilience, the exploratory nature of the project, and the limitations resulting from sample size. Thus, resilience has been determined to be theoretically relevant but is not included in the final empirical model.

4.3. Operationalization of Constructs and Measurement

After developing the conceptual framework and defining the hypotheses of the study, it is necessary to convert the theoretical concepts in the model into observable and measurable variables that can be tested empirically (Blumberg et al., 2011; Creswell, 2018). Using the positivist and deductive approach, the model constructs will use the questionnaire's measurement items to operationalise the theoretical constructs (Blumberg et al., 2011; Saunders et al., 2023).

By creating measurable indicators of the theoretical constructs, the operationalisation process provides a means to represent abstract concepts with observable variables so that statistical analysis may be performed, and by only using measurement items that were based on the literature, operationalisation will provide measurement items that fit the structure of the questionnaire to ensure correspondence

between the theoretical framework and empirical instrument (Blumberg et al., 2011; Saunders et al., 2023).

The various measurement types (e.g., Likert scales, ordinal scales, categorical measures) were developed to determine the intensity and impact of the constructs.

Table 1 - Operationalization of Constructs and Measurement

Construct	Measurement Item
Exposure to International Sanctions	Q51 – Overall Sanctions Impact
	Q52 – Expected Persistence of Sanctions
Dependency on External Suppliers and Markets	Q10 – Export activity
	Q12 – Import activity
	Q15 – Degree of dependence on external suppliers
Institutional Pressure	Q45 - Trade Process Difficulty
	Q48 – CBAM Impact
	Q50 – Regulatory Aggravation
Supply Chain Disruption	Q19 – Access to Critical Inputs
	Q23 – Supply Chain Delays
	Q25 – Planning Uncertainty
	Q27 – Energy Impact
	Q28 – Overall Supply Chain Disruption
Mitigation Strategies	Q37 – Adoption of mitigation strategies
	Q38 – Risk Management Mechanisms
	Q40 – Collaboration with Partners
	Q41 – Internal Development and Innovation
Operational Performance	Q29 – Production Impact
	Q30 – Delivery Performance
	Q32 – Financial Performance Impact

To operationalise exposure to international sanctions, both perceived effects of sanctions on the firm and expected duration of sanctions were considered. The perceived impact of sanctions on the firm was assessed by a five-point Likert scale, with responses from “no effect” to “very much”. The expected duration of sanctions was assessed by a five-point Likert scale, with responses ranging from “not at all likely” to “very likely”.

To operationalise dependency on external suppliers and markets, a combination of indicators was utilised to assess firms’ international activity (export and import behaviour) and their perceived level of dependence on external suppliers. The degree of export and import activity was assessed by completing an ordinal categorical scale with three levels (None, Infrequent, & Frequent), while the level of dependency

on suppliers was assessed using a five-point Likert scale with responses ranging from “very low” to “very high”.

Institutional pressure was operationalised through a series of items that assessed the perceived impact of regulatory frameworks on supplier relationships (Q48) and the perceived effect of EU or national regulatory frameworks on supplier relationships as a result of sanctions (Q50). Both questions were evaluated by employing five-point Likert scales with responses of “very low to very high.” Q45 was included to capture perceived difficulties in trade processes, reflecting the operational burden associated with regulatory and institutional constraints.

The multi-item operationalisation of supply chain disruption consisted of various items reflecting different types of disruption, including frequency, perceived uncertainty, and overall impact. Disruption frequency-based items were included in identifying limits to access, delays, and energy impact items (Q19, Q23, Q27). The use of a Likert-type scale was employed to measure the level of planning uncertainty (Q25), while the overall disruption assessment was captured on a five-point scale (Q28).

Mitigation strategy operationalisation consisted of various indicators comprised of both the actions taken and perceived strategic responses. Ordinal measures such as the diversification of suppliers (Q37) and implementation of risk management reinforcement (Q38) indicated structural adaptations using ordinal categorical scales. Supplier diversification (Q37) was deemed an ordinal variable due to the varying degree of strategic response in supplier diversification, with an "on-going restructuring" level of strategic response reflected at each level of variation in the number of suppliers and degree of diversification. In addition to structural items, perceptual items (collaboration, innovation, and diversification) (Q40–Q42) were measured using five-point Likert Agreement Scales. This dual approach allows for an overall assessment of firms’ response to sanctioning.

It should be noted that the operational performance construct is measured through indicators reflecting negative outcomes (e.g., increased costs, delays and inefficiencies). Therefore, higher values correspond to a deterioration in performance.

Several control variables are also incorporated in the model. The control variables were used to account for structural differences across firms and are critical in isolating the impact of the main constructs, therefore, establishing the validity and reliability of the empirical results (Blumberg et al., 2011; Creswell, 2018; Saunders et al., 2023).

The full questionnaire, including all measurement items and scales, is presented in Appendix A.

Table 2 - Control Variables and Measurement

Construct	Measurement Item
Control Variables	Q5 and Q8 - Firm size
	Q7 - Firm Age
	Q4 - Industry type
	Q6 - Region
	Q9 - Turnover

5. Methodology

The objective of this chapter is to provide a systematic overview of the methodology and procedures that were used in the empirical research. To achieve this goal, this chapter will provide a description of the research problem, research aims, research paradigm, study design, questionnaire, scale, data collection methodology, data analysis methodology, validity and reliability of the research and ethical issues involved with the research.

5.1. Research Paradigm

This study adopts a positivist research paradigm, as it aims to examine relationships between variables through empirical observation and statistical analysis. The primary objective is to investigate the relationship among well-defined variables, using a systematic method of observation and statistical analysis (Saunders et al., 2023).

The adoption of a positivist paradigm enables hypothesis testing and the establishment of measurable relationships between theoretical constructs previously established from the literature (Creswell, 2018; Saunders et al., 2023). This is particularly relevant for the research on the metalworking industry, since this industry relies heavily on international trade flows, external suppliers and access to global markets (AICEP, 2025). Consequently, international sanctions are conceptualised as external shocks and thus generate measurable and observed disruptions in supply chains. Therefore, the proposed relationships can be empirically examined based on valid methodological approaches (Saunders et al., 2023).

As per the above stated paradigm, the research follows a deductive approach. Previous theoretical constructs derived from the literature and the conceptual model have generated hypotheses that will be subsequently tested by collecting and analysing empirical data statistically (Creswell, 2018; Flynn et al., 1990). This ensures consistency between the conceptual framework and methodological design (Flynn et al., 1990; Saunders et al., 2023).

Overall, this framework, coupled with a deductive approach, provides the methodological rigor necessary to examine how external shocks trigger a ripple effect that disrupts the structural dynamics and operational performance of the global supply chain (Flynn et al., 1990; Ketokivi & Choi, 2014; Rinaldi et al., 2022).

5.2. Research Design

This research uses a quantitative design and an exploratory explanatory approach to investigate the research question. The conceptual framework has been established and tested using hypotheses within the framework of theory; however, due to the small sample size and sector-specific analysis, the empirical analysis should be viewed as exploratory in nature (Creswell, 2018; Saunders et al., 2023).

The research utilizes a cross-sectional research design to collect data on firms at one point in time, which is fitting for capturing current perceptions and experiences of firms regarding sanctions and their effects on firm supply chains (Blumberg et al., 2011; Saunders et al., 2023).

Additionally, this research study was supplemented by additional qualitative insights obtained through interviews with industry practitioners, which provided contextual support for interpreting the quantitative findings (Saunders et al., 2023).

5.3. Data Collection Method

Structured questionnaires were used to collect the data based on previous literature reviews and a developed conceptual model presented in Chapter 4. The structure comprised multiple sections that address the various major fields of interest, which included firm characterisation, international trade experience, involvement with sanctioned markets, operational performance, supply chain disruptions, mitigation strategies, institutional pressure and general ratings (Blumberg et al., 2011). In terms of the nature of the questions, most of them were closed-ended and used Likert scale type items, which allowed respondents to identify how much they agree with each item (i.e., from 1 - strongly disagree to 7 - strongly agree) as well as ordinal, categorical and frequency-based measures (Saunders et al., 2023). The different measures combined allowed for capturing both perceptual and behavioural dimensions associated with firm behaviour, as well as allowing the researcher to collect data on the firm/industry at large (Blumberg et al., 2011; Saunders et al., 2023).

The data collection took place through the use of Google Forms and was distributed via direct email contact and telephone outreach to firms. Prior to the entire distribution of the questionnaire, it was pre-tested to ensure sufficient clarity, relevance and appropriate time for completion (Blumberg et al., 2011; Saunders et al., 2023).

5.4. Complementary Qualitative Insights

While the bulk of the research utilized quantitative methods, through the collection and analysis of survey data, additional qualitative interviews were also conducted with practitioners working within the Portuguese metalworking industry. The goal of these interviews was to enhance the contextual understanding of the industry and to assist in interpreting findings obtained from empirical data (Blumberg et al., 2011).

There were three key purposes for conducting these interviews. The first was to ensure that the items on the questionnaire were relevant and understandable; thereby aligning with current industry practices (Blumberg et al., 2011; Saunders et al., 2023). The second was to understand how international sanctions have impacted the operations of firms, specifically with respect to supply chain disruptions, changes in cost structures, and strategic responses (Blumberg et al., 2011). Finally, to identify similar challenges among firms facing an increase in geopolitical uncertainty, and to provide examples of how firms mitigate these challenges (Hosseini et al., 2019).

The format for the interviews was semi-structured, which provided the flexibility to allow exploration of participant-specific issues while retaining focus on the study's core themes. Each interaction lasted approximately 20-40 minutes and was conducted in person or via remote means (telephone, video conferencing, etc.). Notes were taken either during the interview or immediately thereafter, to ensure that all of the key points that arose from the interaction were accurately recorded (Blumberg et al., 2011; Saunders et al., 2023).

The qualitative insights derived from the semi-structured interviews were not subjected to formal statistical analysis, they were used to provide complementary support to the quantitative results obtained in this research study (Creswell, 2018).

The summaries of the interviews conducted for this research are presented in Appendix B

5.5. Population and Sample

All the companies analysed for the purposes of this study are Portuguese companies on the metalworking industry. Due to challenges finding a complete list of the population and limited availability of companies to participate in the study, a non-probability sampling approach was used for this study, namely convenience sampling. This is often done in organizational research, especially when access to people

willing to respond are entirely dependent upon their availability at the time of the research (Blumberg et al., 2011; Saunders et al., 2023).

The companies in the sample are all at different levels of internationalisation; there are companies that export and have been established in overseas markets, as well as companies that operate solely in the domestic market. Being able to include comparisons gives an opportunity to examine the effects of international sanctions across the international and the domestic context (Blumberg et al., 2011; Saunders et al., 2023)

A total of 46 valid responses were collected. The low rate of respondents can be attributed to a variety of reasons, time constraints of the companies, limited number of people available to participate, and sensitivity of the information requested from companies that import internationally and/or distribute their products via international supply chains (Blumberg et al., 2011; Saunders et al., 2023).

Additionally, data collection was affected by contextual constraints. For example, the Central region of Portugal is home to a large concentration of metalworking firms and was severely impacted by lengthy power outages following Storm Kristinn between the end of January and mid-February 2026. Many companies were unable to respond during this time, and therefore this situation may have had a residual impact on response availability during the data collection period (Abreu, 2026).

While there are limitations associated with this sample, it does offer useful information within the area of study (Saunders et al., 2023). As this was an exploratory study and used PLS-SEM for data analysis, no single universally accepted minimum sample size was imposed. In accordance with the "10-times rule," the sample size required is equal to ten times the maximum number of structural paths to any construct in the model, this condition has been met in this research (Rana et al., 2025). As such, it can be concluded that the sample is considered acceptable for exploratory PLS-SEM analysis to support empirical analysis and hypothesis testing

5.6. Measurement of Variables

The measurement of variables follows directly from the operationalisation of constructs presented in the previous section ensuring consistency between the conceptual framework and the empirical instrument.

Given the nature of the research, which combines quantitative data collection with complementary qualitative insights, perceptual measures were considered appropriate to capture firms' experiences and responses to sanctions (Blumberg et al., 2011).

Different types of scales were used to measure different constructs and include the following: Likert scales were primarily used to measure levels of agreement/perceived impact, frequency measures provided measures of how many times disruptions occurred, some ordinal and categorical variables were used to measure firm characteristics and strategic responses. All of the core constructs have been treated as reflective constructs, meaning that it is assumed that observed indicators are manifestations of the underlying latent variable (Blumberg et al., 2011; Saunders et al., 2023). This is consistent with previous supply chain research and previous organisational studies where performance, disruption, or resilience are typically used as the latent variable (Rana et al., 2025).

An evaluation of the reliability and validity of the measurement model is conducted using the PLS path modelling framework (Rana et al., 2025). In particular, internal consistency is assessed using both Cronbach's alpha and composite reliability, along with convergent validity using AVE. Discriminant validity is also evaluated to ensure that each construct is measured as distinct from one another (Rana et al., 2025; Saunders et al., 2023).

The model includes control variables in order to account for firm-specific variations and therefore help to eliminate variability in the main relationships being studied. These control variables are specified in the model and considered in the empirical analyses rather than being continuously discussed throughout the sections (Blumberg et al., 2011; Saunders et al., 2023).

This section presents the operationalisation of the constructs used in the empirical analysis. Each construct was measured using multiple indicators derived from the literature and adapted to the context of the Portuguese metalworking industry. The following Tables summarise the constructs, indicators, measurement scales, and corresponding sources.

Table 3 - Company Characteristics (Control Variables)

Indicator / Variable	Question	Measurement Scale	Source
Company Name	Q1	Open-ended (text)	Author's own elaboration
Respondent Email	Q2	Open-ended (text)	Author's own elaboration
Industry/ Activity Classification	Q3	Open-ended (text)	(AICEP, n.d.-b, n.d.-a; Ali et al., 2024)
Type of Activity	Q4	Nominal Categories	(AICEP, n.d.-b, n.d.-a; Ali et al., 2024)
Firm Size	Q5 and Q8	Ordinal Category	(Pham et al., 2023; Shakeri et al., 2016)
Geographical Location	Q6	Nominal categorical	(Moradlou et al., 2021; Roscoe et al., 2022)
Firm Age	Q7	Ordinal Category	(Gligor et al., 2020)
Turnover	Q9	Ordinal Category	(Pham et al., 2023; Shakeri et al., 2016)

These items were collected for identification and follow-up purposes only and were not used in the empirical analysis to ensure respondent anonymity.

Table 4 - International Trade Context

Indicator / Variable	Question	Measurement Scale	Source
Export Activity	Q10	Ordinal (frequency)	(Le, 2022; Pfeffer & Salancik, 2009)
Export Destinations	Q11	Nominal + ranking	(AICEP, 2025; Kavaklı et al., 2020)
Import Activity	Q12	Ordinal (frequency)	(Pfeffer & Salancik, 2009; Shakeri et al., 2016)
Import Origins	Q13	Nominal + ranking	(AICEP, 2025; Fan et al., 2024)
Type of Sanctions	Q14	Nominal categorical	(Meyer et al., 2023; Wang et al., 2025)
Dependency on External Suppliers	Q15	5-point Likert	(Pfeffer & Salancik, 2009)
Relationships with Sanctioned Countries	Q16	Ordinal categorical	(Meyer et al., 2023)
Countries under Sanctions	Q17	Open-ended	(Imbs & Pauwels, 2024; Meyer et al., 2023)

Table 5 - Impact of Sanctions on the Supply Chain

Indicator / Variable	Question	Measurement Scale	Source
Affected Value Chain Stages	Q18	Nominal categorical	(Roscoe et al., 2022; Shakeri et al., 2016)
Access to critical Inputs	Q19	Frequency (1–5)	(Shakeri et al., 2016)
Supply Chain Visibility	Q20	Ordinal Categorical	(Wang et al., 2025) (Shalpegin et al., 2023)
Increase in Supply Costs	Q21	Likert (1–5)	(Hendricks & Singhal, 2005)
Supplier Substitution	Q22	Ordinal Categorical	(Kırılmaz & Erol, 2016)
Delays	Q23	Frequency (1–5)	(Ali et al., 2024; Hendricks & Singhal, 2005)
Logistics Distribution	Q24	Ordinal Categorical	(Moradlou et al., 2021)
Planning Uncertainty	Q25	Likert (1–5)	(Liagkouras & Metaxiotis, 2023)
Time Horizon	Q26	Nominal categorical	(Gutmann et al., 2023; Wang et al., 2025)
Energy Availability	Q27	Frequency (1–5)	(Omokaro et al., 2025)
Overall Disruption	Q28	Likert (1–5)	(Pham et al., 2023)

Table 6 - Operational Performance

Indicator / Variable	Question	Measurement Scale	Source
Production Impact	Q29	Frequency (1–5)	(Hendricks & Singhal, 2005)
Delivery Performance	Q30	Likert (1–5)	(Ali et al., 2024)
Product Quality	Q31	Frequency (1–5)	(Shakeri et al., 2016)
Financial Performance	Q32	Likert (1–5)	(Hendricks & Singhal, 2005; Qiao, 2024)
Overall Operational Impact	Q33	Likert (1–5)	(Pham et al., 2023)

Table 7 - Mitigation Strategies and Risk Management

Indicator / Variable	Question	Measurement Scale	Source
Nearshoring	Q34	Ordinal Categorical	(Pang et al., 2025)
Digitalization	Q35	Ordinal Categorical	(Rodríguez-González et al., 2023; Roscoe et al., 2022)
Reshoring	Q36	Ordinal Categorical	(Moradlou et al., 2021)
Supplier Diversification	Q37	Ordinal Categorical	(Johnson & Haug, 2021)
Risk Management Mechanisms	Q38	Ordinal Categorical	(Tang & Nurmaya Musa, 2011)
Safety Stock	Q39	Ordinal Categorical	(Tang & Nurmaya Musa, 2011)
Collaboration	Q40	Likert (1–5)	(Cinti et al., 2025)
Innovation	Q41	Likert (1–5)	(Ali et al., 2024)
Market Diversification	Q42	Likert (1–5)	(Le, 2022)
Effectiveness of Strategies	Q43	Likert (1–5)	(Althaqafi, 2025)
Rick Mechanisms (detail)	Q44	Open-ended	(Tang & Nurmaya Musa, 2011)

Table 8 - EU and National Legislation

Indicator / Variable	Question	Measurement Scale	Source
Trade Process Difficulty	Q45	Frequency (1 - 5)	(Roscoe et al., 2022)
Regulatory Examples	Q46	Open-ended	(Early & Peterson, 2023; Scott, 2008)
CBAM Awareness	Q47	Ordinal Categorical	(Belik et al., 2022; European Commission, 2025)
CBAM Impact	Q48	Likert (1–5)	(Belik et al., 2022)
Administrative Burden	Q49	Likert (1–5)	(Ali et al., 2024; Scott, 2008)
Regulatory Aggravation	Q50	Likert (1–5)	(Meyer et al., 2023; Özdamar & Shahin, 2021)

Table 9 - Overall Assessment and Future Expectations

Indicator / Variable	Question	Measurement Scale	Source
Overall Sanctions Impact	Q51	Likert (1–5)	(Shakeri et al., 2016)
Persistence of Effects	Q52	Likert (1–5)	(Wang et al., 2025)
Preparedness	Q53	Likert (1–5)	(Althaqafi, 2025)
External Support	Q54	Dichotomous	(Cooper, 2024; Tavrikov & Yashalova, 2024)
Institutions Used	Q55	Nominal Categorical	(AICEP, 2025; Roscoe et al., 2022)
Additional Comments	Q56	Open-ended	Author's own elaboration

5.7. Data Analysis Techniques

Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed to analyse the data using SmartPLS software, which was chosen for its suitability towards exploratory research especially for studies including smaller collection sizes and have complex models with multiple constructs and relationships. Unlike covariance-based SEM, PLS-SEM does not require strict assumptions regarding data normality, making it appropriate for the characteristics of the dataset used in this study (Rana et al., 2025).

The analysis followed a two-step approach, consisting of the assessment of the measurement model and the structural model. This procedure ensures both the reliability of the constructs and the validity of the relationships tested.

The measurement model was evaluated to assess the reliability and validity of the constructs. Indicator reliability was examined through the use of outer loadings, where loadings higher than 0.70 are considered acceptable (Rana et al., 2025). Internal consistency was established via Cronbach's alpha and composite reliability to determine that the constructs measure consistently the intended concept. Average Variance Extracted (AVE) was used to access convergent validity of the constructs, with any value greater than 0.50 indicating the construct explains more than half of the variance of its indicators. Discriminant validity was assessed using the Heterotrait–Monotrait ratio (HTMT), ensuring that constructs are empirically distinct from one another (Rana et al., 2025; Saunders et al., 2023).

Following the validation of the measurement model, the structural model was then assessed to test the research hypotheses. The path coefficients were analysed to determine the relationship between the constructs, and were assessed for statistical significance using bootstrapping methods. The coefficient of determination (R^2) was then used to quantitatively assess the explanatory power of the model, indicating the proportion of variance in the dependent variables that was accounted for by the independent variables. Additionally, an assessment of multicollinearity of the predictor variables was conducted using the Variance Inflation Factor (VIF) to ensure there were no problematic levels of multicollinearity (Rana et al., 2025; Saunders et al., 2023). This approach allows for a comprehensive assessment of both measurement quality and structural relationships within a single analytical framework.

5.8. Ethical Considerations

All data collected from this research project was securely stored and only used for academic purposes. Participants were informed about the objective of the research and that their involvement in the research was entirely voluntary (Blumberg et al., 2011). No identifying or sensitive information about participants was collected or disclosed.

Participants who attended meetings and provided information during those meetings were also contacted after the data collection process was completed and were specifically asked whether they would allow their name and organisation to be referenced in the publication of the research findings and would allow the information they provided during their meeting to be shared (Creswell, 2018).

6. Results

In this chapter, we provide a descriptive analysis of all of the data collected through the questionnaire. We will analyse the distribution of the responses for each of the main variables of interest by focusing on the frequency distributions and percentage distributions. The descriptive analysis will provide an overview of the characteristics of firms, the extent to which firms are exposed to international sanctions, the types of supply chain disruptions they experience, and the strategic responses they create to combat those disruptions. Graphical representations of the questionnaire results are presented in Appendix A.

6.1. Descriptive Statistics

6.1.1. Sample Characterization

The sampled set is comprised of 46 firms from Portugal's metalworking industry. The sample includes companies with different structural characteristics, reflecting the diversity of the sector.

The organisations within the sample had various characteristics, micro enterprises, represented 21.7% small firms 30.4% of businesses, medium firms 30.4%, and large firms 17.4%, are interspersed throughout the sample. In terms of age of the companies, 73.9% of the firms in the sample have been in business longer than 20 years, indicating that the majority of firms in the sample are mature businesses. The range of revenues for the companies in the sample is also reflective of the wide range of sizes of businesses, with 13% of firms having revenues greater than 50 million euros per year, whilst 34.8% of the firms fall into lower revenue ranges.

Geographically, firms are distributed across different regions of Portugal, although a higher concentration is observed in the North of Portugal, traditionally associated with industrial activity. This reflects the geographical clustering of the metalworking industry.

6.1.2. Dependency on External Suppliers and Markets

This part examines how companies conduct business internationally and whether or not they use outside providers for supplies to illustrate the structure of their supply chains.

First, with regard to exporting, when looking at complete data comparing domestic and foreign company export activities, 43.5% of companies export on an ongoing basis and 23.9% export on an occasional basis, the rest do not export at all. Similarly, when comparing total domestic and foreign import activity for all companies, there are also similar trends, with respect to 54.3% of companies regularly importing

goods and 23.9% of companies occasionally importing and others not importing at all.

Second, when dealing with external supply sources,26.1% of companies indicated that they depend on external providers either highly or very highly, while approximately 30.4% stated that they depend on them moderately, and 43.4% indicated that they depend on them either lightly or not at all. The overall findings indicate that while there exists a small group of firms with a high degree of reliance on external suppliers, most of the other firms in this sample are reported to have lower levels of supplier reliance. This suggests that the supply chains of these firms differ significantly, thus, potentially exposing some firms more than others to risks posed by external disruption. The heterogeneity exists within the context of exploring the effects of an external shock.

6.1.3. Exposure to International Sanctions

The extent to which firms view international sanctions as influencing their business practices and whether they feel those impacts will last were analysed in this section.

The perceived effects of sanctions were measured by examining how many firms responded. Overall, there were 4.4% of firms that rated the overall effect of sanctions as being high or very high, with 30.4% rating the overall effect as moderate and 65.2% rating it as low or non-existent. Therefore, even though sanctions are not experienced equally by all companies, results suggest that sanctions were perceived as having limited direct effects, although a wider a smaller subset of responding firms stating that the impact of sanctions was reported moderate to high.

In addition, a significant number of firms expect that sanctions effects will be ongoing. In fact, 56.5% reported that continued effects from international sanctions were likely or very likely to occur, while 21.7% reported that continued effects from international sanctions were unlikely or very unlikely. This variability suggests that the exposure to sanctions is not homogeneous, and that firms may be affected differently depending on their level of international integration and supply chain structure.

6.1.4. Supply Chain Disruption

This study explores how far supply chains are disrupted for companies using numerous criteria and represents multiple aspects of total disruption as well as those related to frequency and uncertainty.

With regard to access to critical inputs, the results indicate that 10.9% of firms reported occasional difficulties, and 89.1% reported little or no impact. These findings suggest that sanctions have affected firms' ability to secure essential components and technologies required for their operations.

With respect to delay, 2.2% of respondents said they are experiencing delays very often or all the time,

30.4% said they have experienced occasional delays; and 67.4% said they have had delays only almost never or not at all.

Planning uncertainty is also an important area of discussion because 41.3% of firms indicated that they agree or strongly agree that their level of planning uncertainty has increased, while 58.7% did not express any difference in planning uncertainty from previous periods through either neutral or disagreeing responses. Disruptions are, therefore, not only related to operations but also impact how effectively firms will be able to plan for future activities.

With respect to energy-related disruptions, 54.3% of firms reported that sanctions never affected energy availability. In addition, 19.6% rarely reported disruptions, while 23.9% said they experienced it occasionally, while only 2.3% reported frequent impact.

Finally, in terms of overall disruption, 10.9% of firms assessed the impact of sanctions on their supply chain as high or very high, while 23.9% reported moderate levels, and 65.2% indicated low or very low impact.

6.1.5. Institutional Pressure

This section examines the extent to which firms perceive regulatory frameworks, particularly those of the European Union and national legislation, as influencing their operations in the context of international sanctions.

With regard to the impact of the Carbon Border Adjustment Mechanism (CBAM), 21.8% of firms reported a high or very high impact on supplier relationships, while 32.6% indicated a moderate impact, and 45.6% reported low or very low impact.

In terms of the broader regulatory environment, 8.7% of respondents indicated that EU and national legislation have aggravated the effects of international sanctions to a high or very high extent, while 26.1% reported moderate aggravation, and 65.2% indicated little or no additional impact.

6.1.6. Mitigation Strategies

In this section, the strategies adopted by firms to mitigate the effects of international sanctions are examined.

With regard to supplier diversification, the results indicate that 10.8% of firms reported significant or ongoing restructuring of their supplier base, while 19.6% indicated limited diversification, and 69.6%

reported no changes. This suggests that most firms have not substantially adjusted their sourcing strategies in response to external disruptions.

In terms of risk management practices, 8.7% of firms reported having structured mechanisms in place, while 26.1% indicated informal approaches, and 65.2% reported no reinforcement of risk management practices. This indicates that the majority of firms have not significantly strengthened their risk management practices.

Regarding inventory strategies, 47.8% of firms reported increasing safety stock levels significantly or moderately, while 52.2% indicated no changes, suggesting that inventory-based strategies have been adopted by a relevant proportion of firms, although they are not widespread across the sample.

With respect to collaboration within the supply chain, 37% of respondents agreed or strongly agreed that collaboration and information sharing with partners have increased, while 30.4% expressed neutral, 32.6% have opposing views. These results suggest that collaboration has not been consistently strengthened across firms.

In terms of internal development and innovation, 21.8% of firms agreed or strongly agreed that sanctions have stimulated internal development and innovation, 39.1% expressed neutral, while 39.1% reported no significant change. This indicates limited evidence of increased investment in internal capabilities.

Similarly, regarding market strategies, only 17.4% of firms reported diversifying their export markets, reflecting that market diversification has been relatively limited among firms.

Finally, regarding the perceived effectiveness of these strategies, 21.7% of respondents agreed that the measures adopted have reduced the impact of sanctions, while 78.3% expressed neutral or opposing views. Overall, mitigation strategies have not been widely perceived as effective in reducing the impact of sanctions.

6.1.7. Operational Performance

Regarding production, 4.4% of firms frequently or always experienced negative impacts to the production process, with 15.2% indicating they occasionally felt these impacts and 80.4% reporting they experienced little or no impact from sanctions on their production processes. Therefore, the results suggest that sanctions are perceived to have had a limited impact on the production processes of most firms.

In terms of delivery performance, 21.8% of firms agreed or strongly disagreed that their ability to meet

delivery deadlines has become worse/greatly reduced due to sanctions, while 28.2% indicated they didn't agree or disagree. The other 50% either disagreed or strongly disagreed. These findings suggest that, for most firms, delivery performance has not been significantly affected by sanctions.

In terms of financial performance, 34.7% of firms agreed or strongly agreed that the sanctions have negatively impacted their financials, whereas 32.6% indicated there was little or no negative impact on their financial performance as a result of the sanctions imposed. This indicates that the financial impact of sanctions is mixed across firms, with no clear dominant effect.

Lastly, when asked to rate the overall operational impact that the sanctions imposed against them have had on their operations, 2.2% of firms rated the overall impact as being high or very high, 30.4% rated the overall impact as being moderate, and 67.4% rated the overall impact as being low or very low.

Overall, the results indicate that international sanctions have had a generally limited impact on the operational performance of firms, although the extent of this impact varies across the sample.

6.2. Measurement Model Assessment

In order to determine the reliability and validity of the constructs used in this research study, an assessment of the measurement model was conducted. Given the exploratory approach to research, and the application of Partial Least Squares Structural Equation Modelling (PLS-SEM), the assessment was conducted in accordance with standard practices as recommended in the literature. The assessment consisted of determining the internal consistency reliability of the constructs, convergent validity, and discriminant validity.

All constructs within the model were operationalized as reflective constructs and evaluated using external loadings, Cronbach's alpha, composite reliability (CR), the average variance extracted (AVE), and the heterotrait-monotrait ratio (HTMT). Detailed measurement model results are presented in Appendix C.

6.2.1. Internal Consistency Reliability and Convergent Validity

Internal consistency reliability was measured using Cronbach's alpha and composite reliability. The general criterion of acceptable reliability measures lies within the threshold above 0.70 for both indicators; however, lower values can be accepted in exploratory research contexts.

The results indicate that most of the constructs have satisfactory values of reliability. Cronbach's alpha lies within the range of 0.713 to 0.843 for most constructs. The construct Exposure to International Sanctions has a slightly lower level of Cronbach's alpha value, which equals to 0.645. Nevertheless,

this value is considered acceptable due to the exploratory nature of the study and the limited number of indicators used to measure this construct.

Values of composite reliability lie between 0.839 and 0.888 for all constructs. They exceed the threshold of 0.70 for all of them, hence, composite reliability is sufficient for the constructs under investigation.

Finally, convergent validity was estimated by means of average variance extracted (AVE). All constructs show adequate values of average variance extracted, lying within the range of 0.613 and 0.731. All constructs exceed the minimum threshold of 0.50, indicating that a sufficient proportion of variance is explained by the indicators.

The analysis of outer loadings further supports these results. Most indicators exhibit loadings above the recommended threshold of 0.70, indicating strong indicator reliability. Overall, the results confirm that the measurement model demonstrates satisfactory levels of internal consistency and convergent validity.

6.2.2. Discriminant Validity

Discriminant validity of the model was evaluated through the heterotrait-monotrait ratio (HTMT) since this method was seen as a better criterion for discriminant validity compared to conventional techniques. Discriminant validity can be deemed sufficient when HTMT values are lower than 0.90.

Most HTMT values lie within the acceptable range, implying construct separation. However, some values exceed the recommended threshold, particularly between Mitigation Strategies and Operational Performance (HTMT = 0.970), as well as between Supply Chain Disruption and Operational Performance (HTMT = 0.951). Additionally, a marginally high value is observed between Institutional Pressure and Exposure to International Sanctions (HTMT = 0.913).

These results suggest a degree of conceptual overlap between certain constructs, which is theoretically expected given the strong interdependence between supply chain disruption, firm responses, and operational outcomes. In this context, operational performance is directly influenced by both disruption effects and mitigation strategies, which explains the elevated HTMT values. Despite these limitations, the constructs were retained due to their theoretical distinctiveness and relevance within the proposed model. Overall, while minor concerns regarding discriminant validity are present, the measurement model demonstrates an acceptable level of construct differentiation, particularly within the context of an exploratory study.

6.3. Structural Model Assessment

The measurement and evaluation of the relationship among constructs will be accomplished by using the structural model to assess the degree of explanatory power of the model, through an analysis of R^2 (coefficient of determination), path coefficients and statistical significance through bootstrapping. The structural model results obtained through SmartPLS are summarised below, with full outputs presented in Appendix C

6.3.1. Coefficient of Determination (R^2)

The coefficient of determination (R^2) was used to assess the model's explanatory power, indicating the proportion of variance in the endogenous constructs explained by the model.

The results indicated that the Operational Performance construct has a moderate to high level of explanatory power, as evidenced by an R^2 value of 0.678, indicating that Supply Chain Disruption and Mitigation Strategies jointly explain approximately 67.8% of the variance.

Mitigation Strategies has a moderate level of explanatory power, as demonstrated by its R^2 value of 0.519, indicating that approximately 51.9% of the variance is explained by supply chain disruption. This indicates a moderate level of explanatory power, albeit less so than Operational Performance.

Finally, Supply Chain Disruption has an R^2 value of 0.436, indicating that approximately 43.6% of the variance is explained by exposure to international sanctions, dependency on external suppliers and markets, and institutional pressure.

In summary, the degree of explanatory power indicated by R^2 reflects that the model has adequate explanatory capacity with respect to Operational Performance, which is the focus of this study.

6.3.2. Path Coefficients

The strength and direction of the relationship between constructs was examined through a path coefficient analysis.

The analysis suggests that the Exposure to International Sanctions construct has a strong positive impact on the Supply Chain Disruption construct ($\beta = 0.533$), indicating that companies experiencing a higher level of exposure to sanctions will have higher levels of disruption.

The External Supplier and Market Dependency construct has a weaker positive correlation with the Supply Chain Disruption construct ($\beta = 0.171$) than the other predictor constructs, indicating that this factor does not play a decisive role in explaining disruption within the sample.

The Institutional Pressure construct has the weakest effect on Supply Chain Disruption (β = 0.072) compared to the other predictor constructs. Therefore, Institutional Pressure does not seem to be contributing significantly to the Supply Chain Disruption construct for the companies examined in this study, reinforcing the interpretation that institutional factors act as contextual or indirect influences rather than direct drivers of disruption.

In terms downstream effects, the Supply Chain Disruption construct has a strong positive effect on the Mitigation Strategies construct (β = 0.720), indicating that firms experiencing higher levels of disruption are more likely to implement mitigation measures.

Furthermore, the Supply Chain Disruption construct has a strong positive correlation with the Operational Performance construct (β = 0.482), suggesting that higher levels of disruption are associated with a greater perceived impact on operational outcomes.

Finally, the Mitigation Strategies construct has a moderate positive correlation with the Operational Performance construct (β = 0.405), indicating that the implementation of mitigation measures contributes to improving operational outcomes in the presence of disruption.

6.3.3. Bootstrapping and Hypotheses Testing

The evaluation of statistical relevance for the connections amongst variables of interest, was performed via a bootstrap analysis that provided t-statistics and p-values.

Evidence from the analysis reveals that Exposure to International Sanctions has a statistically significant relationship with Supply Chain Disruption (β = 0.533; $p < 0.001$); therefore, H1 is considered supported.

There is no statistically significant relationship between Dependence on External Suppliers and Markets and Supply Chain Disruption (β = 0.171; p = 0.175); therefore, H2 is rejected.

There is statistically significant evidence to support the connection between Supply Chain Disruption and Operational Performance (β = 0.482; $p < 0.001$); therefore, H3 is supported. This result reflects that higher levels of disruption are associated with a greater perceived impact on operational performance.

There is insufficient evidence to support an association between Institutional Pressure and Supply Chain Disruption (β = 0.072; p = 0.613); therefore, H4 is rejected.

There is statistically significant evidence to support the connection between Supply Chain Disruption and Mitigation Strategies (β = 0.720; $p < 0.001$); therefore, H5 is supported.

Finally, the results show that Mitigation Strategies have a statistically significant relationship with Operational Performance (β = 0.405; p = 0.023); therefore, the corresponding hypothesis, H6, is supported.

Overall, the results offer some backing for the proposed model. The relationship between Exposure to International Sanctions and Supply Chain Disruption had strong empirical support, as did the downstream impacts of Supply Chain Disruption on Mitigation Strategies and Operational Performance. However, no empirical support was available for the relationships between Dependency on External Suppliers and Markets and Institutional Pressure indicating they were not the main drivers of disruption within this study's context.

6.4. Hypotheses Testing

The following section summarizes the results for each tested hypothesis as assessed via the structural model and bootstrap analysis of the data. The information presented in Table 10 identifies each proposed relationship, including its associated path coefficient, significance level, and the outcome of the hypothesis.

Given the exploratory nature of the study and the limited sample size, the results are interpreted cautiously and should be understood as indicative rather than conclusive.

Table 10 – Hypothesis Testing

Hypothesis	**Relationship**	**Path Coefficient (β)**	**p-value**	**Result**
H1	Exposure to International Sanctions → Supply Chain Disruption	0.533	0.000	Supported
H2	Dependency on External Suppliers and Markets → Supply Chain Disruption	0.171	0.175	Not Supported
H3	Supply Chain Disruption → Operational Performance	0.482	0.003	Supported
H4	Institutional Pressure → Supply Chain Disruption	0.072	0.613	Not Supported
H5	Supply Chain Disruption → Mitigation Strategies	0.720	0.000	Supported

H6	Mitigation Strategies → Operational Performance	0.405	0.023	Supported

In sum, the empirical evidence generated by the structural model offers a degree of support for the proposed model. In particular, the findings show that being subject to international sanctions is a primary driver for supply chain disruption, and disruption significantly influences both the use of mitigation strategies and the perceived effect on operational performance as well. Moreover, the results also show that mitigation strategies are effective in reducing the adverse impact of disruption on operational performance. On the other hand, dependency on external suppliers and/or markets and institutional pressure were not found to have statistically significant direct effects on supply chain disruption, suggesting that these factors may act as context or indirect influences rather than being primary drivers. Ultimately, the model describes a satisfactory level of explanatory adequacy and provides insight into how international sanctions affect the dynamically changing nature of supply chains and firm performance on the metalworking industry in Portugal.

7. Discussion

7.1. Interpretation of Findings

This study's objective was to analyse the degree to which international sanctions can impact supply chain interruption and operational effectiveness in the Portuguese metalworking sector. The results reveal that national/global firms in an increasingly worldwide and dependent industry have different responses to geopolitical restrictions.

The results generally demonstrate that international sanctions are manifested differently for individual organizations based on their levels of exposure to sanctions, extent of resource dependence on other entities, and position within the chain of suppliers. This is consistent with the literature, where there is an emphasis on the variability in the degree of disruption that sanctions can generate across different firms on a national/global basis (Meyer et al., 2023; Shalpegin et al., 2023)

Regarding H1, the results support the hypothesis that exposure to international sanctions is positively associated with supply chain disruption. Firms that reported higher degree of perceived exposure to sanctions, also reported an increase in supply chain disruption with respect to access to raw materials, delays in delivery, and operational uncertainty. Previous research suggests that national and international sanctions are an additional source of global supply chain structure instability by limiting the movement of goods and services as well as access to key resources (Fan et al., 2024; Roscoe et al., 2022). The descriptive outcomes of this study imply that the perceived direct effect of sanctions is limited for a large number of organisations and therefore show that exposure is not the same across the sector.

Contrary to expectations, H2 is not supported, as no statistically significant relationship was found between dependency on external suppliers and markets and the severity of supply chain disruption. Although Resource Dependence Theory suggests that firms with higher dependency should be more vulnerable, this result may indicate that internationally active firms have developed capabilities, such as supplier diversification and risk management practices, that allow them to better cope with external shocks.

Regarding H3, contrary to the traditional expectation that supply chain disruption negatively affects operational performance, the findings indicate a positive relationship between disruption and operational performance deterioration. The operational definition reflects the deterioration of performance through measuring the negative results of disruption through such things as, rising costs, late delivery of materials or products and economic inefficiency. Thus, increased levels of operational disruption produce greater declines in operational performance.

In addition to this measurement-related explanation, the results may also reflect firms' adaptive responses

to disruption. Data collected from surveys and qualitative results support this notion that firms are altering operational procedures, changing supplier relationships, and passing along the increased costs of operations to customers as a result of operational disruptions. Literature also supports this view that disruptions can stimulate the development of coordination structures and adaptive capability in the supply chain (Pham et al., 2023). While disruptions generally produce negative impacts on firms, the firms' responses to these disruptions may reduce the negative effect of disruption and provide a more complicated measurement of performance results as it relates to disruption.

H4 is also not supported, there was no statistically significant relationship between institutional pressures and supply chain disruptions. Firms found regulatory frameworks, such as the CBAM and related energy transition policies, to be of relevance when determining how environmental pressures affect their supply chain, but the degree of impact appears to be indirect through increased compliance and administrative burdens and not via directly disrupting operational supply chains. This interpretation is supported by qualitative evidence, as firms reported increased complexity and uncertainty related to regulatory implementation, rather than direct disruption of supply chain flows.

These results support H5, indicating that it positively correlates to the implementation of mitigation measures by firms that experience the highest levels of disruption. Firms with greater disruptions often implement measures such as developing multiple suppliers, monitoring supply chain risks more closely, and strengthening internal processes. These findings support previous research on supply chain risk management (Johnson & Haug, 2021; Moradlou et al., 2025), which supports both reactive and proactive approaches to mitigating risk, as well as the qualitative data presented herein that support many firms have changed or reinforced the risk management practices related to supplier selection and management of inventories.

Although H7 and H8 were not explicitly tested as hypotheses, the results provide limited indirect support to the rationale behind each hypothesis. Companies that implemented stronger mitigation strategies reported a greater ability to maintain their level of operational stability than those who did not implement mitigation strategies, which suggests that the implementation of these strategies may contribute to enhancing resilience from a conceptual perspective in an organisation beyond the specific example of mitigating sanctions-based disruptions. However, as the measurement limitations outlined above indicate, the evidence of the relationship between mitigation strategy and operational resilience is conceptual, and therefore must be applied with caution.

Overall, these results indicate that the relationship among sanctions, disruption, and performance is nonlinear in nature. Disruptions do not manifest only as negative outcomes, rather, they cause

organisations to adapt and potentially alter the supply chain and operational processes that they use in business operations. These findings are supported by the statistical results presented in Appendix C

7.2. Theoretical Implications

This research offers significant contributions to the literature regarding firm-level empirical data on the effects of international sanctions as they relate to Supply Chain Management. Previous studies have mainly examined the macroeconomic outcomes of sanctions; however, this study provides an important micro-level understanding of how firms directly experience sanctions as well as how they respond.

The first contribution is that the results validate Resource Dependence Theory. The findings partially support the theoretical framework by confirming that external constraints play a role in shaping firm behaviour. However, contrary to expectations, no significant relationship was found between external dependency and supply chain disruption, suggesting that dependency does not necessarily translate into increased vulnerability. This may indicate that firms actively manage their dependencies through strategies such as supplier diversification and risk management practices, supporting a more dynamic interpretation of Resource Dependence Theory.

The second principal contribution of this paper to the literature is the extension of Institutional Theory. The results of this study demonstrate that Regulatory frameworks function both as sources of legitimacy and as material constraints on operational processes. The positive association between Institutional Pressure and Supply Chain Disruption demonstrates the importance of coercive mechanisms in determining firms' behaviour in highly regulated industries, such as the metal industry.

The third contribution of this research is to expand on the literature about supply chain disruption and operational performance relations by providing a more differentiated view of the connection between disruption and performance. This reflects the measurement of performance through negative indicators, such as increased costs, delays, and inefficiencies. At the same time, the results support emerging literature suggesting that disruption generates both negative outcomes and adaptive responses, reinforcing the idea that performance under disruption is complex and context dependent.

Additionally, while the study did not test empirically the concept of supply chain resilience, it did introduce important conceptual considerations related to the operationalisation of supply chain resilience as an important, but ultimately difficult construct. The results suggest that the resilience of supply chains may develop as firms respond to disruptions, rather than simply being a static capability, this conceptually supports the development of the dynamic and process oriented nature of supply chain resilience.

7.3. Managerial Implications

There are many important managerial considerations for managers within the Portuguese metalworking sector identified by the findings of the study.

The first is ensuring that firms do not become over-reliant on external third-party suppliers and/or international markets. Businesses that heavily rely on international supply chains tend to be more impacted by geopolitical conflict; therefore, managers should consider implementing strategies such as supplier diversification, regionalisation or sourcing within their home country to provide businesses greater flexibility.

Second, increased levels of regulatory and institutional pressure have been noted with regard to the functioning of supply chains. Compliance requirements of the EU legal framework, particularly with respect to environmental directives and trade regulations, are no longer voluntary; rather they require managers to develop proactive compliance plans. Investment in improved visibility of supply chain processes, including data collection, is essential to ensuring compliance and reducing uncertainty.

Third, study shows the impact of mitigation strategies on how management responds to disruptions. Mitigation strategies, supplier diversification, enhanced monitoring and working with supply chain partners, are necessary for managing continuity of operations; thus, Managers must develop and implement structurally sound risk management frameworks rather than reactively respond.

Fourth, results suggest companies view disruptions as both a risk and an opportunity to develop internal capabilities and improve coordination mechanisms. Companies that actively work to overcome disruptions may be better able to deal with future disruptions, thus highlighting the importance of flexibility and learning within an organisation.

The findings illustrate that balancing efficiency with resilience is considered critical for effective supply chain management in the face of geopolitical risks. Companies need to adopt new methods to adapt and respond to an increasingly unpredictable global market rather than using historical methods of cost minimisation.

8. Conclusions

8.1. Main Conclusions

The objective of this study was to investigate how exposure to international sanctions impacts disruption of supply chains as well as performance of operations on the metalworking sector of Portugal. Several important conclusions were drawn from the data analysis performed.

The first conclusion from the study was that international sanctions serve as an impetus to supply chain disruption; however, the types and severity of disruptions will differ between the firms within the sample. For example, one firm may experience only minimal direct disruptions due to its exposure to international sanctions while another firm may experience major difficulties due to disrupted access to inputs, delayed shipments, and increased uncertainty regarding its operations. This demonstrates that the impact of international sanctions will differ depending upon the firm's level of globalization as well as its specific role in the network of global supply chains.

The second conclusion from the data analysis was that external dependency was not a statistically significant predictor of supply chain disruptions. The findings suggest that firms do not passively accept being constrained by their external dependencies; rather, firms take a proactive approach by utilising various strategic tactics (e.g., supplier diversification; development of alternative sourcing options) in an effort to mitigate their external dependency on one or more of their suppliers.

The third conclusion from the data analysis was that disruptions within the supply chain result in declines in operational performance as evidenced by increases in costs, delays, and operational inefficiencies. However, the relationship between the magnitude of supply chain disruption and operational performance was found to be nonlinear. More specifically, the firms that experience supply chain disruptions implement adaptive strategies in response to such disruptions which ultimately partially mitigate the detrimental effects of supply chain disruptions. Collectively, the results demonstrate the complexity of the relationship between the performance of organisations and geopolitical uncertainties.

Fourth, the influence of institutional pressures on the level of disruption in the supply chain was not revealed to directly affect supply chain disruptions. However, institutional pressures do increase the complexity of the supply chain and create more compliance requirements. Therefore, institutional frameworks act as structural restraints rather than as direct drivers of supply chain disruption.

The results of the research, namely, supply chain disruptions can lead to increased levels of mitigation, reinforce to businesses that risk management is a significant competency for businesses operating in volatile or uncertain environments. Businesses may therefore implement risk management processes that allow them to continue their operations despite any impacts of outside factors.

Overall, the findings suggest that the impact of international sanctions on firms is neither uniform nor deterministic. Instead, it varies according to firms' level of international exposure, supply chain configuration, and strategic response. While sanctions may not directly disrupt all firms, they contribute to increased uncertainty and operational complexity, which in turn influence supply chain dynamics and performance outcomes. This reinforces the view that sanctions act as indirect but structurally relevant sources of disruption within global supply chains.

8.2. Contributions of the Study

This research has several implications for the literature on international sanctions and supply chain management.

First, it provides evidence of the impact of international sanctions on individual firms, helping to fill a significant gap in the literature, which has largely focused on aggregate economic impacts.

Second, it adds to the Resource Dependence Theory by demonstrating how a firm's level of external dependence does not necessarily increase its vulnerability, leading to new possibilities for understanding how firms manage their dependencies in a more dynamic way.

Third, it expands on Institutional Theory by showing that regulatory pressures can indirectly impact firms through increasing the complexity of their operations and increasing the compliance requirements they face, rather than through directly disrupting a firm's operations.

Fourth, it improves our understanding of the relationship between supply chain disruption and performance by highlighting the complexity of this relationship, including the importance of measuring the impact of supply chain disruptions on performance and how adaptive responses to a disruption can shape performance outcomes.

Lastly, it makes a conceptual contribution to the study of supply chain resilience by positioning supply chain resilience as a dynamic capability that emerges as firms respond to disruptions.

8.3. Limitations

While this work has contributions, there are limitations to this study that need to be noted.

The first is that using a non-probability convenience sampling method means the results of this study can't be generalised to the broader population. The sample size used in the study is acceptable for exploratory analyses in PLS-SEM, but it is also relatively small. There is a chance, therefore, that this sample does not accurately reflect the wide range of backgrounds within the Portuguese metalworking industry.

The second limitation is that the use of self-report data has the potential to introduce perception bias into the study, particularly regarding people's assessment of sanctions and their effects.

Third, the cross-sectional design of this study limits its ability to capture dynamic change over time, especially since the sanction's effects may change as the situation evolves.

Fourth, there is a limitation in the operational definitions of constructs (i.e., operational performance and resilience) that were utilized in this study. Operational performance was measured by negative measures, which has the potential to affect how results are interpreted. Additionally, resilience construct was not tested empirically due to measurement constraints.

Lastly, qualitative results were incorporated into this study, but were not incorporated into the overall conclusion as a fully integrated qualitative analysis.

8.4. Directions for Future Research

Based on these limitations, several directions for future research can be proposed.

First, future work should involve larger and more representative samples (possibly including additional industries and/or countries) to enhance generalizability. Secondly, longitudinal research designs may provide insight into how the effects of sanctions change over time and will also reflect adaptive behaviour that occurs dynamically. Thirdly, future research should investigate empirical methods for measuring supply chain resilience, providing more reliable indicators to be incorporated into quantitative models. Fourthly, next, it may be helpful for future work to examine the relationship between regulatory pressure and organizational capabilities and thus provide greater clarity about indirect pathways by which context factors can shape supply chain behaviours. Finally, integration of qualitative data (e.g., case studies, in-depth interviews, etc.) will help generate greater insight into organisational decision-making processes when dealing with geopolitical risks.

References

Abreu, P. (2026, February 3). Kristin deixa setores dos moldes e componentes sem capacidade para abastecer multinacionais e exportações. *ECO*. https://eco.sapo.pt/2026/02/03/kristin-deixa-setores-dos-moldes-e-componentes-sem-capacidade-para-abastecer-multinacionais-e-exportacoes/

AICEP. (n.d.-a). *Advanced manufacturing industry*. Retrieved 31 October 2025, from https://www.portugalglobal.pt/en/investment/key-industries/advanced-manufacturing/

AICEP. (n.d.-b). *Metal*. Retrieved 31 October 2025, from https://www.portugalglobal.pt/investimento/principais-setores/metal/

AICEP. (2025, February). *Metalomecânica molda o crescimento em Portugal*. https://www.revista.portugalglobal.pt/AICEP/PortugalGlobal/portugalglobal-n183-fev25/?page=4

AIMMAP. (2023). *Diagnóstico Estratégico do Setor da Metalurgia e Metalomecânica em Portugal* (No. 1). https://www.metalportugal.pt/files/SS01%20Metalurgia%20de%20Base.pdf

Ali, I., Gligor, D., Balta, M., Bozkurt, S., & Papadopoulos, T. (2024). From disruption to innovation: The importance of the supply chain leadership style for driving logistics innovation in the face of geopolitical disruptions. *Transportation Research Part E: Logistics and Transportation Review*, *187*, 103583. https://doi.org/10.1016/j.tre.2024.103583

Althaqafi, T. (2025). Assessing the evolving role of geopolitical risks in supply chain logistics: An empirical analysis of risk management strategies. *International Journal of Computing and Digital Systems*, *17*(1). https://doi.org/10.12785/ijcds/1571007558

Arcipowska, A., Blanco Pérez, S., & Lopez-Olmedo, A. (2026). *Study on DPP content for iron and steel products under ESPR*. European Commission. https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2026-03/Submission_ESPR%20Steel%20DPP%20Content%20Proposal_0.pdf

Bastani, P., Dehghan, Z., Kashfi, S. M., Dorosti, H., Mohammadpour, M., Mehralian, G., & Ravangard, R. (2021). Strategies to improve pharmaceutical supply chain resilience under politico-economic sanctions: The case of Iran. *Journal of Pharmaceutical Policy & Practice*, *14*(1), 1–14. https://doi.org/10.1186/s40545-021-00341-8

Belik, I. S., Starodubets, N. V., Yachmeneva, A. I., & Prokopov, K. A. (2022). Border carbon adjustment: Implications for Russian companies and regions in the context of the Russia sanctions (the case of Magnitogorsk Iron and Steel Works and Chelyabinsk region). *R-Economy*, *8*(3), 252–267.

https://doi.org/10.15826/recon.2022.8.3.020

Blanco Pérez, S., Arcipowska, A., Ranea Palma, A., Maury, T., Napolano, L., Estevenon, L., Fiorese, G., & Torres de Matos, C. (2025). *Preparatory study iron & steel—Ecodesign measures under the ESPR (Draft report)*. European Commission. https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2025-05/Draft_Preparatory%20study%20iron%20%26%20steel_May%202025.pdf

Blumberg, B., Cooper, D. R., & Schindler, P. S. (2011). *Business research methods* (3. European ed). McGraw-Hill Education.

Chen, Y., Jiang, J., Wang, L., & Wang, R. (2023). Impact assessment of energy sanctions in geo-conflict: Russian–Ukrainian war. *Energy Reports*, *9*, 3082–3095. https://doi.org/10.1016/j.egyr.2023.01.124

Cinti, A., Marcone, M. R., Sabatini, A., & Temperini, V. (2025). Enhancing supply chain resilience through the supply network approach. *Journal of Business & Industrial Marketing*, *40*(4), 858–876. https://doi.org/10.1108/JBIM-02-2023-0106

Confederação Empresarial de Portugal. (2026, February 19). *Indústria Metalúrgica e Metalomecânica atinge recorde histórico de exportações em 2025 e exige ação urgente do Governo e da Comissão Europeia*. https://cip.org.pt/industria-metalurgica-metalomecanica-exportacoes-2025/

Cooper, J. (2024). The machine tool industry of Russia at a time of war and sanctions. *Post-Communist Economies*, *36*(5), 527–561. https://doi.org/10.1080/14631377.2024.2325787

Council of the European Union. (2025). *Council recommendation on the economic, social, employment, structural and budgetary policies of Portugal*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C_202503996

Creswell, J. W. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (Fifth edition). SAGE.

DiMaggio, P. J., & Powell, W. W. (1983). The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review*, *48*(2), 147–160. https://doi.org/10.2307/2095101

Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. (2025). *A European Steel and Metals Action Plan—Internal Market, Industry, Entrepreneurship and SMEs* (No. 125). European Union. https://single-market-economy.ec.europa.eu/publications/european-steel-and-metals-action-plan_en

DN/Lusa. (2025, October 30). *Tarifas: Metalurgia alerta CE para impacto negativo das novas taxas sobre o aço*. Diário de Notícias. http://dinheirovivo.dn.pt/empresas/tarifas-metalurgia-alerta-ce-para-impacto-negativo-das-novas-taxas-sobre-o-ao

Drees, J. M., & Heugens, P. (2013). Synthesizing and extending resource dependence theory. *Journal of Management*, *39*(6). https://doi.org/10.1177/0149206312471391

Early, B. R., & Peterson, T. M. (2023). The enforcement of U.S. economic sanctions and global de-risking behavior. *Journal of Conflict Resolution*. https://doi.org/10.1177/00220027231214748

ECO. (2026, February 10). Indústria do metal bate novo recorde de exportações, mas avisa para riscos em 2026. *ECO*. https://eco.sapo.pt/2026/02/10/industria-do-metal-bate-novo-recorde-de-exportacoes-mas-avisa-para-riscos-em-2026/

Ellis, E. (2021). The ethics of economic sanctions: Why just war theory is not the answer. *Res Publica*, *27*(3), 409–426. https://doi.org/10.1007/s11158-020-09483-z

European Commission. (n.d.). *Metal industries—Internal Market, Industry, Entrepreneurship and SMEs*. Retrieved 12 November 2025, from https://single-market-economy.ec.europa.eu/sectors/raw-materials/related-industries/metal-industries_en

European Commission. (2025). *Clean industrial deal*. https://commission.europa.eu/topics/competitiveness/clean-industrial-deal_en

European Commission. Directorate General for Taxation and Customs Union. (2023). *Carbon border adjustment mechanism: Information for importers of iron & steel.* Publications Office. https://data.europa.eu/doi/10.2778/544161

EY-Parthenon. (2023). *Metal 2030 Plano Estratégico e de Ação para o Setor da Metalurgia e Metalomecânica em Portugal*. https://www.ey.com/content/dam/ey-unified-site/ey-com/pt-pt/insights/strategy/documents/metal_2030_plano_estrategico_e_acao_ebook.pdf

Fan, D., Ma, P., Cui, L., & Yiu, D. W. (2024). Locking in overseas buyers amid geopolitical conflicts. *Journal of Operations Management*, *70*(5), 756–792. https://doi.org/10.1002/joom.1316

Flynn, B. B., Sakakibara, S., Schroeder, R. G., Bates, K. A., & Flynn, E. J. (1990). Empirical research methods in operations management. *Journal of Operations Management*, *9*(2), 250–284. https://doi.org/10.1016/0272-6963(90)90098-X

Fu, Q., Gong, Q., Zhao, X.-X., & Chang, C.-P. (2022). The effects of international sanctions on green innovations. *Technological and Economic Development of Economy*, *29*(1), 141–164. https://doi.org/10.3846/tede.2022.17782

Ghironi, F., Kim, D., & Ozhan, G. K. (2025). International trade and macroeconomic dynamics with sanctions. *Journal of Monetary Economics*, *154*, 103810. https://doi.org/10.1016/j.jmoneco.2025.103810

Gligor, D., Bozkurt, S., Gölgeci, I., & Maloni, M. J. (2020). Does supply chain agility create customer value and satisfaction for loyal B2B business and B2C end-customers? *International Journal of Physical Distribution & Logistics Management*, *50*(7/8), 721–743. https://doi.org/10.1108/IJPDLM-01-2020-0004

Gutmann, J., Neuenkirch, M., & Neumeier, F. (2023). The economic effects of international sanctions: An event study. *Journal of Comparative Economics*, *51*(4), 1214–1231. https://doi.org/10.1016/j.jce.2023.05.005

Hendricks, K. B., & Singhal, V. R. (2005). An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. *Production and Operations Management*, *14*(1), 35–52. https://doi.org/10.1111/j.1937-5956.2005.tb00008.x

Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. *Transportation Research Part E: Logistics and Transportation Review*, *125*, 285–307. https://doi.org/10.1016/j.tre.2019.03.001

Imbs, J., & Pauwels, L. (2024). An empirical approximation of the effects of trade sanctions with an application to Russia. *Economic Policy*, *39*(117), 159–200. https://doi.org/10.1093/epolic/eiad027

Jiang, H., Luo, Y., Xia, J., Hitt, M., & Shen, J. (2023). Resource dependence theory in international business: Progress and prospects. *Global Strategy Journal*, *13*(1), 3–57. https://doi.org/10.1002/gsj.1467

Johnson, J. E., & Haug, P. (2021). Modifications to global supply chain management strategies resulting from recent trade disruptions: An exploratory study. *Journal of Global Operations and Strategic Sourcing*, *14*(4), 701–722. https://doi.org/10.1108/JGOSS-12-2020-0074

Kavaklı, K. C., Chatagnier, J. T., & Hatipoğlu, E. (2020). The power to hurt and the effectiveness of international sanctions. *Journal of Politics*, *82*(3), 879–894. https://doi.org/10.1086/707398

Ketokivi, M., & Choi, T. (2014). Renaissance of case research as a scientific method. *Journal of Operations Management*, *32*(5), 232–240. https://doi.org/10.1016/j.jom.2014.03.004

Kırılmaz, O., & Erol, S. (2016). A proactive approach to supply chain risk management: Shifting orders among suppliers to mitigate the supply side risks. *Journal of Purchasing and Supply Management*, *23*(1), 54–65. https://doi.org/10.1016/j.pursup.2016.04.002

Le, H. T. (2022). Global economic sanctions and export survival: Evidence from cross-country data. *Entrepreneurial Business and Economics Review*, *10*(1), 7–22. https://doi.org/10.15678/EBER.2022.100101

Lee, H., Kim, M. S., & Kim, K. K. (2014). Interorganizational information systems visibility and supply chain performance. *International Journal of Information Management*, *34*(2), 285–295. https://doi.org/10.1016/j.ijinfomgt.2013.10.003

Li, W., Zhang, M., & Han, M. (2025). Geographical linkage and trade disruption within global photovoltaic supply chains. *Geography and Sustainability*, *6*(5), 100323. https://doi.org/10.1016/j.geosus.2025.100323

Li, Y., & Han, J. (2025). International sanctions and export restructuring: How economic integration among BRICS nations drives trade transformation in Russia. *Finance Research Letters*, *85*, 108022. https://doi.org/10.1016/j.frl.2025.108022

Liagkouras, K., & Metaxiotis, K. (2023). Sources of uncertainty and risk quantification methods in supply chain management: A literature study. *Operations Research Forum*, *4*(4), 90. https://doi.org/10.1007/s43069-023-00275-8

Mahoney, J., & Thelen, K. (2009). A theory of gradual institutional change. In *Explaining Institutional Change* (pp. 1–37). Cambridge University Press. https://doi.org/10.1017/CBO9780511806414.003

Meyer, K. E., Fang, T., Panibratov, A. Y., Peng, M. W., & Gaur, A. (2023). International business under sanctions. *Journal of World Business*, *58*(2), 101426. https://doi.org/10.1016/j.jwb.2023.101426

Moradlou, H., Reefke, H., Skipworth, H., & Roscoe, S. (2021). Geopolitical disruptions and the manufacturing location decision in multinational company supply chains: A Delphi study on Brexit. *International Journal of Operations & Production Management*, *41*(2), 102–130. https://doi.org/10.1108/IJOPM-07-2020-0465

Moradlou, H., Skipworth, H., Bals, L., Aktas, E., & Roscoe, S. (2025). Geopolitical disruptions and supply chain structural ambidexterity. *International Journal of Operations & Production Management*, *45*(4), 836–862. https://doi.org/10.1108/IJOPM-11-2023-0915

Narkhede, G., Samuel, C., Mahajan, S., Verma, D., Sakhare, N., & Chaudhari, T. (2024). Beyond traditional supply chain management: Addressing sociopolitical challenges in increasingly turbulent global trade landscape. *Business Strategy & Development*, *7*(2), e397. https://doi.org/10.1002/bsd2.397

Negri, M., Cagno, E., Colicchia, C., & Sarkis, J. (2021). Integrating sustainability and resilience in the supply chain: A systematic literature review and a research agenda. *Business Strategy and the Environment*, *30*(7), 2858–2886. https://doi.org/10.1002/bse.2776

Omokaro, G. O., Nafula, Z. S., Iloabuchi, N. E., Efeni, O. S., Adeyanju, O. I., Janet, O. O., & Idiong, O. U. (2025). Energy sanctions in the global economy: Geopolitical disruptions, market fragmentation, innovation and green transition. *International Journal of Innovation Studies*, *9*(3), 246–261. https://doi.org/10.1016/j.ijis.2025.07.003

Özdamar, Ö., & Shahin, E. (2021). Consequences of economic sanctions: The state of the art and paths forward. *International Studies Review*, *23*(4), 1646–1671. https://doi.org/10.1093/isr/viab029

Pang, Y., Pan, S., Zhou, W., & Ballot, E. (2025). Resilience of global supply chains with logistics service uncertainty: Onshoring versus offshoring strategy. *Transportation Research Part E: Logistics and Transportation Review*, *204*, 104416. https://doi.org/10.1016/j.tre.2025.104416

Pfeffer, J. (Ed.). (1997). *New directions for organization theory: Problems and prospects*. Oxford University Press.

Pfeffer, J., & Salancik, G. R. (2009). *The external control of organizations: A resource dependence perspective*. Stanford Business Books.

Pham, T. H., Testorelli, R., & Verbano, C. (2023). Supply chain risk and its impact on performance: A structured literature review. *Journal of Industrial Engineering and Management*, *16*(2), 236–262. https://doi.org/10.3926/jiem.4719

Qiao, C. (2024). Financial risks and economic costs of trade sanctions. *Finance Research Letters*, *69*, 106113. https://doi.org/10.1016/j.frl.2024.106113

Rana, J., Ahmad, M. Z., Islam, M. F., Jihad, M. N. I., Rashed, Md., & Kamruzzaman, M. (2025). Optimizing supply chain performance through sustainable manufacturing practices and capabilities in emerging markets: An integrated linear (PLS-SEM) and non-linear (fsQCA) approach. *Cleaner Logistics and Supply Chain*, *16*, 100257. https://doi.org/10.1016/j.clscn.2025.100257

Razek, N., Galvani, V., McQuinn, B., & Rajan, S. (2025). Does Saudi Arabia's international competitiveness improve due to sanctions imposed on competitors? The case of two wars. *Structural Change and Economic Dynamics*, *74*, 457–482. https://doi.org/10.1016/j.strueco.2025.04.011

Rinaldi, M., Murino, T., Gebennini, E., Morea, D., & Bottani, E. (2022). A literature review on

quantitative models for supply chain risk management: Can they be applied to pandemic disruptions? *Computers & Industrial Engineering*, *170*, 108329. https://doi.org/10.1016/j.cie.2022.108329

Rodríguez-González, R. M., Madrid-Guijarro, A., & Maldonado-Guzmán, G. (2023). Digital organizational culture and absorptive capacity as precursors to supply chain resilience and sustainable performance. *Journal of Cleaner Production*, *420*, 138411. https://doi.org/10.1016/j.jclepro.2023.138411

Roscoe, S., Aktas, E., Petersen, K. J., Skipworth, H. D., Handfield, R. B., & Habib, F. (2022). Redesigning global supply chains during compounding geopolitical disruptions: The role of supply chain logics. *International Journal of Operations & Production Management*, *42*(9), 1407–1434. https://doi.org/10.1108/IJOPM-12-2021-0777

Roscoe, S., & Blome, C. (2019). Understanding the emergence of redistributed manufacturing: An ambidexterity perspective. *Production Planning & Control*, *30*(7), 496–509. https://doi.org/10.1080/09537287.2018.1540051

Sarkis, J., Zhu, Q., & Lai, K. (2011). An organizational theoretic review of green supply chain management literature. *International Journal of Production Economics*, *130*(1), 1–15. https://doi.org/10.1016/j.ijpe.2010.11.010

Saunders, M., Lewis, P., & Thornhill, A. (2023). *Research methods for business students* (Ninth edition). Pearson.

Scott, W. R. (2008). *Institutions and organizations: Ideas and interests*. SAGE.

Shakeri, E., Vizvári, B., & Nazerian, R. (2016). The impacts of economic sanctions on supply chain management: Empirical analysis of Iranian supply chains. *Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas*.

Shalpegin, T., Kumar, A., & Browning, T. R. (2023). Undiversity, inequity, and exclusion in supply chains: The unintended fallout of economic sanctions and consumer boycotts. *Production and Operations Management*, poms.14001. https://doi.org/10.1111/poms.14001

Sheppard, J. P. (1995). A resource dependence approach to organizational failure. *Social Science Research*, *24*(1), 28–62. https://doi.org/10.1006/ssre.1995.1002

Tang, O., & Nurmaya Musa, S. (2011). Identifying risk issues and research advancements in supply chain risk management. *International Journal of Production Economics*, *133*(1), 25–34. https://doi.org/10.1016/j.ijpe.2010.06.013

Tavrikov, D. M., & Yashalova, N. N. (2024). Sanctions pressure on the metalware industry: Problems

and ways to overcome them. *Steel in Translation*, *54*(12), 1176–1180. https://doi.org/10.3103/S0967091225700056

Wang, S., Wen, J., Zhao, X., & Zhou, X. (2025). Impacts of international sanctions on sender countries' innovation. *Economic Analysis and Policy*, *85*, 1357–1373. https://doi.org/10.1016/j.eap.2025.01.026

Appendices

Appendix A – Questionnaire

A.1. Questionnaire in English

A.2. Graphical Representation of Questionnaire Results

A.3. Questionnaire Open Ended Responses

A.1. Questionnaire in English
Questions 1 to 9 – Company Profile

1. Company name:

   (Short open-ended response)

2. Email contact of the person responsible for completing the questionnaire:

   (Short open-ended response)

3. Company's main economic activity code (CAE):

   (Short open-ended response)

4. What is the company's primary type of activity?

   (Measurement scale: Nominal categorical – single choice)

   Manufacturing / Production

   Subcontracting / Component supply

   Distribution / Logistics

   Other:

5. What is the size of the company?

   (Measurement scale: Ordinal categorical – based on EU classification)

   Micro enterprise

   Small enterprise

   Medium-sized enterprise

   Large enterprise

6. In which region of the country is the company's headquarters located?

   (Measurement scale: Nominal categorical – single choice)

   North

   Centre

   Lisbon Metropolitan Area and Tagus Valley

   Alentejo

   Algarve

   Autonomous Region of the Azores

   Autonomous Region of Madeira

7. How many years has the company been in operation?

   (Measurement scale: Ordinal categorical)

   Less than 5 years

   Between 5 and 10 years

   Between 11 and 20 years

   More than 20 years

8. What is the number of employees in the company?

   (Measurement scale: Ordinal categorical)

   Fewer than 10

   10 to 49

   50 to 249

   250 or more

9. What is the company's approximate annual turnover?

   (Measurement scale: Ordinal categorical)

   Less than €2 million

   €2 to €10 million

   €10 to €50 million

   More than €50 million

Questions 10 to 16 – International Trade Context

10. Does your company export products to foreign markets?

    (Measurement scale: Ordinal categorical – frequency-based)

    Yes, regularly

    Yes, occasionally

    No

11. Please indicate the main export destination countries (select and rank up to three, with 1 being the main):

    (Measurement scale: Nominal categorical + ranking)

    [List as provided]

12. Does your company import raw materials or components from abroad?
    (Measurement scale: Ordinal categorical – frequency-based)
    Yes, regularly
    Yes, occasionally
    No

13. Please indicate the main countries of origin of imports (select and rank up to three, with 1 being the main):
    (Measurement scale: Nominal categorical + ranking)

14. Which types of sanctions have most significantly affected your company?
    (Measurement scale: Nominal categorical – multiple choice possible)
    Trade sanctions
    Financial sanctions
    Technological sanctions
    None

15. What is the company's level of dependence on external suppliers?
    (Measurement scale: 5-point Likert scale – intensity)
    Very low
    Low
    Moderate
    High
    Very high

16. Did your company maintain commercial relationships with countries currently subject to international sanctions?
    (Measurement scale: Ordinal categorical – degree)
    Yes, to a significant extent
    Yes, to a limited extent
    No

Question 17 – Countries Subject to International Sanctions

17. Please indicate the main countries...

    (Measurement scale: Open-ended response)

Questions 18 to 28 – Impact of Sanctions on the Supply Chain

18. Which stages of the value chain were most affected?

    (Measurement scale: Nominal categorical – multiple choice possible)

19. Access limitations due to sanctions

    (Measurement scale: 5-point frequency scale)

    Never → Always

20. Visibility over second-tier suppliers

    (Measurement scale: Ordinal categorical)

21. Increase in supply costs

    (Measurement scale: 5-point Likert scale – agreement)

    Strongly disagree → Strongly agree

22. Number of suppliers replaced

    (Measurement scale: Ordinal categorical)

23. Supply chain delays

    (Measurement scale: 5-point frequency scale)

24. Changes in logistics/transport

    (Measurement scale: Ordinal categorical – impact on cost)

25. Planning uncertainty

    (Measurement scale: 5-point Likert scale – agreement)

26. Period of impact

    (Measurement scale: Nominal categorical)

27. Energy cost/availability impact

    (Measurement scale: 5-point frequency scale)

28. Overall supply chain impact

    (Measurement scale: 5-point Likert scale – intensity)

    Very low → Very high

Questions 29 to 33 – Effects on Operational Performance

29. Impact on production levels

    (Measurement scale: 5-point frequency scale)

30. Ability to meet delivery deadlines

    (Measurement scale: 5-point Likert scale – agreement)

31. Product quality impact

    (Measurement scale: 5-point frequency scale)

32. Financial performance impact

    (Measurement scale: 5-point Likert scale – agreement)

33. Overall operational impact

    (Measurement scale: 5-point Likert scale – intensity)

Questions 34 to 43 – Mitigation Strategies and Risk Management

34. Relocation of production/sourcing (nearshoring)

    (Measurement scale: Ordinal categorical)

35. Investment in digital technologies

    (Measurement scale: Ordinal categorical – degree)

36. Relocation to Portugal (reshoring)

    (Measurement scale: Ordinal categorical)

37. Supplier diversification

    (Measurement scale: Ordinal categorical – degree/process stage)

38. Risk management mechanisms

    (Measurement scale: Ordinal categorical)

39. Safety stock levels

    (Measurement scale: Ordinal categorical – degree)

40. Collaboration and information sharing

    (Measurement scale: 5-point Likert scale – agreement)

41. Internal innovation and capability development

    (Measurement scale: 5-point Likert scale – agreement)

42. Export market diversification

    (Measurement scale: 5-point Likert scale – agreement)

43. Effectiveness of mitigation strategies

    (Measurement scale: 5-point Likert scale – agreement)

Question 44 – Risk Management Mechanisms

44. Main mechanisms adopted

    (Measurement scale: Open-ended response)

Questions 45 to 50 – Impact of EU and National Legislation

45. Difficulty in import/export processes

    (Measurement scale: 5-point frequency scale)

46. Examples of legislation

    (Measurement scale: Open-ended response)

47. Awareness of CBAM

    (Measurement scale: Ordinal categorical)

48. Expected impact of CBAM

    (Measurement scale: 5-point Likert scale – intensity)

49. Administrative burden (Portugal)

    (Measurement scale: 5-point Likert scale – agreement)

50. Aggravation of sanctions' impact

    (Measurement scale: 5-point Likert scale – intensity)

Questions 51 to 54 – Overall Assessment and Future Expectations

51. Overall impact

    (Measurement scale: 5-point Likert scale – intensity; 1 = none, 5 = very high)

52. Persistence of sanctions' effects

    (Measurement scale: 5-point Likert scale – probability)

53. Preparedness for future sanctions

    (Measurement scale: 5-point Likert scale – agreement)

54. Use of external support

    (Measurement scale: Nominal categorical – dichotomous)

Question 55 – External Entities Contacted

55. External entities

    (Measurement scale: Nominal categorical – multiple choice possible)

Question 56 – Additional Considerations

56. Additional comments

    (Measurement scale: Open-ended response)

A.2. Graphical Representation of Questionnaire Results

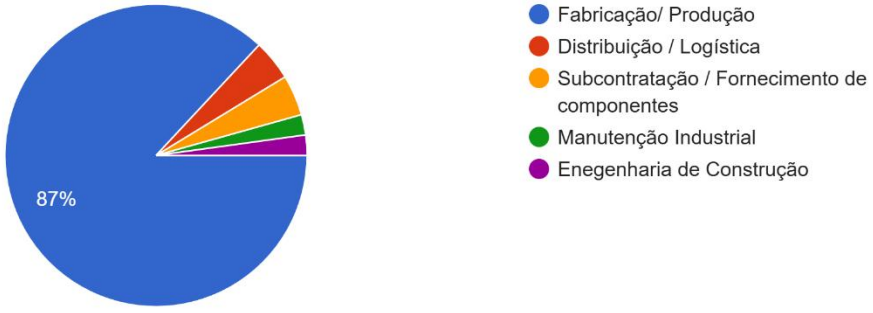
O Impacto das Sanções Internacionais nas Cadeias de Abastecimento da Indústria Metalomecânica Portuguesa

O presente questionário integra um estudo académico desenvolvido no âmbito da Dissertação de Mestrado em Gestão e Negócios, da Escola de Economia, Gestão e Ciência Política da Universidade do Minho.
O objetivo deste estudo é analisar o impacto das sanções internacionais nas cadeias de abastecimento das empresas da indústria metalomecânica portuguesa, bem como avaliar os seus efeitos no desempenho operacional, nas estratégias de mitigação adotadas pelas empresas e no papel da legislação da União Europeia e da legislação nacional neste contexto.
O preenchimento do questionário demora aproximadamente 5 minutos. As respostas são confidenciais e serão utilizadas exclusivamente para fins académicos, sendo tratadas de forma agregada e anónima. Em nenhum momento será possível identificar individualmente os participantes ou as empresas envolvidas.
Solicita-se que responda a todas as questões, assinalando a opção que melhor reflita a situação da sua empresa e a sua perceção relativamente aos temas abordados.
Desde já agradeço a sua colaboração.
Para qualquer esclarecimento adicional sobre este questionário ou sobre o estudo, poderá contactar:
Beatriz Sousa através de: **pg55195@alunos.uminho.pt**

Ao submeter o questionário, declara que leu e compreendeu a informação acima apresentada e que aceita participar voluntariamente neste estudo, autorizando a utilização dos dados fornecidos para fins científicos, em conformidade com as garantias de anonimato e confidencialidade.

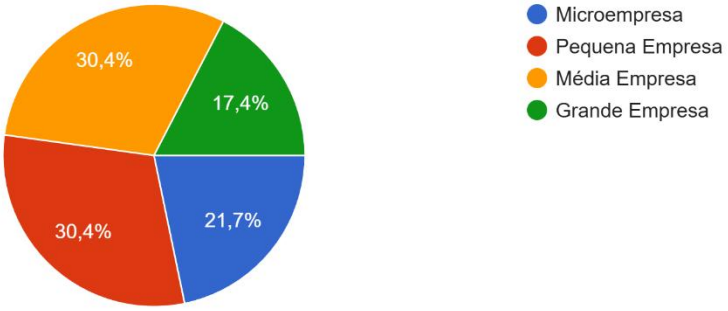
Caracterização da Empresa

Qual é o principal tipo de atividade da empresa?
46 respostas



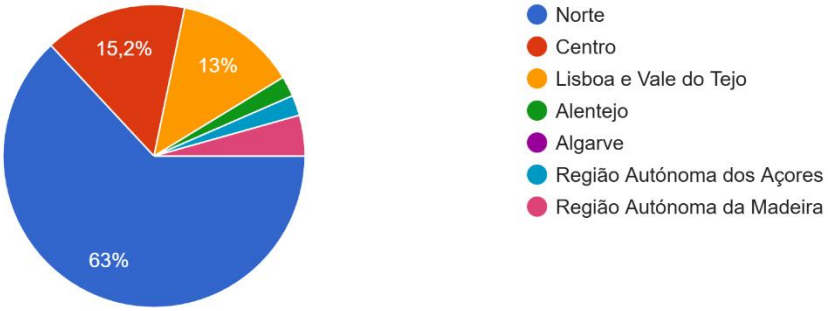
Qual é a dimensão da empresa?

46 respostas



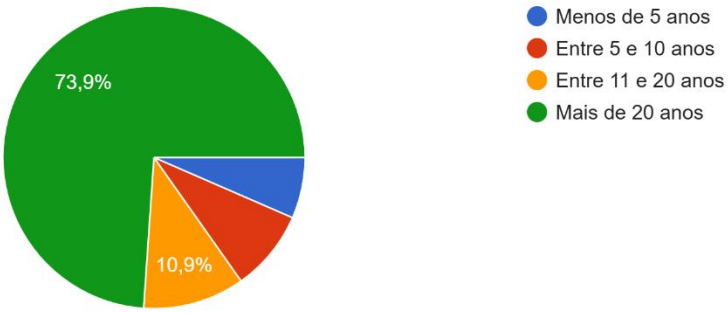
Em que região do país se localiza a sede da empresa?

46 respostas



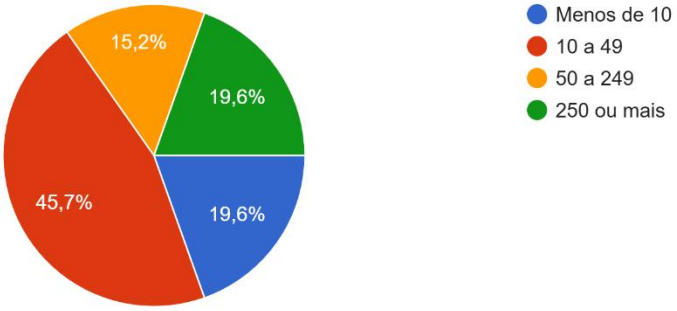
Há quantos anos a empresa se encontra em atividade?

46 respostas



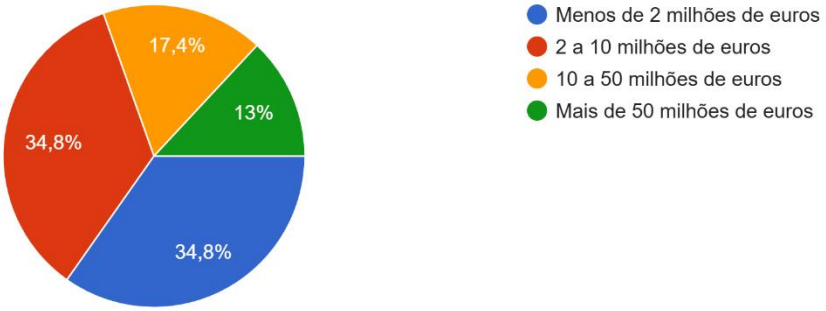
Qual é o número de trabalhadores da empresa?

46 respostas



Qual é o volume de negócios anual aproximado da empresa?

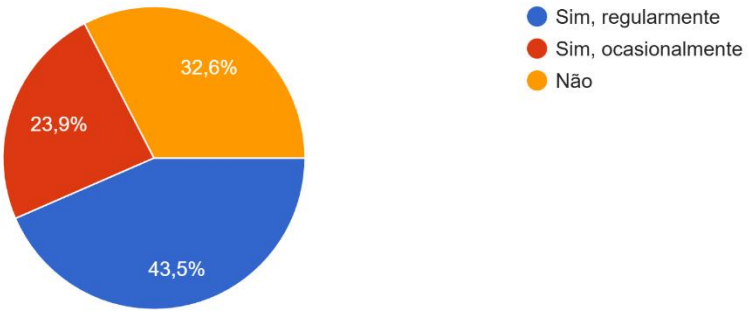
46 respostas



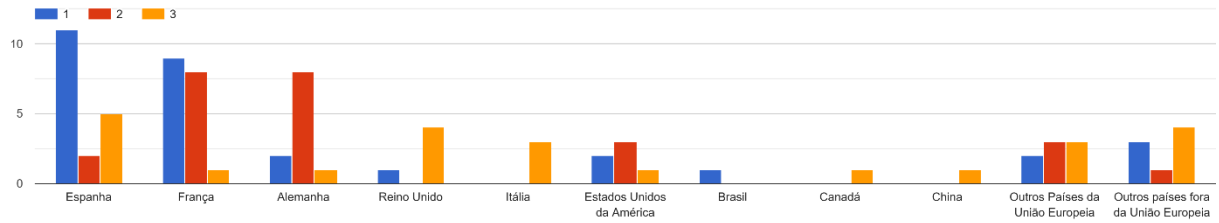
Enquadramento no Comércio Internacional

A sua empresa exporta produtos para mercados externos?

46 respostas

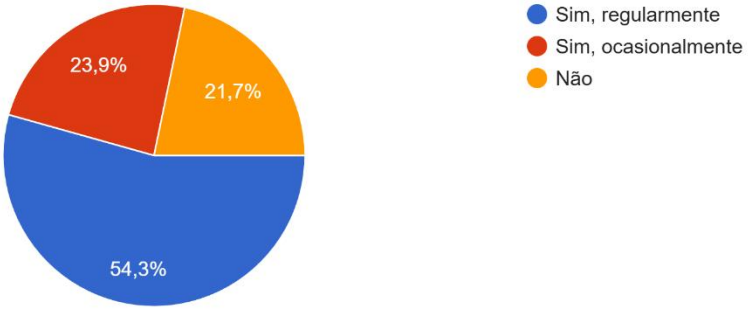


Indique os principais países de destino das exportações (assinale e ordene até três, sendo 1 o principal):

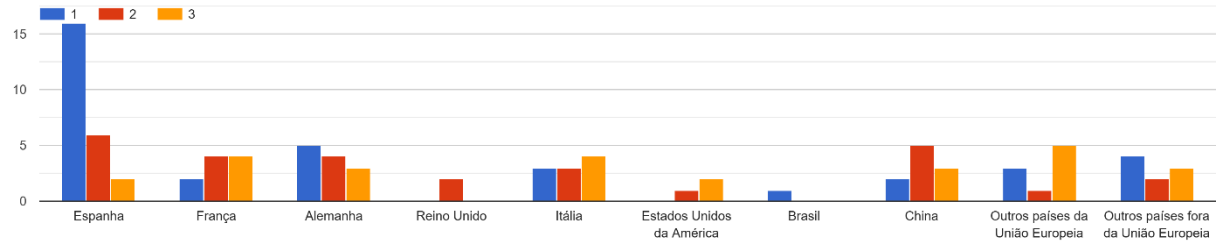


A sua empresa importa matérias-primas ou componentes do estrangeiro?

46 respostas

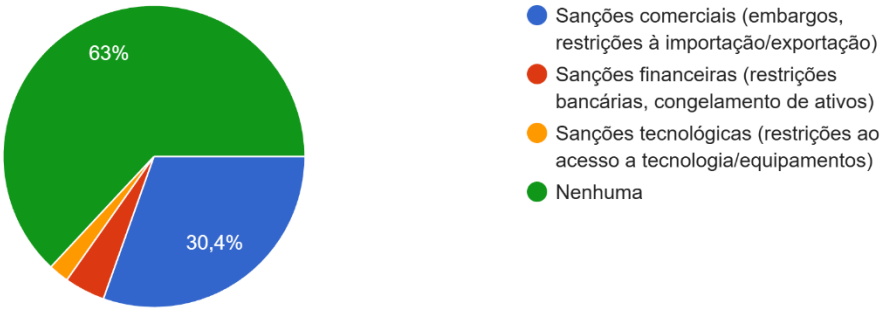


Indique os principais países de origem das importações (assinale e ordene até três, sendo 1 o principal):



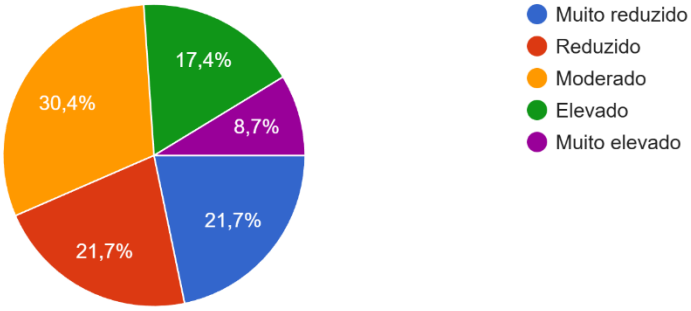
Que tipo(s) de sanções afetaram mais significativamente a sua empresa?

46 respostas



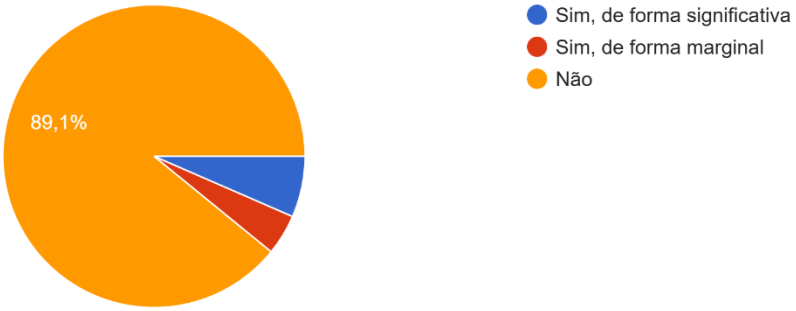
Qual é o grau de dependência da empresa em relação a fornecedores externos?

46 respostas



A sua empresa mantinha relações comerciais com países atualmente sujeitos a sanções internacionais?

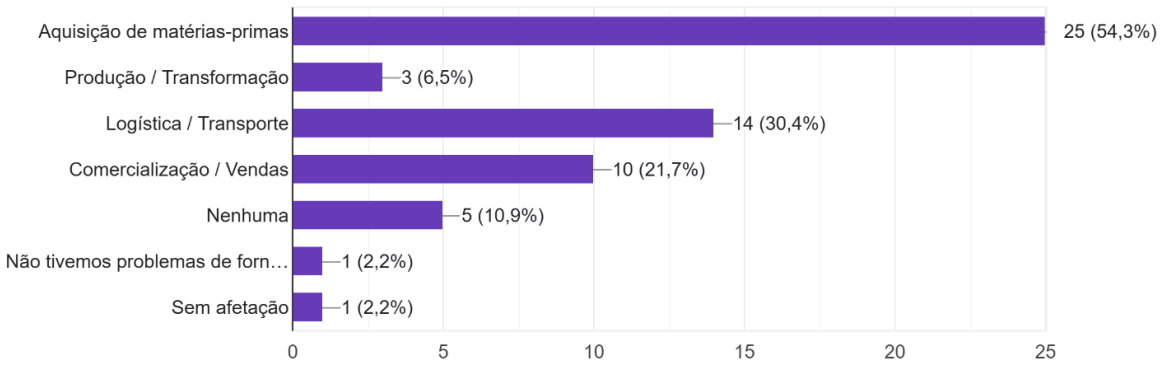
46 respostas



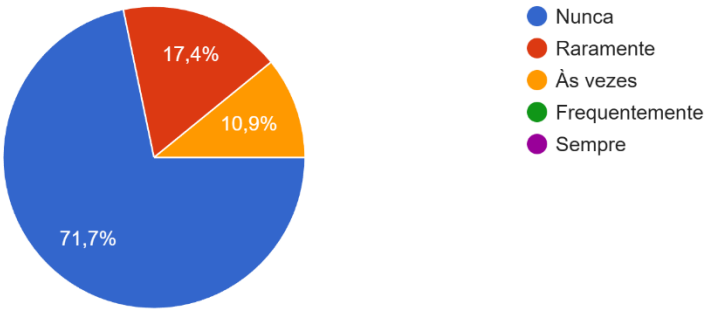
Impacto das Sanções na Cadeia de Abastecimento

Indique, por favor, quais as fases da cadeia de valor da sua empresa que foram mais afetadas pelas sanções internacionais:

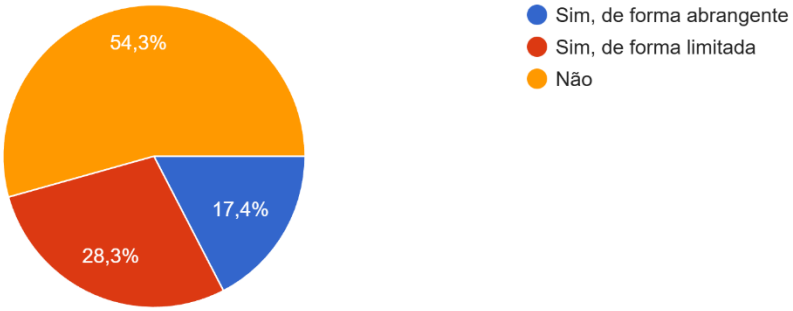
46 respostas



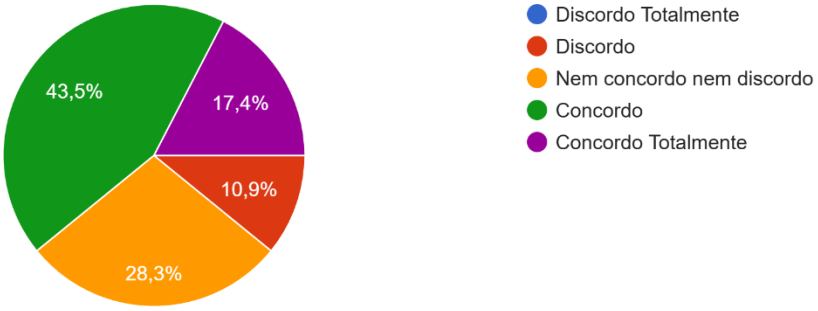
As sanções limitaram o acesso da empresa a tecnologia, equipamentos ou componentes críticos?
46 respostas



A empresa dispõe de visibilidade sobre os fornecedores dos seus fornecedores (fornecedores de segundo nível ou superiores)?
46 respostas

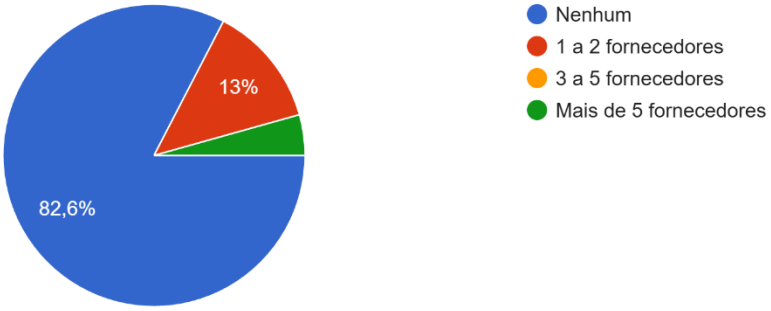


As sanções provocaram aumentos significativos nos custos de fornecimento?
46 respostas



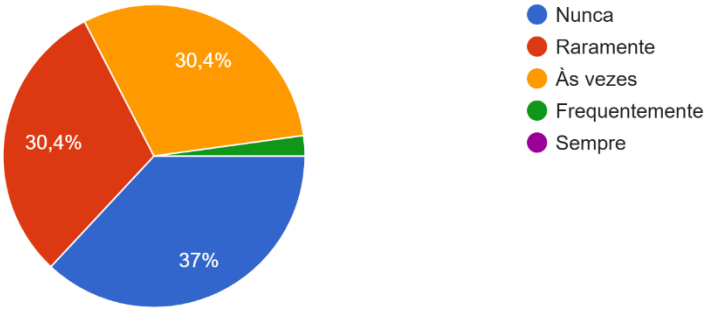
Quantos fornecedores a empresa teve de substituir devido às sanções?

46 respostas



As sanções causaram atrasos relevantes na cadeia de abastecimento?

46 respostas



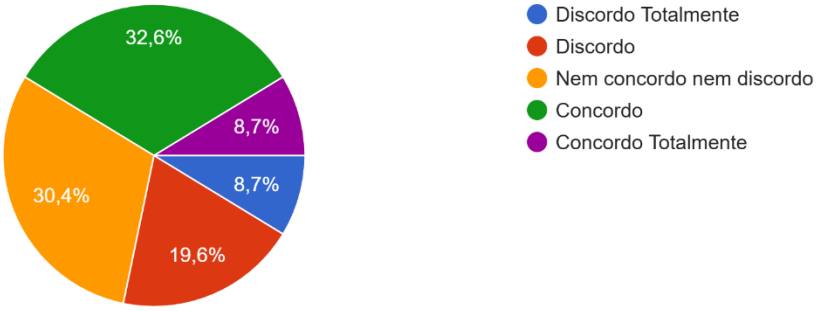
As sanções obrigaram a empresa a alterar rotas de transporte ou modos logísticos?

46 respostas



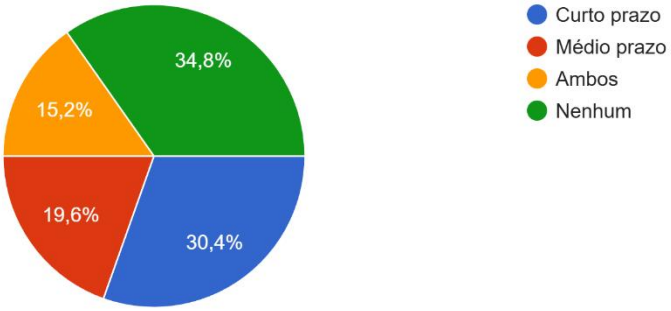
As sanções aumentaram a incerteza no planeamento da cadeia de abastecimento?

46 respostas



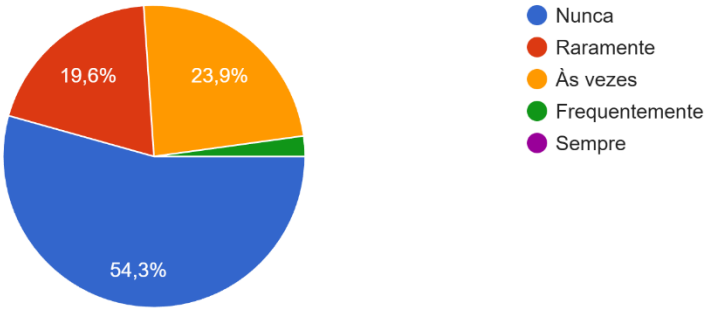
Em que período o impacto foi mais intenso?

46 respostas



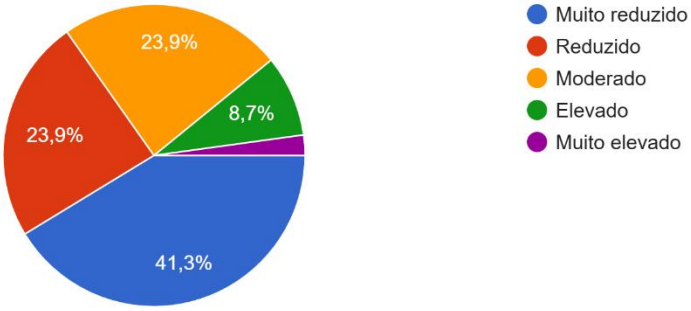
As sanções internacionais afetaram os custos ou a disponibilidade de energia para a empresa?

46 respostas



Em termos globais, o impacto das sanções na cadeia de abastecimento foi:

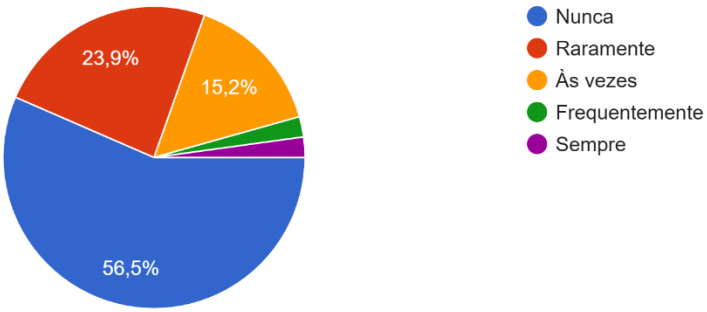
46 respostas



Efeitos no Desempenho Operacional

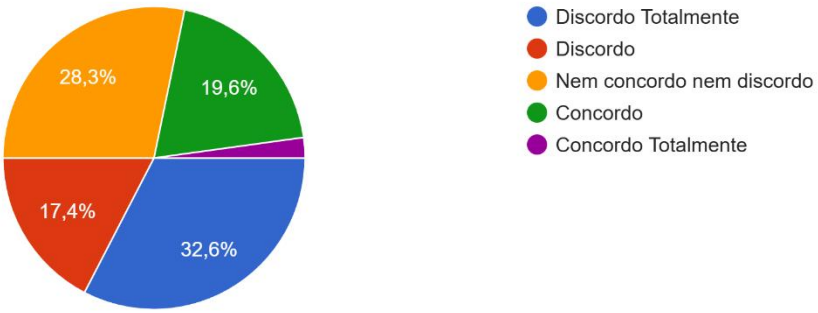
As sanções afetaram negativamente os níveis de produção da empresa?

46 respostas



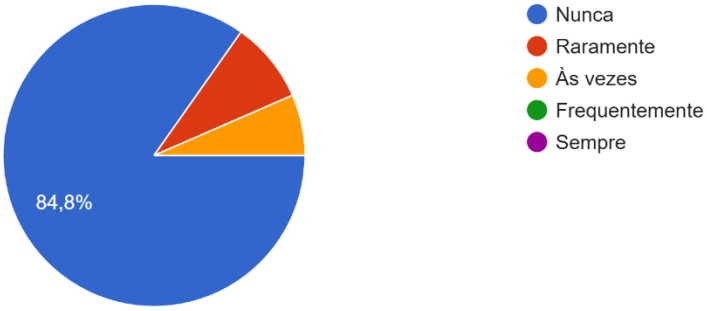
As sanções reduziram a capacidade de cumprir prazos de entrega?

46 respostas



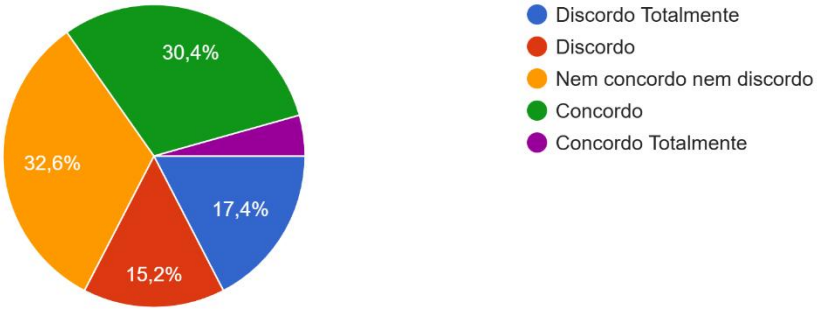
As sanções afetaram a qualidade dos produtos finais?

46 respostas



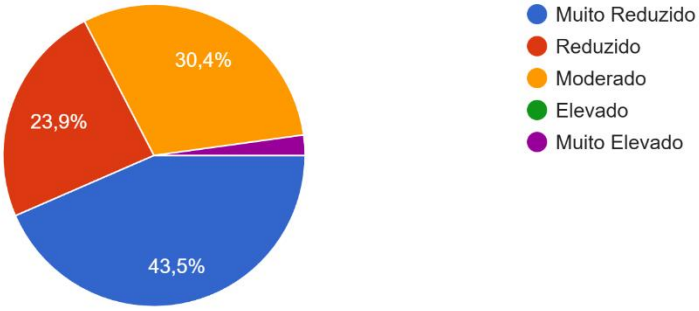
As sanções tiveram impacto negativo no desempenho financeiro da empresa?

46 respostas



Em termos operacionais, o impacto global das sanções foi:

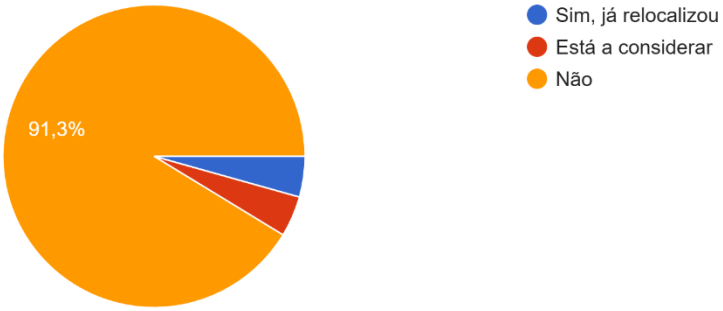
46 respostas



Estratégias de Mitigação e Gestão de Risco

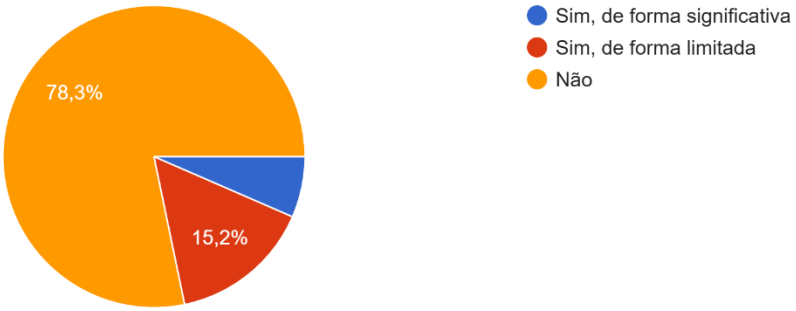
Na sequência das sanções, a empresa relocalizou ou considerou relocalizar parte da sua produção ou fornecimento para regiões mais próximas?

46 respostas



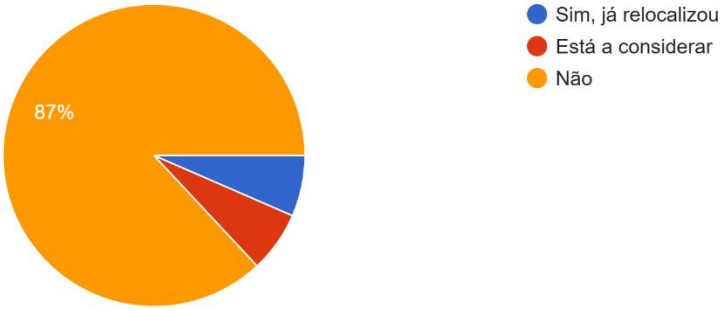
A empresa investiu em tecnologias digitais para melhorar a visibilidade e gestão da cadeia de abastecimento em resposta às sanções?

46 respostas



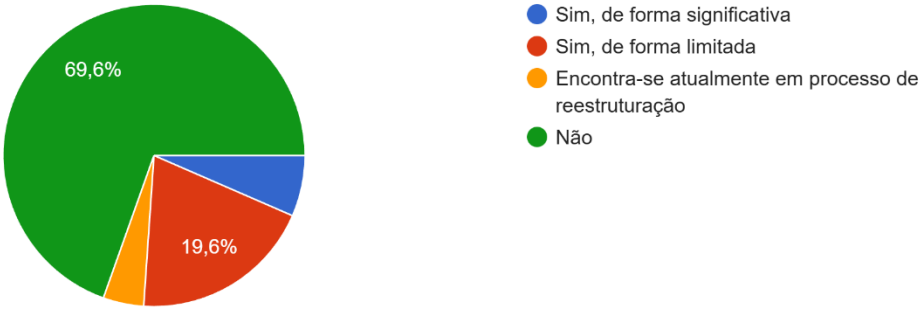
A empresa relocalizou ou considerou relocalizar produção/fornecimento para Portugal?

46 respostas



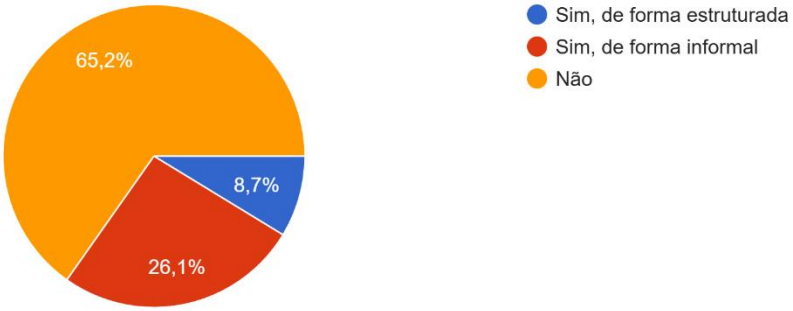
A empresa diversificou a sua base de fornecedores em resposta às sanções?

46 respostas



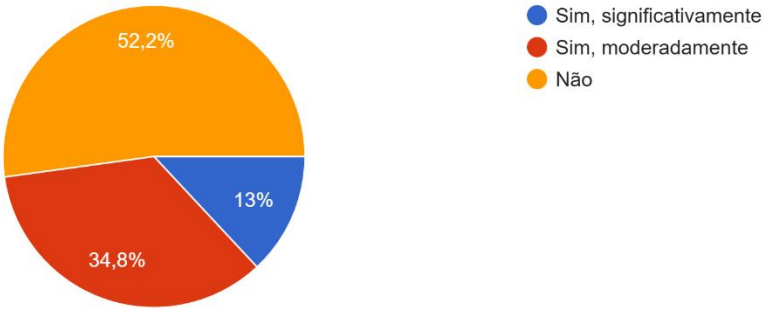
A empresa reforçou mecanismos formais de gestão de risco na cadeia de abastecimento?

46 respostas



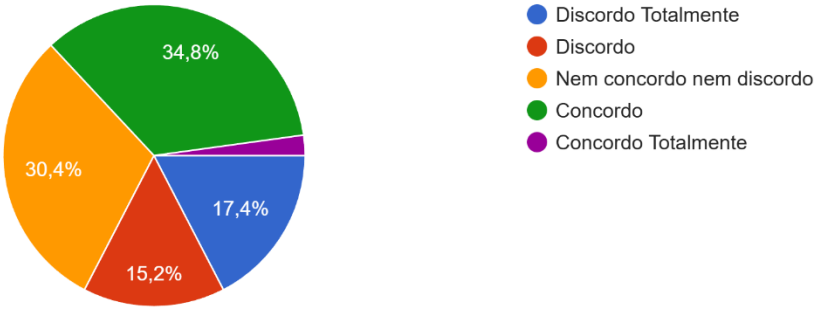
A empresa aumentou os níveis de stock de segurança para reduzir riscos?

46 respostas



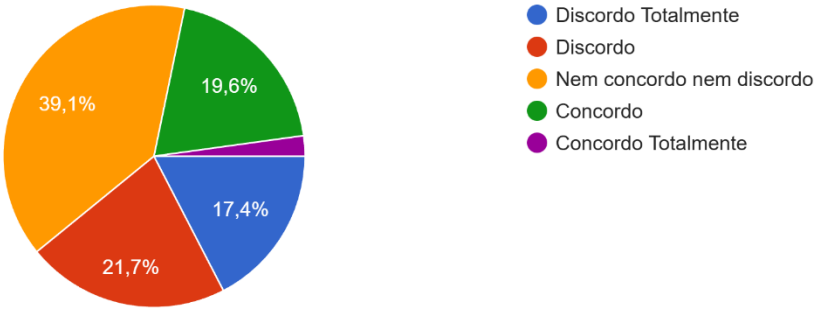
A empresa reforçou a colaboração e partilha de informação com parceiros da cadeia de abastecimento em resposta às sanções?

46 respostas



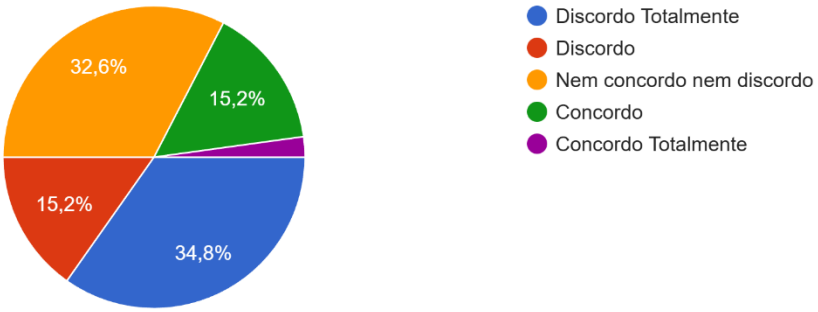
As sanções estimularam a empresa a desenvolver soluções internas ou a investir em inovação para reduzir dependências externas?

46 respostas



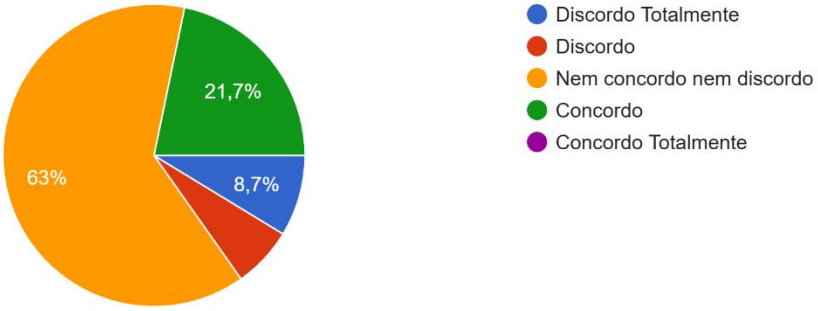
Na sequência das sanções internacionais, a empresa diversificou os seus mercados de exportação.

46 respostas



As estratégias adotadas reduziram efetivamente o impacto das sanções?

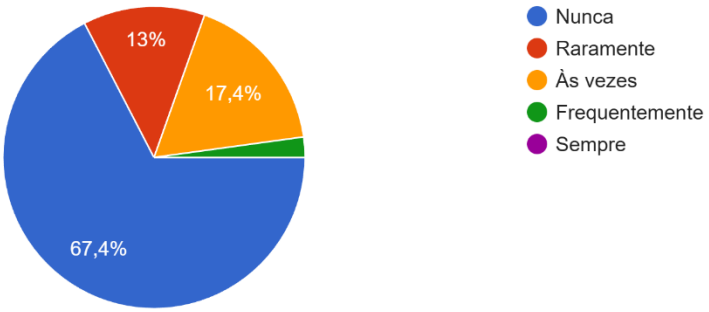
46 respostas



Impacto da Legislação da União Europeia e Nacional

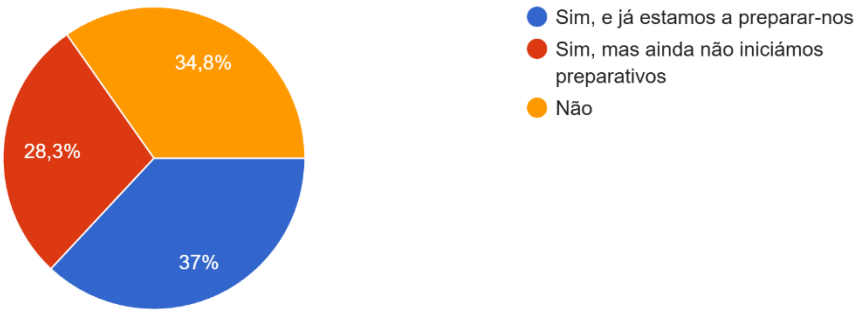
A legislação da União Europeia dificultou os processos de importação e exportação da empresa?

46 respostas



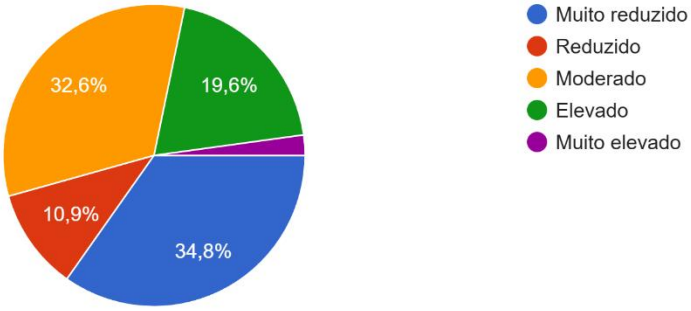
A empresa está ciente das exigências do Mecanismo de Ajustamento Carbónico Fronteiriço (CBAM) da União Europeia?

46 respostas



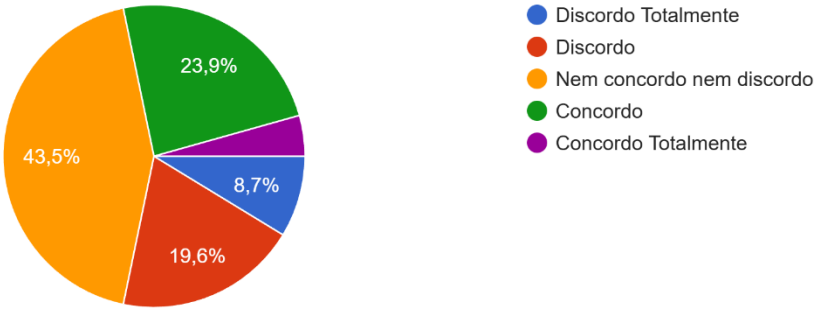
Prevê que o CBAM terá impacto nas relações com fornecedores externos à UE?

46 respostas



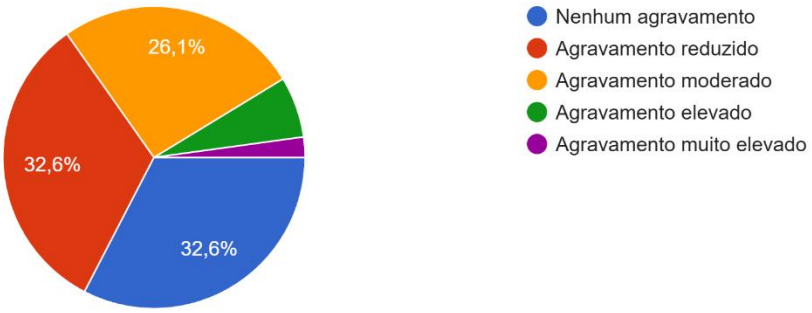
As exigências legais portuguesas aumentaram a carga administrativa associada ao comércio internacional?

46 respostas



A legislação da UE e de Portugal agravou o impacto das sanções na cadeia de abastecimento?

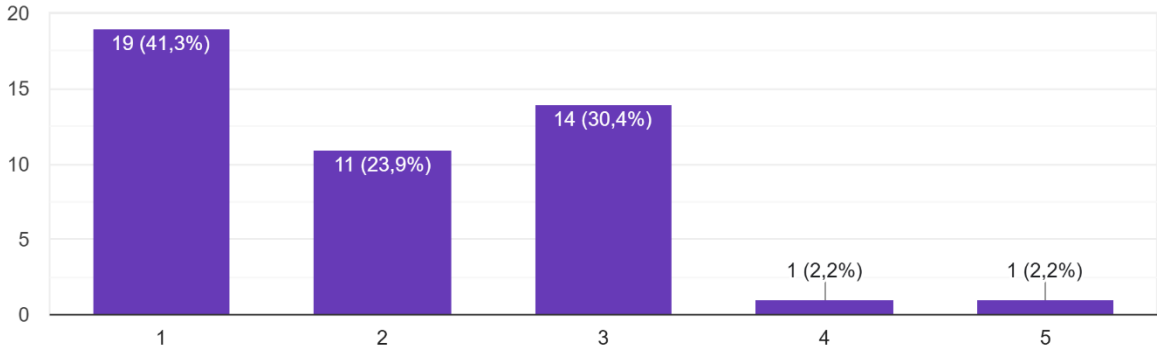
46 respostas



Avaliação Global e Expectativas Futuras

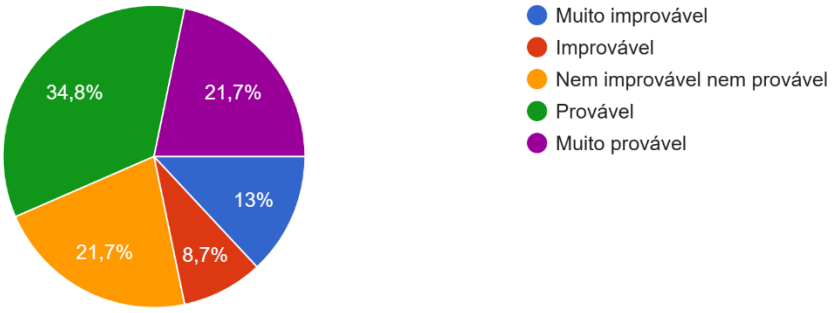
Avaliação global do impacto das sanções na empresa (escala 1–5): 1 = Nenhum impacto | 5 = Impacto muito elevado

46 respostas



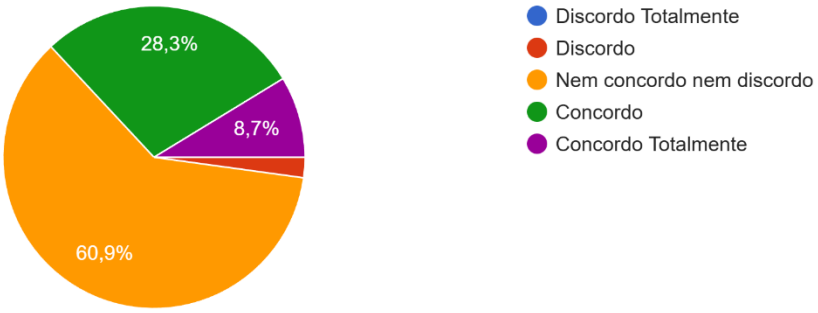
A empresa considera que os efeitos das sanções irão manter-se nos próximos 12 meses?

46 respostas



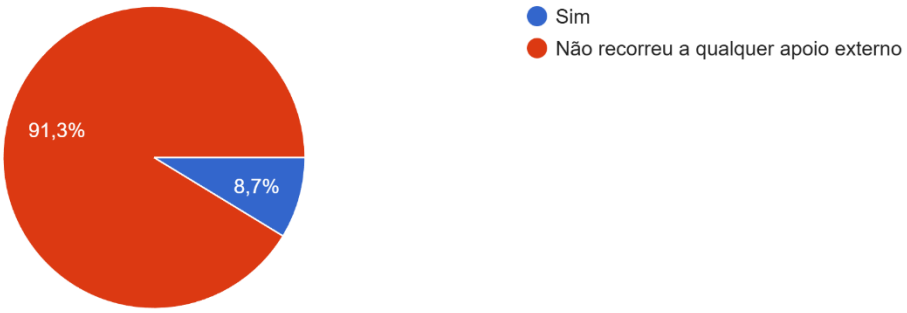
A empresa considera-se atualmente mais preparada para enfrentar futuras sanções internacionais?

46 respostas



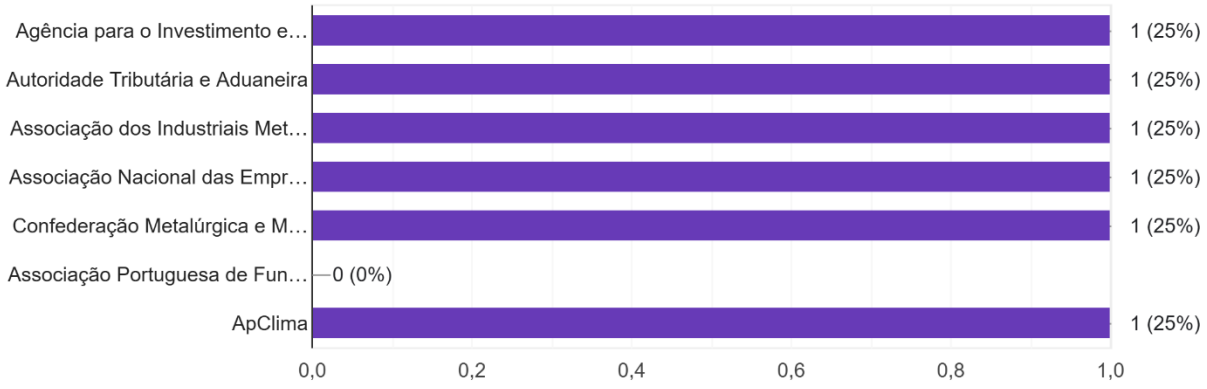
Para lidar com os efeitos das sanções, a empresa recorreu a apoio de entidades externas?

46 respostas



Indique, por favor, a(s) entidade(s) externa(s) às quais a empresa recorreu.

4 respostas



A.3. Summary of Open-Ended Responses

Q17 – Countries currently subject to international sanctions with which firms maintained commercial relationships.

Responses to the survey demonstrate a somewhat ambiguous and sporadic pattern of these responses across several firms. Russia is mentioned and, due to the current geopolitical environment. Most frequently, firms expressed a connection with the United States, the US is not currently a sanctioned country per se but is the basis for many import/export restrictions and/or regulatory restrictions that impose restrictions on trade with Portugal. One respondent mentioned the United States as a relevant country if the question were interpreted more broadly in terms of trade restrictions affecting Portugal, despite it not being a sanctioned country. Under a strict interpretation of sanctions exposure, this respondent would also be classified as having no exposure.

Overall, few companies appear to have direct exposure to countries under international sanctions, but companies have likely experienced indirect consequences from trade and regulatory restrictions, making these types of restrictions appear more relevant.

Q44 – Risk management mechanisms reinforced or implemented

Firms have an apparent convergence of risk management methods that have either been reinforced or implemented. The most pronounced method of risk management identified is supplier diversification (often by having dual sources coupled with developing alternative sources of supply locally) to diminish external dependency. In addition to these supplier diversification strategies, many firms noted reinforcement of stock as a method to hedge against uncertainty in supply or volatility in customer demand. The practice of continuous monitoring of risk as well as assessing supplier performance has also been frequently highlighted as evidence of an increasing focus on controlling and detecting future disruptions that may occur.

Also, some firms are implementing more formalised methods in their risk mitigation strategies, such as alternate contracts that contain compliance clauses, establishing contingency planning in their procurement process, and exercising more stringent controls over third-party suppliers. Some firms also mentioned the implementation of more sophisticated management practices, such as the use of formal analytical methods to determine risk, reducing lead times, and enhancing communication with suppliers, particularly concerning demand projections. In a few instances, regulatory frameworks (such as the Carbon Border Adjustment Mechanism) have been highlighted as a major catalyst for change, prompting firms to increase their stock levels and closely monitor potential financial implications of future compliance with certificate requirements. Overall, firms' responses suggest that the majority of the firms employ an

operationally driven and prevention-driven approach that focuses on increasing the flexibility of their supply chain, increasing buffer capacities, and enhancing monitoring and control systems.

Q46 - Please indicate, if possible, examples of legislation or regulations that have caused difficulties:

Responses reveal that while regulatory challenges are not numerous, concentration exists around certain areas. The Carbon Border Adjustment Mechanism (CBAM) was mentioned most often as a significant source of business operation challenges. As the CBAM matures, it becomes a more significant factor in the day-to-day operating requirements for certain businesses. Other businesses reported having issues related to strict product quality standards - especially ISO-related standards - which are not yet recognized in the United States, thus creating more significant impediments to international trade. Additionally, several businesses reported high export-related costs for exporting products to the United States due to tariffs and fees on goods. However, at least one respondent reported no difficulties with either import or export regulations, indicating that these challenges appear to be firm-specific in nature.

Q56 - If you would like, please leave any comments or additional remarks regarding the impact of international sanctions on your company:

Responses to the survey indicate that firms have not been significantly affected by international sanctions directly. Most of the survey respondents stated their company was not materially impacted, especially regarding firms with no operations or trade with sanctioned countries.

However, businesses are experiencing indirect impacts due primarily to the increase in the cost of raw materials and have had to adjust prices and pass along those costs to consumers as a result.

Some survey respondents do believe there can be negative impacts on a company's financial performance due to the sanctions, but respondents agreed that while they understand the reasons for the sanctions, they are at times too restrictive and perhaps should be eased. Furthermore, as some respondents stated, sanctions have caused many broader economic pressures in Portugal such as inflation, thereby causing large and systemic indirect impact throughout the marketplace.

Appendix B – Meetings with Portuguese Companies and Entities

AIMMAP

AICEP

SILAMPOS

Mind for Metal

Grupo Iberomoldes

B.1. Summary of the Meeting with a representative from AIMMAP

AIMMAP - Associação dos Industriais Metalúrgicos Metalomecânicos e Afins de Portugal

The purpose of the meeting with a representative from the communication department of **AIMMAP**, was to gather input about how international sanctions, political developments, and regulations affect the Portuguese metal fabrication and metallurgy sector, particularly concerning its supply chain management and operational performance.

It was pointed out at the beginning of the meeting that this sector is one of the pillars of the national economy and is very diversified (e.g., moulds, tooling, automotive parts, and technical equipment). The Portuguese metalworking and metallurgy sector are very much export-oriented, and a good proportion of their production is sold to Europe (especially Spain, France, and Germany); however, they also have connections to global markets, particularly the United States. Additionally, many of the companies in this sector have substantial indirect exposure to external shocks via European value chains, therefore, external shocks will significantly affect the sector as well.

The discussions indicted that trade policies, particularly those adopted by President Donald Trump, have had measurable impacts on the sector, while Portugal does not have a lot of direct exposure to the U.S. market due to its limited size, it has substantial indirect exposure, and, as a result of Trump's administration's trade policies, many of the European countries that the Portuguese metalworking and metallurgy sector sells to are experiencing reduced demand, which therefore reduces the demand for products made in Portugal as viewed through the lens of the global supply chain.

Identified subsectors facing a larger dependency upon the US market experienced disproportionate impacts, resulting in some companies mulling their production moves as a way to address these constraints. In addition, adjustments arising from post-pandemic conditions were noted, with particular emphasis on the growing trend of nearshoring. One example is that European industrial clusters are increasingly moving their supply chains closer to home, creating an opportunity for Portugal to build its position as a competitive supplier in the European market. This change has been made strategically by responding to supply chain disruptions that occurred during the pandemic.

The European Union's regulatory environment was identified as a major issue for companies in the sector, with tariffs and safeguard measures on imports from Asia cited as being major factors that impact source selection and cost structure, and the perception of these regulations as having a greater effect on companies than other external trade legislation supports the view that institutional pressure from the EU is a key influence on company behaviour.

Further, the meeting focused on the larger context of global risk where it is said the current situation is unprecedented in terms of intensity as a result of the combination of many different disruptive events happening at once. The result of these global events has created a state of uncertainty for companies and led to firms pursuing a more cautious and diversified approach to market entry and investment decisions.

Finally, there was an exploration into the structural aspects of business in Portugal, where the overall high ratio of small and medium-size firms (most of which are family-owned) substantially restricts their ability to achieve the scale necessary for sustainable competitiveness. Historically, firms have addressed this limitation by employing differentiation-based strategies to compete on quality, flexibility, and engineering ability, but there remains much uncertainty around how to grow through acquisition or merger activity. The cultural and psychological barriers tied to ownership structure continue to delay the consolidation process but awareness around addressing the limitation caused by scale is growing.

Overall, the meeting confirmed that the Portuguese metalworking industry operates in a highly complex environment that is heavily impacted by international sanctions, regulatory burdens, and geopolitical instability, all of which are having a direct impact on supply chain dynamics and strategic planning.

B.2. Summary of the Meeting with a representative from AICEP

AICEP – Agência para o Investimento e comércio Externo de Portugal

The objective of the meeting with a Manager of the Metalworking Sector, Internationalisation Department, AICEP, is to include practical insight on the consequences of international sanctions to Portugal's firm operating internationally in manufacturing and metalworking industries.

Examples of consequences include how international sanctions have adversely affected daily business operations of these companies by disrupting supply chains. Access to raw materials is a fundamental concern for the use of products needed by our companies because European manufacturing companies are becoming more reliant on sourcing materials outside of the European Union. This increased dependency has caused raw material shortages and supply chain disruptions that ultimately impact how much our companies can produce and can deliver to customers on or before the expected or requested date.

AICEP states that **international sanctions have had a notable effect on Portugal's exporting firms globally**. However, the level of disruption across sectors varies somewhat, but in general, they are comparable to what was experienced during the COVID-19 pandemic. Additionally, the pandemic demonstrated the need for greater strategic independence and autonomy for Europe in certain industries like medical devices. As a result, many firms produced a portion of their products through reshored operations.

To face these obstacles, Portuguese companies, particularly those operating in export-oriented sectors such as the moulds industry, which has close ties to the automotive industry, have pursued the adaptation of their business models with new market opportunities and integration into alternative value chains. This is illustrated by their entry into new industries, mainly of aeronautics and defence manufacturing, demonstrating direction toward strategic diversification.

The primary future challenge identified by Portuguese companies is uncertainty with regard to investment and exports. While the US is one of the primary markets for exports from Portugal, companies that are exporting from Portugal can only operate on a limited basis due to their size and financial capabilities; as a result, their competitors are mainly competing on differentiated business strategies (i.e., using technical capabilities, producing higher value-added products and having flexible production facilities) rather than on mass production.

B.3. Summary of the Meeting with representatives from SILAMPOS

SILAMPOS - Sociedade Industrial de Louça Metálica Campos, S.A.

The representatives of **SILAMPOS**, including an Operations and Quality Manager and a Purchasing and Procurement Officer, were invited to participate in the meeting for the purpose of collecting information about how international sanctions, geopolitical conflict and legislations impact supply chain management and operations.

It was clearly articulated in the discussion that the impact of external factors such as restrictions from Brexit; international sanctions and the war in Ukraine, have had significant negative effects on the ability of firms to negotiate on their production capacity. These external restraints have led to the inability to obtain necessary raw material for production, which directly impacts firms' ability to execute their production planning. KPIs such as the cost of raw materials, the cost of transportation and legal compliance with an emphasis on their relationship to the costs of raw materials have all been seriously impacted due to these constraints.

As SILAMPOS is a global firm that exports both finished products and intermediate products throughout the world including the Middle East, North Africa, central Europe, the United States, Japan and Australia, SILAMPOS has an enormous amount of international exposure, which increases its ability to be affected by external disruptions. Because of the global conflicts and trade restrictions, firms such as SILAMPOS can expect to be impacted by disruptions in the supply of inputs (raw materials) and the reduction in the availability of markets to sell to (input availability).

Discussions also included the impact of European regulations on the market system. While not the focus of this discussion, mechanisms such as tariffs, quotas, and antidumping help dictate how the market functions and remain stable, especially as it relates to raw materials. Changes in governmental regulations often lead to increased costs for input and decreased flexibility in imports, which negatively influences business who rely on outside purchasing.

One of the proposed regulatory approaches was the Carbon Border Adjustment Mechanism (CBAM), however, there was a concern with the implementation of the CBAM during the transition from the preliminary to final implementation phase and clarity in relation to compliance; specifically, the timeliness of when to comply was problematic to the businesses impacted by the CBAM.

Additionally, the implications for energy and raw materials markets resulting from global geopolitical pressure were discussed. As such, due to the conflict within Ukraine the energy price has notably increased, regarding gas caused by the war in Ukraine, as well as increasing the cost of inputs including steel, aluminium and other raw materials associated with the production of stainless steel. These growing

costs put additional pressures on companies' supply chains.

Finally, the need for collaboration and cooperation at the international level with organizations like AIMMAP was noted, as these organizations support businesses in accessing market intelligence, enabling them to have timely information for pricing purposes and to facilitate the procurement of energy through energy auctions, among other ways. The assistance provided by these organizations results in an improvement of the firms' dynamic capabilities, allowing them to better assess their potential risks and implement appropriate strategic responses to unexpected events.

It has been highlighted that in Portugal a culture of associativism is still developing. Therefore, this was seen as a historical characteristic, which is shaped by the dictatorship, creating an individualistic mentality that impacts on the ability to work together. In contrast, from the perspective of associativism and collaborative practices, Spain, France, Germany, and the UK established strong collaborative methods as a result of reconstructing after the Civil War (Spain), and the Second World War (rest of the countries); this was due to the fact that both events created conditions that increased the necessity of collaboration.

B.4. Summary of the Meeting with Nuno Pereira from Mind for Metal

MCG | MCG Automotive, MCG Transportation, MCG Industry

A meeting was held with **Nuno Pereira**, Supply Chain Director of **Mind for Metal** in an effort to learn about the firm's exposure to global markets as well as about how disruptions from outside of the firm have impacted operations. These disruptions include geopolitical tensions and regulatory changes.

According to Nuno Pereira, the analysis indicated that Mind for Metal's sales are relatively unaffected by international sanctions since the majority of the company's sales take place in Portugal and Europe, with a very small portion of their sales being made in the U.S. In addition, although **Mind for Metal**'s sales have been relatively stable, there has been increasing uncertainty with respect to selling conditions in the marketplace. Most of the company's immediate suppliers (Tier 1 suppliers) are located in Portugal. Nevertheless, many of these suppliers obtain some of their inputs from outside of Portugal; most of these imported goods come from other countries in Europe, with the obvious exception of China.

On the operational side of the equation, **Mind for Metal** has not faced significant supply shortages, but rather has been impacted by increasing instability in the overall market, resulting in an increase in forecast and planning reliance, which has decreased their ability to accurately respond to changes in demand due to price instability and limited supplier flexibility. In comparison to previous periods when companies could stop their supply chains for a period of time, firms are now required to continue to produce due to ongoing demand pressures.

The firm utilizes a make-to-order type of business model that includes constant marketplace engagement and actively sourcing alternate solution(s) for its products. While material shortages have not posed any immediate concerns, one factor of price volatility (particularly with regards to aluminium) since the start of the COVID-19 pandemic and the ongoing conflict in Ukraine has continued to challenge their procurement strategy. The firm is often required to purchase materials at current market prices, which limits flexibility in their procurement process.

Procurement and supply chain coordination is usually one of the first places impacted when there are disruptions externally. The fluctuation in market behaviours (e.g., stockpiling) has driven up the prices of materials that are typically procured from areas with unstably predictable behaviours (e.g., the Middle East). In addition, the process of changing suppliers (i.e., obtaining pre-approval) is lengthy and complicated, which prolongs lead time and response time to unanticipated demand; especially with respect to urgent and/or additional orders.

The response to mitigate these risks is to have the firm maintain greater than normal levels of inventory, allowing for continuity of operations. This has been necessary with regard to aluminium due to its

significant price volatility and the need for constant and ongoing management and monitoring.

With regard to regulatory changes, among the most significant developments is the Carbon Border Adjustment Mechanisms (CBAM) and associated regulations. In light of uncertainty about supplier compliance with CBAM rules, the company has identified these regulations as imposing further administrative burden (complexity) and restrictions (strategic) on supply chains. Because of the uncertainty surrounding when CBAM would be fully effective, the company indicated it would be temporarily suspending the import of some products until January 2026, because of the risk of these products being subject to retroactive application. However, based on subsequent interactions with the company after this period, it was indicated that operations gradually adjusted as regulatory requirements became clearer, allowing the firm to resume and stabilise its sourcing practices.

Overall, the company indicated that numerous regulatory measures (e.g., quotas and pricing adjustments) were expected to increase cost to the end consumer. While some regulatory and/or geopolitical disruption would have a relatively minor impact on the company overall, with regard to longer-term contracts (e.g., related to the rail sector), it was noted that long-term contracts will likely be impacted more severely due to disruption both from a timing perspective (e.g., when can manufacturing resume at normal capacity) as well as economically. However, due to the inherent nature of a make-to-order sector, the metal working sector recognized that it could react to changeable conditions with some level of flexibility in delivery of total value when operating under uncertain circumstances.

B.5. Summary of the Meeting with Mihai Fontul (Iber-Oleff, part of Grupo Iberomoldes)

Iberoleff Portugal

The aim of the meeting with Mihai Fontul, Innovation Manager at Iber-Oleff, was to gain insight into the market position of the company within the value chain, its risk of being impacted by global markets and geopolitical disruptions and regulatory pressures in the continuation of its operations.

Iber-Oleff is an industrial supplier that operates primarily in the automotive sector. It falls within the Iberomoldes Group which encompasses the entire value chain for the plastic transformation of products; from product concept & design/engineering stage through tooling, including mould-making, assembly, and final industrialization.

Iber-Oleff is the last stage of this value chain and provides design-for-manufacturing services (i.e., product designs that can be manufactured) as well as industrializing products for delivery to customers in a near-turnkey basis (i.e., ready for final assembly by the customer). The company's core business involves manufacturing automotive parts (e.g. dashboards, central consoles and door panels), and supplies parts directly to top-tier automotive producers (i.e., Porsche, Audi, BMW) as either a tier-1 or tier-2 supplier through system integrators (i.e. other suppliers who assemble multiple components together into larger assemblies for their customers).

With about 98% of its manufacturing headed overseas, the company is highly exposed to global markets. Even with the disruption brought on by the war in Ukraine, Iber-Oleff still achieved growth thanks to other less-resilient competitors that failed to survive the combined effects of COVID-19 and geopolitical instability. By keeping their supply chain integrated and locally based, Iber-Oleff has avoided reliance on outside suppliers, especially located in China, for tooling and raw materials, but at the cost of higher manufacturing costs, which ultimately increase both the company's reliability in producing products and the level of trust between Iber-Oleff and its principal customers.

The company's relatively small and localised supply chain has helped Iber-Oleff manage the issues of disruption such as delays and inventory, etc. However, the sanctions imposed and geopolitical issues are recognised as having a direct impact on the company's ability to operate in terms of increased cost of raw materials, increased level of competition and decreased profitability. Additionally, because the company is largely dependent upon petroleum for the production of its plastic products, it is subject to fluctuations in the price of energy and raw materials. Recent events related to the conflicts in the Middle East and ongoing logistical issues such as limited access to strategic transportation routes have contributed to increased concerns regarding the availability of materials within Europe.

Dual sourcing is not used by the company as a means of mitigating risk; however, the company does maintain inventories of raw materials in order to buffer against short-term disruptions in its supply chain, while also expecting that supply chain situations will return to normal. While the company feels that it has better prepared itself now than it has in the past to handle instability in the marketplace, it also acknowledged that current global events, such as geopolitical tensions, are highly unpredictable and are not something that can be managed with traditional risk management techniques.

Regarding the regulatory pressures the company faces, the company commented that compliance with EU regulations is an ongoing process, particularly with respect to transitioning to more sustainable materials, such as replacing fossil fuel-based feedstocks with bio-based feedstocks. The company is a participant in several initiatives that support this transition, and the company is accustomed to adapting to regulatory requirements. However, the company believes that the geopolitical crises that are occurring today are a very different type of challenge for companies to manage than they are for companies to manage through traditional means.

Finally, the subject of inventory management was discussed, with the company utilizing contractual safety stocks (typically one month to two months of production) to ensure continuity of supply for instances of interruptions in production such as strikes and natural disasters. While this safety stock is continuously monitored, it is not significantly increased due to the financial implications of holding excess inventory.

Appendix C – SmartPLS Results

C.1. Final Structural Model

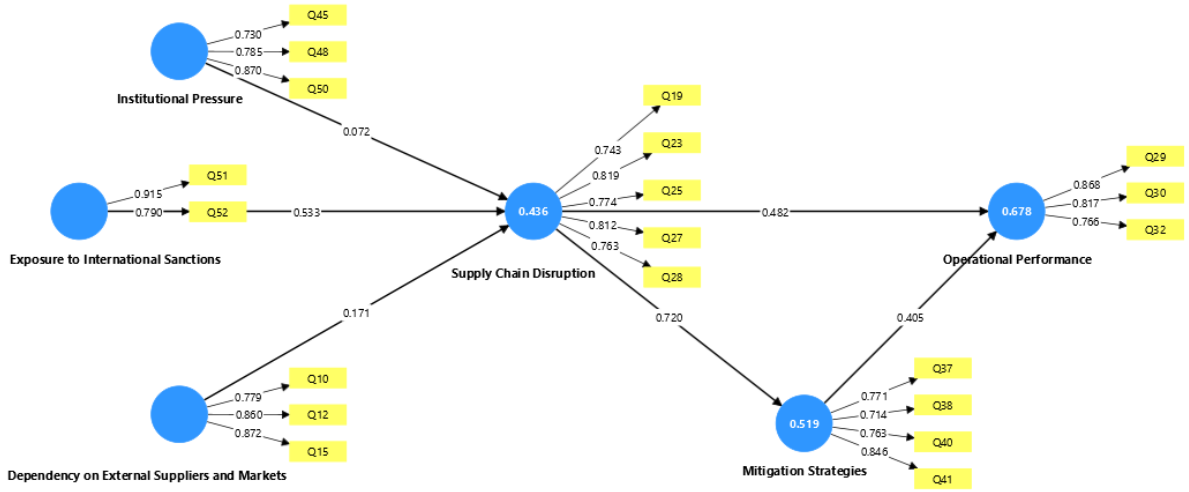
C.2. Outer Loadings

C.3. Reliability and Convergent Validity

C.4. Discriminant Validity

C.5. Bootstrapping

C.1. Final Structural Model



C.2. Outer Loadings

Construct	Indicator	Loading
Dependency on External Suppliers and Markets	Q10	0.779
	Q12	0.860
	Q15	0.872
Exposure to International Sanctions	Q51	0.915
	Q52	0.790
Institutional Pressure	Q45	0.730
	Q48	0.785
	Q50	0.870
Supply Chain Disruption	Q19	0.743
	Q23	0.819
	Q25	0.774
	Q27	0.812
	Q28	0.763
Mitigation Strategies	Q37	0.771
	Q38	0.714
	Q40	0.763
	Q41	0.846
Operational Performance	Q29	0.868
	Q30	0.817
	Q32	0.766

C.2. Reliability and Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability (rho_c)	AVE
Dependency on External Suppliers and Markets	0.792	0.876	0.702
Exposure to International Sanctions	0.645	0.844	0.731

Institutional Pressure	0.713	0.839	0.635
Mitigation Strategies	0.777	0.857	0.601
Operational Performance	0.752	0.858	0.669
Supply Chain Disruption	0.843	0.888	0.613

C.3. Discriminant Validity

Constructs	**HTMT Value**
Exposure – Institutional	0.913
Mitigation – Performance	0.970
Disruption - Performance	0.951

C.4. Bootstrapping

Relationship	**Path Coefficient (β)**	**t-value**	**p-value**
Exposure to International Sanctions → Supply Chain Disruption	0.533	4.374	0.000
Dependency on External Suppliers and Markets → Supply Chain Disruption	0.171	1.357	0.175
Supply Chain Disruption → Operational Performance	0.482	3.016	0.003
Institutional Pressure → Supply Chain Disruption	0.072	0.506	0.613
Supply Chain Disruption → Mitigation Strategies	0.720	12.258	0.000
Mitigation Strategies → Operational Performance	0.405	2.274	0.023