Risk Analysis and Modelling

Case Study of a Portuguese Codfish Processing Company

Sofia Tomaz de Menezes

Dissertation to obtain the Master of Science Degree in

Industrial Engineering and Management

Supervisor: Prof. António Manuel da Nave Quintino

Examination Committee

Chairperson: Prof. José Rui De Matos Figueira
Supervisor: Prof. António Manuel da Nave Quintino
Member of the Committee: Prof. Daniel Rebelo dos Santos

November 2021

Abstract

Firms are exposed to the uncertainty of both internal and external factors to their operation, which could adversely affect their future results. Nevertheless, they could reduce this uncertainty and create value by managing their risk exposure, according with their risk preferences and objectives. Therefore, this research seeks to provide a methodology to study the companies' risk exposure, applied to a codfish processing company case study. The methodology implemented follows some of the ISO 31000 framework steps, which include defining the context of the company, assessing the risks and treating them. For a clearer understanding of the future results uncertainty, the company's future net income was modelled using Monte Carlo Simulation. Additionally, the company's risk profile was defined by using an exponential utility function. Even though the future net income model has resulted in a wide range with some limitations, possible prevention and mitigation strategies could be modelled and their added utility to the company was measured. The results of this investigation have shown that the price fluctuation of codfish is crucial for the company under study, being the mitigation of this risk very recommended.

Keywords: Enterprise risk management, Risk profile, Risk modelling, Monte Carlo simulation, Codfish industry

Resumo

As empresas estão expostas à incerteza de fatores internos e externos à sua operação, que podem afetar adversamente os seus resultados futuros. No entanto, as empresas poderiam reduzir esta incerteza e criar valor se gerissem a sua exposição ao risco, de acordo com a sua tolerância ao risco e objetivos. Desta forma, esta investigação propõe uma metodologia para estudar a exposição das empresas ao risco, aplicada a um caso de estudo de uma empresa processadora de bacalhau. A metodologia implementada segue alguns dos passos da norma ISO 31000, incluindo definir o contexto da empresa, avaliar os riscos e tratá-los. Para uma compreensão mais clara da incerteza dos resultados futuros da empresa em estudo, os resultados líquidos futuros foram modelados utilizando simulação Monte Carlo. Além disso, o perfil de risco da empresa foi definido através de uma função de utilidade exponencial. Embora o modelo dos resultados líquidos futuros tenha resultado num intervalo muito amplo com algumas limitações, possíveis estratégias de prevenção e mitigação puderam ser modeladas e a utilidade adicional que as mesmas acrescentam medida. Os resultados desta investigação mostraram que a flutuação do preço do bacalhau é determinante para a empresa em estudo, sendo a mitigação deste risco muito recomendada.

Palavras-chave: Gestão de risco, Perfil de risco, Modelação de risco, Simulação Monte Carlo, Indústria do bacalhau

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Glossary

CE cost of employees.

CEO chief executive officer.

CodPT quantity of codfish produced in Portugal.

COSO Committee of Sponsoring Organizations of the Treadway Commission.

CPI consumer price index.

CSF critical success factor.

CVaR conditional value at risk.

DV dependent variable.

ERM enterprise risk management.

GDP gross domestic product.

ISO International Organisation for Standardization.

IV independent variable.

KPI key performance indicator.

MC material costs.

MCS Monte Carlo simulation.

MLR multiple linear regression.

MSC Marine Stewardship Council.

NPM net profit margin.

OR operating revenue.

PESTEL Political Economic Social Technological Ecological and Legal.

R&D research and development.

ROI return on investment.

SME small and medium-sized enterprises.

SWOT Strengths Weaknesses Opportunities and Threats.

TE total equity.

TS total sales.

VaR value at risk.

VIF variance inflation factor.

Chapter 1

Introduction

1.1 Problem Context

In Portugal, the industry of fish processing can be divided in three main sub-sectors: (1) canned fish; (2) salted and dried fish and (3) fresh and frozen fish [1].

Codfish products are mainly included in two of the previous sub-sectors, as they can be sold as salted dried codfish or in frozen packages, either fresh or precooked. Currently, there are about 50 companies processing codfish in Portugal, after buying it from the sellers mostly located in Iceland, Norway and Russia.

The operation and results of the companies depend on the external factors they are exposed to. These factors can relate to the market in which they operate, consisting in, for instance, changes in the relationships with suppliers, customers and competitors. Also, external conditions to the market can jeopardize their performance. These conditions can usually be classified in one of the Political Economic Social Technological Ecological and Legal (PESTEL) categories. The **Political** one consists in the impact of the government in the companies. For example, the government can be directly involved in the market as a customer, supplier and owner of different businesses. The **Economic** factors relate predominantly to changes in economic growth, exchange, interest and unemployment rates. Also, **Social** factors include, for example, the population's demographics, geographic locations and culture, which impact the demand for the different products. Besides, **Technological** innovations may contribute to the arise of new opportunities for the most adaptable companies and new threats to companies operating with traditional methods. Other important factors are the **Ecological** ones. These do not only include the impact of the climate changes in a company's activity, but also the waste production, resources consumption and pollution. Finally, the **Legal** factors relate to the compliance of regulation and taxation [2].

Thus, changes in the surrounding conditions might trigger unexpected consequences for the companies, and these possible changes constitute risks. Risk definition has not been consensual between different authors [3], but there is always a general agreement that a risk is the impact of an uncertain event on a certain objective of an organization [4].

Therefore, companies can benefit from managing risks [5], adopting different approaches and measures to deal with several types of risks, depending on the company's tolerance to losses. One possible way to measure risk, is using the value at risk (VaR), which is a statistic that estimates the possible losses an investor may incur in a certain time period with a given probability. As a result, it allows the quantification of risk when considering the possible losses of an investment, providing a basis for analysis and decision-making.

1.2 Motivation

The problem studied in this dissertation is the insufficient implementation of risk management practices in small and medium-sized enterprisess (SMEs) [6], applied to the case study of a Portuguese codfish processing company.

This problem is getting more and more relevant, specially with the emergence of the COVID-19 pandemic, that triggered an economic crisis [7]. Actually, 66% of the companies that were formed in 2020 went bankrupt, which corresponds to an increase of 22 percentage points when compared with the previous year [8]. According to Smit and Watkins [6], SMEs do not manage risks as effectively as larger enterprises, because they do not have as many capabilities to do so, even though they compete in the same market. Besides, if these firms are affected by some catastrophe, or other type of event that can jeopardize their activity, they do not usually have enough funds to cover the damages, and eventually go bankrupt [9].

Focusing on the case of the codfish processing company under study, despite recent good performance, they are vulnerable to a number of potential risks. The past results of a company are not a guarantee of their future success [10]. Hence, it would be important to understand and simulate the company's future results under a variety of scenarios and their respective probabilities, taking into account the external threats and opportunities. So far, they have solely concentrated on credit risk, even though they are exposed to other risks, which may contribute to the volatility of their results and jeopardize their ability to reach their strategic goals. For example, laws and regulations may change, prompting the payment of fines or requiring a significant change in the way the business runs. Furthermore, there are other uncertain variables, such as fluctuations on the tax rates in the countries where they operate, changes in the demand for codfish, changes in the codfish price, among others. Thus, the company's future results are uncertain in a broad range of values. Besides, the level of risk the company is exposed to might not match their risk preferences, stressing the importance of studying the strategies that should be ensuring their strategic goals.

The available literature already presents many risk management frameworks [11–13]. However, the authors usually agree that the risk management practices must be unique and perfectly adapted to each company and situation [14, 15]. Therefore, this dissertation will have a positive impact on the existing literature, providing a clear methodology on how to implement some of the most common risk management steps and how to adapt different techniques to the company in study.

1.3 Objectives

In conformity with the problem previously mentioned, a dissertation in Industrial Management and Engineering was developed. The purpose of this dissertation is to study the risk exposure of the codfish processing company under study. In this regard, the following objectives can be considered:

1. The determination of the company's risk profile, which relates to their willingness to take risks.
2. Modelling their future net incomes, combining the different possible values of revenues and costs, that will depend on several factors, including the probability and impact of the most relevant risks their are exposed to. The final result of this model will consist in a net income distribution, representing the probability of the company achieving certain results in the future, until 2029.
3. Suggestion of the most adequate risk management practices and mitigation strategies to improve the company's future results, considering their risk profile and the impact of the strategies in the developed future results model.

1.4 Thesis Outline

This document is divided in six chapters. After this introduction, the researched problem is detailed in **Chapter 2**, including the characteristics of the internal and external environment of the company under study.

Subsequently, **Chapter 3** summarizes the most relevant studies for this research available in the present literature, including important methodologies and frameworks developed by several authors. Some of the methodologies will be implemented during this investigation, as explained in **Chapter 4**, which reveals the methods used, detailing and justifying the steps followed during the research.

The results of the previous methodologies are then presented and discussed in **Chapter 5**, which describes the achieved simulation model, the company's risk profile and the simulation of events, such as risks and mitigation strategies.

Finally, to provide the final conclusions and summarize the discussed investigation, **Chapter 6** presents the key takeaways of the developed research.

Chapter 2

Problem Definition

The problem studied in this research is related with the uncertainty of a codfish processing company's future results. So, this chapter will clearly characterize the elements involved in the company and its context of operation, focusing on their available risk management practices and revealing the gaps, where they present the greatest risk exposure. Section **2.1** starts by detailing how the company operates, explaining the process beginning with the buying of the raw materials and ending with selling it to their buyers. Afterwards, Section **2.2** contains the characterization of the other elements involved in the supply chain, from their suppliers to their consumers. Still in this section, the way the government and the economy impact the business of the company under study are detailed. Finally, two frameworks are applied in Section **2.3** — a Five forces of Porter, to better study the attractiveness of this industry, and a Strengths Weaknesses Opportunities and Threats (SWOT) analysis, for a summary of the company's internal and external environment.

2.1 Characterization of the Company in Study

The company under study is a Portuguese family-owned business and one of the largest codfish processing companies in the world, producing approximately 25 thousand tonnes of codfish per year, which corresponds to almost 10% of all the quantity caught in the world, and exporting a significant percentage of their production to several countries. They have around 500 employees and two industrial units, one of them being the largest unit in the world operating exclusively with codfish.

2.1.1 Activity of the company

The activity of the company can be summed up in four main categories. First, they must buy the raw material, selecting the best suppliers and deciding on the optimal quantities. Second, they process the fish mostly by soaking, salting and cutting it. Afterwards, the company sells its products on trade, to restaurants, and off trade, to points of sale as the supermarkets, both inside Portugal and through exportation. Finally, they focus on achieving the best levels of efficiency by managing all the process.

Buying the fish

Every year, the company spends around 100 million euros to buy codfish. And, towards purchasing this large quantity, the company uses credit lines, which correspond to a short-term debt, always paid in less than a year.

Their results depend on the prices at which they buy the codfish. Therefore, they depend on their suppliers, who tend to follow the prices recommended by the governments. These prices are defined according with the fishing quotas of each year, as it will be further explained.

About the purchasing procedure, the company has the advantage of the large quantity they buy and the disadvantage that the prices do not vary almost anything between different sellers and for different customers, leaving low margins for the negotiation.

When choosing the best deals, the decision-makers do not only take the negotiated price into account, but also the quality of the fish, prioritizing the producers who demonstrate to have the most sustainable practices. They choose a high quality codfish, or, in other words, without blood marks or wrinkled and damaged parts, that, despite having a higher price per kilogram, leads to a higher percentage of raw material used.

Processing the fish

The company operates with codfish bought in three different forms: fresh, salted (*salgado verde*) and dry. The processing of the fish comprises the phases of salting, drying, soaking (*demolhar*) and ultra-freezing.

The process starts with the Portuguese cure, which is a process that involves putting the fish in large quantities of salt, which will provide a natural conservation and maturation of the product. After 4 to 12 months of maturation, the fish is finally washed to remove the excess of salt. Next, the codfish proteins are dehydrated in controlled chambers, to dry the codfish.

Afterwards, it is time for the cutting phase. This phase consists in cutting the codfish according with specified references to create the desired shapes for the final products. The diversity of shapes allows the creation of a variety of products, adapted to different consumers and needs. The codfish cutting is made by machines and complemented with a strong component of manual work, since the raw material comes in different forms and it is intended that the process has almost 100% efficiency, producing nearly zero waste.

Subsequently, the codfish is soaked for a certain time and water temperature, both determined according with the size and type of each steak. Lastly, the parts are deep-frozen at $-40°C$ for four hours and sorted in small packages of ready-to-cook codfish.

Despite being a very difficult process to automate, the company has a department specialized in continual improvement that is responsible for analysing and upgrading the processes.

During the process, they are very concerned about food safety and the quality of their products, monitoring and testing it according with certified norms.

Selling the products

They have a total of 30 different products to sell to restaurants and 24 for home consumers. These products differ from each other in weight and quantity per package, part of the fish, preparation mode and even type of fish, as they also sell pollack fish and other species. They have packages with just the tongues, just the cheeks, loins, steaks, cod pastels, shredded fish and prepared for stews. All these products are a result of their ability to innovate and to react to new trends and consumer preferences. This way, they can capture different types of customers, selling higher quantities, and keep pace with the changes in the market.

To ensure that the goods reach their customers, the company has a contract with a logistic operator who is in charge for almost all the distribution process.

Managing all the process

To manage all this process, the company has several departments with different key performance indicators (KPIs).

Regarding their strategic decisions, as the company is a family-owned business, at the beginning, decisions were exclusively made by one person, the owner. However, over the years, an increased responsibility has been given to each area of the company and, inclusively, a formal board of directors has been put in place, allowing the strategic decision-making power to be shared among more members.

2.2 Characterization of the External Environment

Regarding the external environment of the company, some details about their suppliers, competitors, customers and consumers will be provided. Additionally, the impact of the codfish quotas, the government and the economy in their business is also going to be explored.

2.2.1 The Other Elements of the Supply Chain

The Suppliers

The codfish supply chain starts with the fishermen, who have to comply with the fishing quotas established each year by the governments. These quotas represent maximum quantities that can be caught legally. Usually, Russia and Iceland tend to follow the values defined by the Norway's quota system, and the quotas established by these three countries correspond to 80% of all codfish quotas in the world. Nowadays, there are about 5 big fishing companies and countless smaller ones.

After setting the fishing quotas, the governments establish some recommended prices for the fisheries, according with the quotas of each year. The fishing companies usually follow these recommended prices when selling to the producers, who are responsible for preparing the fish, separating the head and the liver. Later, they sell it to industrial companies in a slightly more negotiable manner. Nevertheless, the prices do not differ more than 5% between different sellers.

The Competitors

Concerning the competition, the company's managers affirm that there are seven main companies competing in this market including themselves, who have the largest market share.

Besides, new players may attempt to enter in this market. Nonetheless, the company's managers have shown little concern about the introduction of a Norwegian player into the market. They claim that the advantage of a Norwegian player being close to the fishing zone would be offset by their high labour costs, as they have one of the Europe's most expensive labours. In addition, the company in study is able to utilize a higher percentage of codfish because, in Portugal, there are several traditional dishes that use the different parts of the codfish, including the tongues and loins. Hence, Norwegian cod producers seem to be more interested in selling the whole product, with no waste.

Conversely, the demand for codfish might be affected by substitute goods. Therefore, companies selling other types of fish, meat and other vegetarian options can also compete for the same customers.

The Customers

The company primarily sells two types of codfish — dry cod and ready-to-cook packages. The first one, dry cod, is mostly sold to points of sale (off trade) for the supermarket brands and to restaurants (on trade). Regarding the second one, the ready-to-cook packages, it corresponds to the codfish that passes through the steps of soaking and ultra-freezing and its mostly sold off trade, in ready-to-cook packages of the company's brand.

The Consumers

Finally, relating to the final consumers, the company's experts defend that the demand for codfish ready-to-cook products is expanding due to the evolution of our society's habits towards more practical and fast practices. Hence, the demand for ready-to-cook codfish products has a tendency to expand while the popularity of dry cod is expected to slowly decrease.

Also, the habits of eating codfish are increasing in other countries, especially in Europe, what triggered the increase of 14.5% of the quantity of frozen codfish exported form 2018 to 2019 [16]. People have a preference for this type of fish because it is very healthy and has many benefits as, for example, its high composition of proteins, low fatness and being a very satiating food. Also, it is a certified product by the Marine Stewardship Council (MSC) and, therefore, it is the result of a sustainable fishing.

As a result of these factors, it is conceivable to forecast an increase in the price of cod in the medium term. Nonetheless, codfish products are highly seasonal. Codfish meals are particularly traditional in Portugal during Christmas, which leads to a substantial increase of the demand during that season.

2.2.2 The Context of Operation

The activity and success of the company is affected by its external environment, that includes the context in which they operate. For that reason, a brief explanation of some factors that might jeopardize their results is going to be given.

Codfish Quotas

As mentioned before, the company's results are very dependent on the cod prices, wish follow the codfish quotas, defined by the fishing countries' governments. These quotas can pose unexpected threats.

As one can see in Figure 2.1, the codfish price is volatile inside a certain range. During 2019, the importation prices from Iceland, Russia and Norway were continually increasing and decreasing unexpectedly, but always inside the range from 6 to 10 $/tonne [17]. The demand for codfish has shown to be inelastic in that range of values [18]. Nevertheless, this rigid demand is assumed for the small variations that the price of codfish has been having. Eventually, if the price increases more than the usual, the demand might decrease. For example, the quotas might not be enough to fulfil the growing global demand of codfish, triggering an increase in its price and limiting the quantity sold in the Portuguese market. In that case, despite the increase in the codfish price, the volume of sales of the Portuguese companies would probably decrease, together with their revenues.

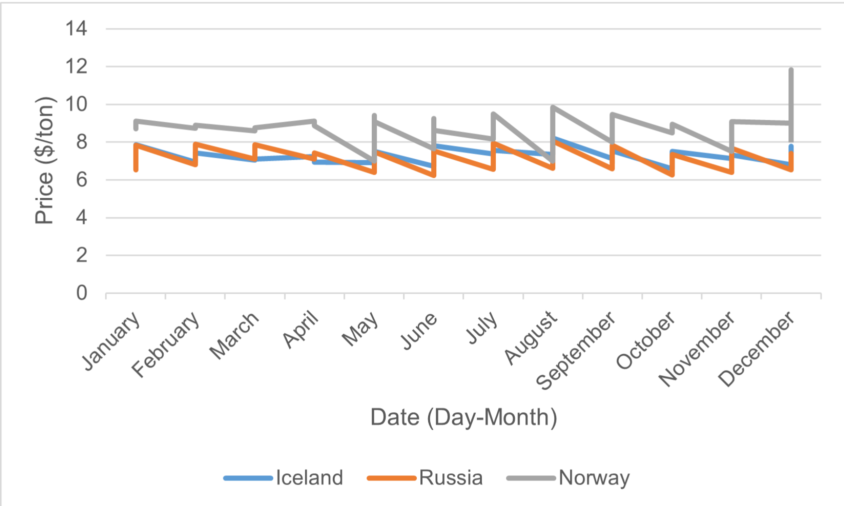

Figure 2.1: Codfish exportation prices of Iceland, Russia and Norway during 2019 (Adapted from Tridge [17]).

Government

The Portuguese government has a significant impact in the company's operation. First, by subjecting it to the payment of taxes and to the possibility of changes in these taxes. Also, by implementing legislation that would affect several areas of the business and that might force them to change the way they operate or end up paying fines. Besides, the governments from where they import and to where they export also impact their activity. For example, as seen before, the exporting countries establish the fishing quotas and recommend selling prices.

Existing regulation that affects the company under study relates to processing, packaging, storage, distribution, advertising, labelling, quality and safety of food products and environment. The emergence of new regulation might compromise their costs, affecting their results. For example, in regard of the environmental regulation, climate changes, including global warming, might lead to the development of new regulation about the use of fuels and affect their transportation costs.

Economy

Economies might fall for diverse reasons. As verified by history, world wars were responsible for huge damages in the economy, forcing people to relocate and the governments to invest in the country's recovery. Also, a more actual example is the economic crisis caused by the COVID-19 pandemic, which forced many companies to stop operating during lock downs. Nevertheless, these rare events are not the only triggers of economic crises, which can be caused by catastrophes, as tsunamis and earthquakes, and by a bad management of the country's financial condition, leading to an excessive indebtedness.

Having said this, the company in study is exposed to the possibility of economic crisis, not only relating to the Portuguese economy, but also to the economies of all the countries from where they import and to where they export. This constitutes a threat to their profits and, in particular, to a shrink in the demand for their products, caused by a decrease in the buying power of the population in general.

2.3 Context of Operation Frameworks

To complement the context previously defined, some frameworks are also explored in this section. First, a Five Forces of Porter analysis is presented. It is a framework that helps to define the attractiveness of an industry, by analysing the threats and the competitiveness associated with five different forces. These forces are the competitive rivalry, the threat of entry, the threat of substitutes, the power of buyers and the power of suppliers.

Additionally, a SWOT analysis will also be presented. In this analysis, the strengths, weaknesses, opportunities and threats of the company are discussed. The strengths and the weaknesses are based on their internal capabilities, whereas the opportunities and threats relate to the external environment of their operation.

2.3.1 Five Forces of Porter

Competitive Rivalry

The codfish processing industry is composed by several players with very asymmetric market shares. There are players with a much larger share than others, which means that the companies with a larger share have more influence and there is less competition than if all the companies were equally sized.

Furthermore, the demand for codfish is expanding and the industry is growing. This attenuates the competitive behaviour of the companies because each company can grow with the industry, without appropriating their competitors' market share. Additionally, the industry is characterized by very high variable costs, because of the codfish cost, and not so relevant fixed costs. This decreases the level of competitiveness because there are no scale economies, encouraging companies to decrease their prices, in order to increase the quantities sold.

Finally, in markets with lower differentiation between the products, there is more competition. In this case, one can say that the dry salted codfish is a homogeneous good, as it does not differ much from brand to brand. Conversely, the ready-to-cook and ready-to-eat alternatives are ways for companies to differentiate themselves and create different products adapted to different preferences and needs. These products have a less elastic demand, allowing pricing to be less dependent on the competition prices.

The Threat of Entry

Regarding the threat of entry, the brand loyalty that the consumers have developed for different firms and the compliance requirements relating to this industry regulation may work as a barrier for new entrants.

Also, the incumbents of this market benefit from experience economies, what may represent a threat for the new entrants. The more efficient a firm is, the less codfish it will waste, boosting output for the same cost of raw materials.

The Threat of Substitutes

As mentioned before, the substitutes of the codfish products are other types of fish, meat and vegetarian options. In this situation, consumers favor products that are healthier, more tasty, and need less time to prepare. As a result, if people value a product more, they are willing to pay more for it. Having stated that, it is reasonable to assume that enterprises can choose between lowering prices and enhancing performance, or a combination of the two, in order to attain their targeted level of sales.

The Power of Buyers

The more concentrated the buyers are, that is, fewer companies with greater market shares, the more power they will have. Regarding their off trade buyers, there are only about 10 supermarket companies. So, these might have some power to negotiate prices and to reduce the margins of the sellers. When selling on trade, the buyers are restaurants and, because there are hundreds of restaurants in Portugal, they have relatively small market shares and, as a result, less power.

Lastly, stores benefit from buying processed codfish from suppliers. It would be inefficient for each store to invest in machinery and professionals rather than have specialized enterprises producing greater amounts. In addition, retailers can buy from a range of vendors, giving their customers a wider variety of options.

The Power of Suppliers

As previously explained, the prices of the products sold by the different codfish producers tend to follow the fishing quotas established by the governments. Also, the suppliers would gain more influence if they threaten the cod processing companies that they could begin processing codfish and selling it directly to merchants in Portugal. However, they have not shown interest in doing so, so far.

2.3.2 SWOT analysis

Regarding the first analysis, Table 2.1 shows the developed SWOT matrix. This matrix summarizes important characteristics of this research problem, which will later be used to help with the risk identification.

Table 2.1: SWOT analysis.

Strengths	**Weaknesses**
Very large market share Largest sellers of codfish in Portugal Powerful brand recognition Business know-how Efficient and sustainable Continual improvement efforts Large variety of products Ability to innovate Healthy, safe and sustainable product Have a global supply network	Strong component of handwork Dependency on qualified employees Tendency to accumulate stocks High and inconstant inventory costs Not analysing macroeconomic variables Not managing all types of risk Having centralized decision-making power
Opportunities	**Threats**
Expanding demand Increase market share by innovating Reach new market segments Expand to new geographical markets Advancements in technology	Codfish quotas Dependency on buyers and suppliers Increase of the competition Increased demand for substitute goods Climate changes affecting cod reproductive cycles Increased popularity of plant-based diets Negative public opinion Seasonality Change in regulation and legislation Unstable economy

2.4 Problem Statement

To conclude, the company under study has several competitive advantages in its industry, as the consumers preference for the quality of their products. As a result, they have been having increasingly success over the years, increasing their annual net income almost every year.

Nevertheless, as mentioned before, uncertain factors might affect their business and completely change their results. The improvement of their practices, or the implementation of new ones, could contribute to lock in their positive profits and prevent worst future results. For a better understanding of the peculiarities that contribute to their risk exposure, some examples of possible consequences, given the company's current way of operation, are going to be provided:

- A **centralized decision-making power** has disadvantages for the company, when compared with a situation where the decisions were shared by a larger group of managers with different backgrounds and expertise. Also, it makes the information flow slower, as a larger number of tasks have to wait for the approval of the same person.
- Codfish processing has a **strong dependence on hand work**. This way, if their competitors discover more efficient and automated methods of processing their food products, they will be able to lower their prices and win some of the company's clients. In this instance, investments in continuous process improvement are critical to keep the organization from falling behind competitors who are also striving to enhance their efficiency.
- Uncertain changes in the demand and seasonality contribute to the **accumulation of stocks**. These inventory costs affect very significantly the company's results. Therefore, an unpredictable change in the demand for codfish could trigger a huge increase in the storage costs in that specific year, completely wiping out the company's profits. An improvement opportunity for the estimation of the needed quantities is, for example, the creation of a department responsible for a thorough analysis of the consumers' demand curve and correlation factors with macroeconomic variables and other demand curves of complementary and substitute products. This way, the company would be able to make more accurate estimations and better predictions.
- The company in study **only manages credit risk**, being exposed to other types of risks, as the ones triggered by the PESTEL external factors, previously mentioned in Chapter 1. Hence, the company would exploit from the creation of a risk management department, that would allow them to take early mitigation measures depending on the external threats. Besides, this department would allow them to match their risk exposure with their risk profile. In other words, if they mapped and monitored the risks, they could decide whether or not to accept certain risks, according their risk preferences.
- As they operate in the food industry, they have to be very concerned about **food safety** and hygiene standards. A failure to comply with any standard could lead to the payment of fines and to the waste of stocks. Also, injured customers for damaged food products might ask for compensations, which could compromise the company's reputation and results.
- Finally, they are very **dependent on their buyers**. A very significant percentage of their sales derive from only a few clients, which means that the loss of one of those clients would have an huge impact in their sales.

Chapter 3

State of the Art

Risk management provides a strong basis for planning and decision-making, contributing to an increase in the processes' efficiency and compliance of regulation [19]. As it includes reducing the impact of uncertain changes in prices, firms facing financial distress and under investment are more likely to benefit from managing risk, reducing the variability of their cash flows [20]. Some case studies in the literature have shown the impact of the lack of risk management and the effectiveness of its implementation in different industries [21, 22]. However, despite the fact that companies should manage risk to prevent having bad results, Altuntas et al. [23] show that companies are generally more likely to adopt or improve their enterprise risk management (ERM) practices only after having the bad results.

This chapter will start by presenting some of the most known risk frameworks in Section **3.1**. Later, the topic of risk profile will be explored in Section **3.2**, revealing the most common techniques to measure a decision-maker's risk utility function, which relates with his risk preferences. Afterwards, Section **3.3** summarizes some strategies used by different authors to manage risk, including some case studies with the implementation of mitigation strategies. Finally, Section **3.4** presents previous studies regarding codfish, and its price fluctuations.

3.1 Risk Frameworks

Risk management frameworks have been evolving year after year. In 2004, the Committee of Sponsoring Organizations of the Treadway Commission (COSO) has issued an ERM Integrated Framework, which was updated later in 2017. In 2009, the International Organisation for Standardization (ISO) decided to develop a universal standard for risk management, called ISO 31000, which defined risk as a measure of the uncertainty of a company's objectives [24]. ISO 31000 has also been updated in 2018 and is the most accepted framework between the community so far. For example, Gjerdrum and Peter [19] defend that the ISO framework is easier to implement when compared with the COSO one. Besides, they defend that ISO guidelines include communication and adaptation through all the risk management process, whereas COSO is not iterative and it is only implemented by the internal audit department, instead of being reported and communicated by all the parts of a company. Nevertheless, they point out that, even though the ISO framework is more complete, the two frameworks are not very different, having many steps in common. So, their final suggestion consists in using the ISO framework or complementing the weaknesses of the COSO framework, if the company has already followed this methodology.

3.1.1 ISO 31000

ISO 31000:2018 contains a detailed explanation of how risk should be managed, including the principles, framework and overall process. It provides generic guidelines that can be adapted for any individual or organization [11]. As a universal framework, the way how each company implements and interprets the ISO guidelines significantly affects its efficiency [14].

Principles

When establishing the framework and process, the integration of some principles is crucial to the quality of the risk management implementation and will contribute to the improvement the company's results [25]. ISO principles defend that risk management should be: **(a)** integrated, **(b)** well structured, **(c)** customized, **(d)** inclusive, **(e)** dynamic, **(f)** making use of the best available information, **(g)** adapted to cultural factors, and **(h)** continually improving.

Framework

Regarding the framework, it is constituted by six components. The first one is **leadership and commitment**, and defends that top management should ensure the effectiveness of the risk management process and the alignment of the framework with the objectives and values of the company.

The second is **integration**, since risk management should be integrated in all parts of the company and everybody should be responsible for managing risk. The third one is the **design** of the framework, which includes:

1. Defining the internal and external context of the company.
2. Committing to manage the risk and purposing to achieve the objectives of the company.
3. Identifying the responsible employees for each task of the risk management process and assuring the communication among them. A well structured and strong risk management committee contributes for the effectiveness of the risk management [26].
4. Assuring the necessary resources for the risk management.
5. Providing the right means for communication and consultation of the required information for risk management purposes.

The forth component of the framework is the **implementation** of the plan, which includes following the planned schedule and allocated resources. The implementation of this plan must be dynamic and adapted to all the circumstances. Doval [27] reinforces the importance of continually searching for risk triggers and developing action plans to reduce the risks.

After, the companies must perform an **evaluation** of the risk management practices implemented. This review should be made periodically to ensure the actions still align with the company's objectives and context, and the plan is being correctly implemented, according with the expectations.

Finally, the last component is the continual **improvement** of the risk management by the identification of gaps or opportunities, creating more and more value for the company.

Process

Considering now the process, it must be iterative instead of sequential, and it includes the steps presented in Figure 3.1.

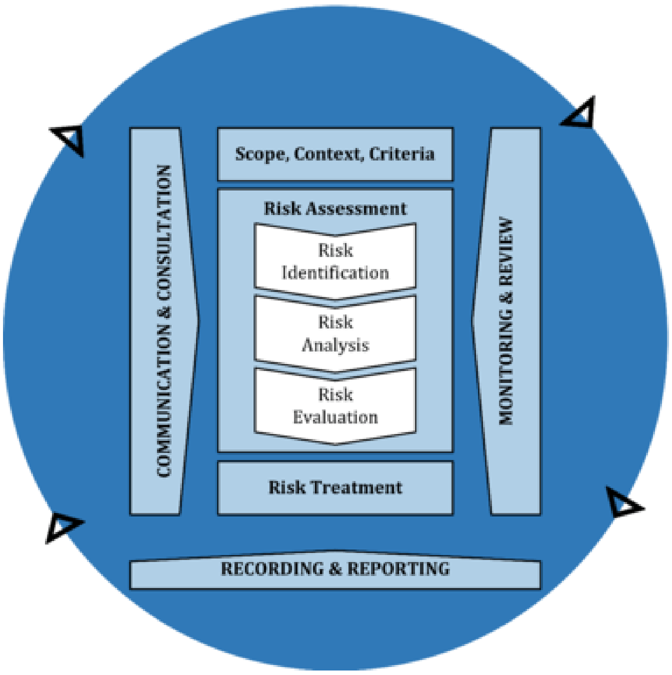

Figure 3.1: Process of ISO31000:2018 (Source: ISO 31000:2018 [11]).

The first step of the process is to establish the context of the company, considering the firm's operation and stakeholders. Thus, the application of a risk management framework is a complex task that requires a broad research and context characterization [15].

Regarding the risk assessment, it must consider short and long term risks, the operational and the strategic ones, respectively [28]. After the identification and analysis of the risks, they must be evaluated. Mitchell [29] shows that the risk can be defined by a possible loss multiplied by the respective probability of that event.

Afterwards, the companies should decide on the risk treatment actions. The risk response strategies found in the literature can be classified as avoidance, reduction and acceptance, depending on the level of risk exposure the company wants, from completely eliminating it to completely taking it. Also, the strategy can consist in transferring the risk to another party, exploiting the risk if it constitutes an opportunity, and even ignoring it, not analysing it at all [30].

Together with these 3 steps, the company must continually monitor and report, allowing the best communication and reviewing all the process.

3.1.2 ERM COSO

Similarly to ISO 31000:2018, COSO suggests that the steps to manage risks are the identification, assessment and response, with the help of risk scales and matrices.

For the risk assessment, they suggest the development of scales to measure the impact and likelihood of the risks. Regarding the impact scale, it can be measured by the financial impact, negative media coverage, loss of market share, loss of key personnel, damaged facilities and hurt employees. Concerning the likelihood scale, it can be measured as an annual frequency or a probability of occurrence during a certain period [12].

Also, the COSO framework suggests some tools such as the scenario analysis, risk interaction analysis and the creation of visual structures to organize the risks. The last can be made, for example, with bow tie analysis, event trees, fault trees and risk mapping. Risk mapping consists in using the scales previously defined, for example from 1 to 5, to map each risk inside a matrix, such as the one presented in Figure 3.2 [12].

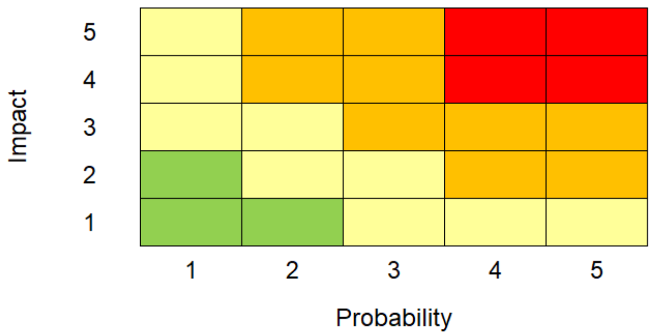

Figure 3.2: Risk matrix example.

COSO emphasizes the importance of defining the risk appetite of the company, that is affected by each company's mission, values, culture, strategic path and the managers risk profile. Having a well defined risk appetite, the companies are able to reevaluate alternatives, set their business goals and change their value creation techniques [13].

3.2 Risk Profiles

Most of the times, risk management practices do not correspond to the managers risk profiles [31], as many firms make their decisions based on expected value analysis instead of performing an expected utility analysis, that takes into account the risk profile and objectives of the company [32]. The risk profile of the companies can be modelled in utility functions, whereas their objectives must be ensured by well defined critical success factors (CSFs) that will allow the definition and measurement of the success and performance of the companies [33].

3.2.1 Utility functions

The utility functions enables a quantitative analysis of how beneficial a decision is, considering the risk profile of an investor. As a result, having a well-defined utility function allows a decision-maker to compare the added value of different decisions. The decisions resulting in higher utility values are better choices for that investor.

Some of the most used utility functions are the logarithmic, the quadratic, the exponential and the power function. The power and the exponential functions have less limitations than the other two functions, since the logarithmic does not allow an analysis with a continuous function, since it is not defined for all real numbers, and the quadratic one predicts positive utility values for losses, meaning that the decision-makers would take utility from losing money [34].

Kirkwood [32] suggests using the exponential utility function which, according with his simulations, leads to more accurate results in different situations and with low levels of error associated. This function is defined by:

$$u_x = 1 - e^{-x/\rho} \tag{3.1}$$

Where u is the utility associated to the gain x, ρ is the risk tolerance coefficient and sgn(ρ) corresponds to the sign of ρ.

To estimate the risk tolerance coefficient, Delquié [35] defends that it only depends on the maximum acceptable loss for a given probability, not depending on the possible gains. He suggests finding the maximum loss (L) that makes the gamble in the Figure 3.3 acceptable.

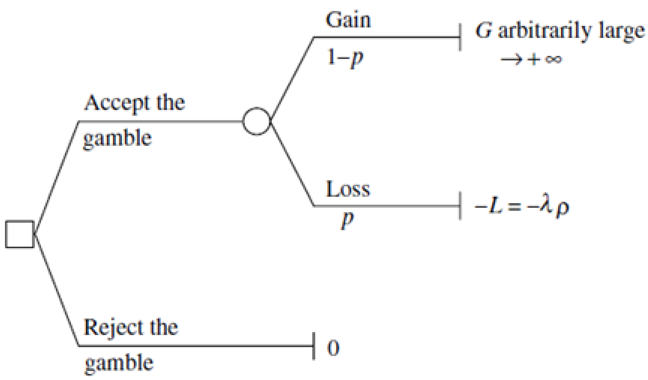

Figure 3.3: Gamble to find the maximum acceptable loss (Source: Delquié [35]).

In other words, he suggests finding the value of L that makes the decision-maker indifferent between accepting or rejecting the gamble, where p is the probability of losing L in the gamble, $1 - p$ is the probability of gaining G (which is an arbitrarily large number), $\lambda = -ln(p)$ and ρ is the risk tolerance. After finding L, the risk tolerance coefficient is calculated by:

$$\rho = \frac{L}{\lambda} \tag{3.2}$$

The author also emphasizes the limitations of this model, including the fact that it does not take into account the wealth of the investor, which also has impact, because a wealthier decision-maker is probably willing to lose more money. Therefore, the risk tolerance coefficient must be used to make decisions in the environment in which it was calculated, and not as a constant value. If the managers or the business conditions change, this value must be readjusted.

This model is similar to the definition of risk tolerance, defined by Neapolitan and Jiang [36], in which ρ corresponds to the largest value of X the decision-maker is interested in betting in a gamble with 50% probability of gaining X and 50% probability of losing $X/2$.

Trying to find an easier way to calculate this coefficient, Howard [37] noticed that the risk tolerance coefficient values for different companies are usually proportional to the the total equity and total sales of each company. His findings show that the risk tolerance normally corresponds to about 6% of the total sales (TS) of the company and to around one sixth of the total equity (TE) of the company:

$$\rho \approx 0.06 \times TS \approx \frac{TE}{6} \tag{3.3}$$

These equations constitute a simpler approach for any company to calculate an approximation of its risk tolerance coefficient. However, the author has only used a small number of companies in their study, that were all somehow connected to similar industries, related with oil and chemicals.

Finally, for more accurate results, Walls [38] proposes a more complex technique to calculate the risk tolerance coefficient, which consists in performing a survey to the managers of the company. The survey presents 10 investment opportunities with independent outcomes, similar to the decisions that the managers usually face in the industry in which they operate. Each opportunity has 2 different outcomes — success or failure, and the correspondent probabilities and results (gain and loss values). For each of these opportunities the managers should decide on their level of participation in that investment, in percentage. To compute the risk tolerance coefficient, it is necessary to calculate the Certainty Equivalents (C_X). For that, Cozzolino, quoted by Walls [38], developed the following equation:

$$C_X = -\rho \cdot \ln\left(\sum_{i=1}^{n} P_i \cdot e^{-X_i/\rho}\right) \tag{3.4}$$

Where C_X is the equivalent cash value of a decision with probability P_i of having an outcome X_i for a manager with a risk tolerance coefficient of ρ. The computation consists in calculating C_X for each participation level and for different values of ρ, and choosing the value (or range of values) of ρ that provides a greater C_X for the participation level specifically chosen by the managers, when compared to the other participation levels. This makes sense because the managers will choose the best option for them, with the greatest C_X, given their ρ. So, if any other participation level would lead to a greater value of C_X for the same ρ, the manager would choose that option.

3.2.2 Risk Aversion

Most of the managers are risk averse, which might lead to sub optimal decisions [39]. Managers are considered risk averse if their financial insecurities or stress can lead to bad decisions and bad results. The main characteristics of risk aversion are the preference for not losing compared with the preference for gaining, fear of the unknown, decision bias when considering only the most recent facts and anchoring to a certain reference point, searching for information that will match their insecurities to find an excuse for acting over them, and copying the decisions of other managers [40].

Risk aversion may vary depending on the economy, politics, culture and individual characteristics, as the age, gender, ethnicity, work experience, financial expertise and mathematical skills [31, 41]. For example, older people are usually more averse to risk than the younger ones [41]. Also, the expectations and current condition of some macroeconomic factors might affect the current level of aversion to risk of a decision-maker. These factors include, for instance, the consumers confidence and monetary policy stance [42].

Having said this, the risk profile of a person might change depending on the circumstances. Brocas et al. [43] show that people tend to accept higher levels of risk after having gains. They also point out that an individual's perception of his own risk utility function does not typically match with his actual risk profile. Also, the perception of a person's own risk profile may vary with her emotions. For example, if the person is in a good mood, she might overestimate her willingness to take risks, whereas if she is in a bad mood, this person might seem to be more averse to risk than she actually is [44].

Regarding the businesses, the highest incomes that an organization can make arise by investing in risky projects that turn out to succeed. However, the managers of a company are generally more averse to risk than the chief executive officer (CEO), focusing on safe investments and small improvements [45]. Besides this, there is the principal-agent problem, which consists in the differences between the interests of the CEOs and the shareholders [46]. Bickel [46] believes that the principal-agent problem is the main reason why companies tend to be risk averse. His findings show that the high costs of financial distress and external finance have a very reduced correlation with the aversion to risk.

Aside from the aversion of losing, Gollier [47] emphasizes the importance of another type of aversion, the aversion of regretting to not taking a certain risk, also known as regret-risk-aversion. This type of aversion can lead managers to make riskier decisions, that have higher possible payoffs, even if that is not the optimal decision.

3.3 Risk Analysis and Response

3.3.1 Risk Assessment

As suggested by the ISO 31000:2018 framework, assessing the risks includes the identification, analysis and evaluation of the risks. First, firms should identify the critical objectives of their businesses. Afterwards, the risk identification starts with the determination of the factors that can compromise the achievement of those objectives [48]. One of the most common techniques to identify risks with low probability but very high impact is brainstorming, which consists in the gathering of ideas from a group of people. This way, the risks are identified based on the perception of hazard of different members of a company [49].

Subsequently, to measure the risks, Moon and Krahel [48] propose a methodology that starts with the identification of relevant indicators to monitor the risk factors. After, some threshold values and significance weights must be defined for each indicator. In other words, critical levels of these indicators that reveal that the risk might happen. The levels of the indicators must be monitored frequently and an alert must be issued if the critical levels are achieved. In particular, Alexander et al. [50] suggest using VaR as a measure of risk, highlighting that, to minimize the risk of certain project or portfolio, minimizing conditional value at risk (CVaR) is a better objective because of this measure's subadditivity and convexity properties.

These measures can be simulated using different types of models: quantitative, qualitative and hybrid. Regarding the quantitative models, there are the simulation and the analytical ones. The simulation models are usually stochastic models that help to visualise the uncertainty of the risks, when applied to risk management. These models include, for example, discrete event simulation, agent based simulation, system dynamics, Monte Carlo simulation (MCS) and petri-nets [30].

The literature presents many algorithms to calculate different measures. For example, Ozkan and Kilic [51] propose a MCS algorithm to calculate the reliability of a complex system, given the probability that each component of the system will successfully perform the expected task, and the effectiveness of the link between different components. In addition, Cheung and Powell [52] show that VaR can be calculated by using historical data, parametric equations and MCS, having all these methods advantages and disadvantages, as show in Table 3.1.

Table 3.1: VaR calculation methods (Source: Cheung and Powell [52]).

Method	Advantages	Disadvantages
Historical data	Accurate past results	Future results compromised by market shifts
Parametric equations	Simple to implement	Narrow range of application
Monte Carlo simulation	Large number of observations	Intensive computer effort and time consuming

An example of a case study using MCS is the one performed by Crum and Rayhorn [53]. They have made a forecast of the financial statements of a small business, arguing that using MCS allows a complete picture of the future results and helps decision-makers running their businesses, forcing them to consider the risks they are exposed to and their possible impacts. They conclude that the results may not be accurate, because of the assumptions needed for the input distributions and possible miss understandings relating to the variables' correlations. Nevertheless, they point out that this lack of certainty is still verified when using any other method, emphasizing that using MCS leads to better decisions.

Additionally, many authors have used multiple linear regression (MLR) to estimate the future values of explained variables, based on the values of determined explanatory variables. For example, Huang et al. [54] tried to predict the damage caused by birds in power towers using MLR. For that, they started by clearly defining the environment and characteristics of the towers to then select the explanatory variables. After, they collected data for that variables during 4 years and calculated their correlation with the explained variable. Afterwards, they combined the explanatory variables in three different groups and selected the one that leaded to a MLR with a greater R^2, defending that the higher the R^2 the better, since it corresponds to a greater fitting degree. They conclude that this method provides a fast and accurate way of predicting bird damages.

On the other hand, Kieu et al. [55] defend that an higher R^2 does not necessarily imply a more accurate prediction, having shown an example where this does not happen in a case study to predict the future stock value of the S&P 500. For that, they collected data from 250 health care companies, which were used as explanatory variables, in a time set containing 255 values for each company. First, they grouped the companies in 1000 random groups of 10 and performed several MLRs using different numbers of observations, saving 10 known values for error prediction analysis. For example, when using a sample of 245 values to calculate the MLR, the first 5 values that are out of the sample (from 246 to 250) are considered the near out-of-sample predictions, whereas the last 5 values (from 251 to 255) are called the far out-of-sample predictions. This way, by calculating the errors associated with near and far out-of-sample predictions, they could conclude with a 99% confidence that the near out-of-sample errors are greater than the far out-of-sample errors 60% of the times. Also, they noticed that the experiment which leads to greater R^2, obtained with the method stepwise, did not correspond to the MLR that had smaller errors associated in the out-of-sample analysis.

Moreover, to develop an accurate MLR model, a near linear relationship between the dependent variable and each independent variable is required. On the other hand, the independent variables must not have this relationship between them. In other words, it is important to ensure that there is no multicollinearity between the independent variables [56]. For that, Montgomery et al. [56] suggest verifying if the variance inflation factors (VIFs) correspond to reduced values, pointing out that values above 10 units are resultant from a non reliable model, with multicollinearity. Finally, to validate the MLR, the error of the regression must have a mean of zero and a constant variance. Also, the errors must be uncorrelated and normally distributed [56].

3.3.2 Risk Treatment

Artzner et al. [57] define unacceptable risks as positions that will lead to an undesirable future net worth. They also point out that there are two types of actions one can do when dealing with unacceptable risks – change the position or add some instruments that make its future value acceptable. If the risk is unacceptable, firms can opt between different techniques to mitigate the risks, such as prevention, insurance, sharing the risk, diversification, removing the risk source, buying options and doing a vertical integration [58, 59].

There are several ways to decrease the risk of an event. Which can include reducing the probability the risk factors, their impact, or both. The literature presents many relevant examples of mitigation strategies applied to different scenarios and risk exposures, as the following ones:

- Firms are exposed to the politics of the countries in which they operate. Zhu and Sardana [60] suggest different mitigation strategies, depending on the political capabilities of the company and the political challenges that it faces. If the company does not have many political capabilities, and is not facing significant political challenges, their optimal mitigation strategy would simply be the **compliance** of the norms. If these norms have a huge impact on their business, a better mitigation strategy is to **avoid** operating in such way that forces them to comply to them. On the other hand, when having more political capabilities, the company should opt to **ally with the political leaders** of that location, trying to reduce the impact of the political challenges and maximizing its profits. In accordance with this, Vorotnikov et al. [61] suggest that **partnerships between public and private sectors** of the food industry will benefit the companies by sharing the risk management practices between them, taking advantage of the expertise of each party.

- To decrease the likelihood of corruption inside a company, one should try to **increase the transparency** of all its operation [62].

- According to Pretorius and Zaaiman [63], communication is one of the most important CSFs, since many projects that have a well structured plan end up failing because of miscommunication. This way, by ensuring a **clear and effective communication** between the involved parties in a company, the risk of failure of a certain project or operation will be reduced.

- As a diversification strategy, companies might reduce their supply chain risk exposure by **increasing the number of suppliers and customers** and **increasing inventory and production capacity** [64].

- Concerning the commodities price risk, firms can opt to hedge, reducing the impact of the price volatility in their results. In general, firms facing financial distress find more value in hedging, having a greater incentive to do it [65]. This incentive increases as higher is the correlation between the price of the commodities, or other exchange traded derivative instrument, and the price in the actual market [66]. However, firms should **hedge selectively**. Wojakowski [67] defends that the optimal hedging value should depend on the future earnings of the firm, and not on the risk profile of the decision-makers. He suggests that firms should hedge to lock in profits when having satisfactory results and, when facing worst results, decrease the hedging and wait for more favourable conditions. Nevertheless, there is not a futures market for codfish yet. Despite that, Pettersen and Myrland [68] consider that codfish is a commodity and they have found a price index that aggregates the prices of the different codfish forms, and which is correlated with the first-hand price of codfish.

- Regarding the natural disasters, firms can opt to reduce the impact in their businesses by being prepared for these events and reducing the damages that they can cause. First, to reduce the surprise effect, allowing enough time to take earlier mitigation measures, the companies can monitor the risk factors. For example, monitoring the wind, temperatures and ocean levels, to be aware of the possibility of earthquakes and tsunamis. On the other hand, they should try to always be prepared for these type of events, making sure they will have the minimum impact possible in their businesses. For instance, industrial units can opt to have **backup systems for electricity and**

water, whereas companies working with important sets of data should have **backups of their information** saved in other locations, or even online [69].

- Besides, Strelnik [59] suggests an alternative mitigation technique to the ones previously mentioned, which is **corporate restructuring**. This involves changing the organizational structure of a company, for example, in order to change its risk exposure. The main disadvantage of this technique is the possibility of emergence of new risks.

Aside from these examples, there are many other strategies to reduce or remove the risk. To choose the best ones, first, one should identify the procedures to prevent and control the damages caused by the risky event. Second, create a risk ranking sorted by the risk with highest likelihood and impact to the one with lowest ones. Finally, choose the best prevention and control strategies according with their effectiveness in reducing the probability and impact of the highest risks in the ranking and the available resources [48].

3.4 Codfish Related Studies

The codfish market is very volatile and presents a high level of risk due to market conditions and seasonal fluctuations of the specie quantity [70]. Holm and Nielsen [71] define the causes of the decrease of the cod population as natural mortality, the one caused by natural factors as the ocean conditions, and fishery mortality, caused by over-fishing. The decrease in the available quantity of codfish is a key factor impacting the increase in the traded prices. Anyway, the quota system guarantees that fishers will have higher penalties for over-fishing than the profits that the extra fisheries would provide, developed to protect the sustainability of the species [72]. Besides the impact of the available quantity, Hammarlund [73] defends that the codfish price also depends on its characteristics, such as size and freshness, that determine its quality.

Koul et al. [74] have developed a multiple linear regression capable of predicting the codfish quotas based on the water temperature and carbon levels of the ocean. They predict that these conditions will continue to deteriorate and cod the quotas will not reach the high levels they had in the past years again. According with Krinner et al. [75], although changes in temperature will be very different depending on the region, the global mean temperature will very likely increase. Moreover, the average pressure in the sea level is likely to decrease in high latitudes and increase in medium latitudes. Their studies also conclude that the average global precipitation is projected to increase, the contrast between dry and wet seasons and regions will probably increase and the Arctic sea ice is expected to continue melting. These climate changes are very likely to be irreversible for many centuries. To change these predictions, it would be necessary that humanity not only stopped emitting CO_2 to the atmosphere, but also started being carbon negative for a long period.

3.5 Chapter Remarks

The available literature as shown that the companies may create value by managing risk, providing some frameworks to do it, that must be adapted to each company and context. One of the most accepted standards for managing risk is ISO31000, which contains guidelines regarding the principles, framework and process to manage risk. In particular, the process is composed by the phases of establishing the context, assessing risk (or, in other words, identifying, analysing and evaluating it) and treating risk, together with continual communication, monitoring and reporting.

Additionally, the objectives of the organizations must be determined in accordance with their risk preferences and tolerance. As a result, utility functions can be used to measure and compare the utility supplied by various options. In particular, to calculate the risk tolerance coefficient of the exponential utility function, several authors propose different approaches, including maximum losses the companies' managers would accept.

To estimate the future results of a company, it is adequate to calculate their VaR and to use MCS, which is a method that allows the definition of each variable with uncertainty and provides a good basis for decision-making.

Finally, the risks may be dealt with by resourcing to several strategies, depending on the risk and its impact in the business. The strategies may vary from accepting the risk to completely eliminating it, with the implementation of mitigation strategies, as, for example, having an insurance.

Chapter 4

Investigation Methodology

This chapter describes the methodology used in this investigation. First, in **Section 4.1**, the strategies to define the context and identify the risks that the company in study is exposed to are going to be described, culminating in the methodology for the creation of a risk register containing a ranking of the most relevant risks, with higher impact and probability. Afterwards, **Section 4.2** describes the process to develop a model to predict the company's future net incomes, describing how to select the variables used, how to assign values to those variables and how to interconnect them to find an expected net profit margin (NPM). In addition, **Section 4.3** provides an explanation about how the mitigation strategies used in the model were selected and implemented. Later, in **Section 4.4**, the steps to calculate the utility function are described, resulting in a function that describes the utility that each net profit represents to the company. Finally, **Section 4.5** details the methodology to compare the added value that each mitigation strategy provides to the company, taking into account their risk profile and net income prediction.

4.1 Risk Management Process

As presented in the state of the art, the ISO framework process contains the steps of the scope, context and criteria definition; the risk assessment and the risk treatment. In this section, the methodology to define the context of the company is provided, together with a description of the analysis performed. Later, the steps for the risk assessment are described, consisting in the methods to identify, analyse and evaluate the risks. The phase of risk treatment will be explored in Section 4.3, where the methods to identify the mitigation strategies are explored.

4.1.1 Defining the Company's Context

To model the company's future net incomes, first, it was necessary to define the context of the company. As seen in the literature review, the first step to manage the company's risk exposure is clearly defining its context of operation, which was done in detail and already presented in Chapter 2.

The Five Forces of Porter and the SWOT analysis revealed key aspects that triggered the identification of the risks to create the risk register and the identification of the mitigation strategies that were studied as well. The SWOT analysis is particularly relevant to empower the identification of the risks to which the company is exposed, especially when studying the external threats.

4.1.2 Risk Assessment

After the context and capabilities characterization, the risks were identified based on the company's external environment and current operation. The identified risks were classified in one of the following classes: **(a)** strategy, **(b)** finance, **(c)** operations, **(d)** legal and governance, **(e)** information technology, and **(f)** human resources.

The objective of this step, was the creation of a risk register, including the explanation of the possible impacts and risk factors associated with each risk, to enable the identification of the most relevant ones, with the highest impact and probability. Thus, two scales were used to attribute values from 1 to 5 to each risk, characterizing their probability and impact. The probability scale was defined according with the happening frequency of the risk factors, whereas the financial impact scale corresponds to the loss that the company would face if the risky situations took place. The last one is adapted to the company's results in the past 10 years. Table 4.1 details the scales used. The classification of the risks was made by resorting to the company's managers expertise to assign a value of the scale to each risk.

Table 4.1: Probability and financial impact scales.

Scale	Probability	Financial Impact
1 (Very Low)	Once in periods over 15 years	Losses below 100K €
2 (Low)	Once in every 5 to 15 years	Losses between 100K € and 500k €
3 (Medium)	Once in every 3 to 5 years	Losses between 500K € and 1M €
4 (High)	Once in every 1 to 3 years	Losses between 1M € and 5M €
5 (Very High)	At least once a year	Losses above 5M €

Following the risk identification and analysis, the evaluation phase consists in selecting the risks which can jeopardize the company's results the most, between the ones available at the risk register previously developed.

Thus, the risks were ranked according with their risk level. To calculate this level, Mitchell's [29] interpretation of risk was used:

$$Risk_n = P(Loss_n) \times I(Loss_n) \tag{4.1}$$

Where P represents the value in the probability scale assigned to the risk n, whereas I represents the impact scale value of that same risk. After calculating the risk level ($Risk_n$) associated with each of the n identified risks, the ones with a higher level associated were chosen for further analysis and modelling.

To add a visual help to the results of this step, the risk matrices of the five first risks in the ranking were developed.

4.2 Future Net Incomes Model

The model was developed in Microsoft Excel, using the @Risk add-in from Palisade Decision Tools. This model contains a simulation of the company's net income depending on the simultaneous uncertainty of the risky events, quantities sold, buying and selling prices, and other relevant components that impact their results. The final purpose was the definition of a distribution curve, providing relevant information about the probability the company has of achieving certain results in each year. To develop the model, first it was necessary to define its inputs. In other words, the variables that affect the company's results and their respective probabilistic distributions.

4.2.1 Variables Definition

The variables used in this model are obtained via a top down approach. The final output of the model is the net income, in accordance with the investigation objectives previously described. So, as presented in Figure 4.1, the estimated variables are related with the interest and taxes paid, the depreciation and amortizations, operating revenues, material costs, cost of employees and other operating costs.

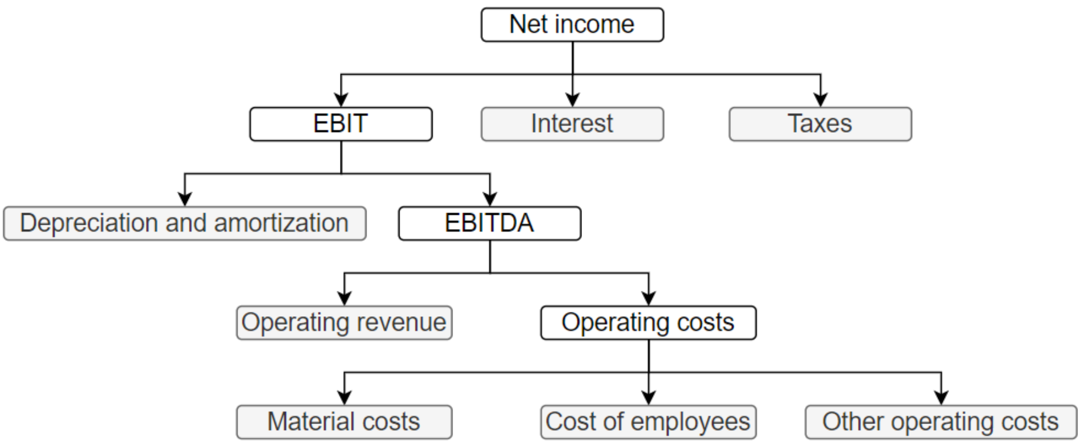

Figure 4.1: Variables used in the MCS model.

The implementation of these variables in Excel was made by applying the following formulas to relate the cells:

$$Net\,income = EBIT * (1 - \%\,of\,Tax) + Financial\,revenue - Financial\,expenses \tag{4.2}$$

$$EBIT = EBITDA - Depreciation\,and\,amortization \tag{4.3}$$

$$EBITDA = Operating\,revenue - Operating\,costs \tag{4.4}$$

$$Operating\,costs = Material\,costs + Cost\,of\,employees + Other\,operating\,costs \tag{4.5}$$

Some of these variables are not inputs of the model, since they depend on other external variables. For example, the Operating revenues depend on the quantity and price at which they sell. In turn, these might depend on the established quotas in each year, macroeconomic factors, and so on.

For that reason, the software IBM SPSS statistics was used to search for MLRs that predict the value of these variables, the dependent variables (DVs), based on the values of some inputs, the independent variables (IVs). This was performed using the method stepwise, which adds variables to the regression model according with their statistical significance. To better estimate the **operating revenue**, its relation with the following variables was studied: **(a)** gross domestic product (GDP) per capita in Portugal, **(b)** inflation in Portugal, **(c)** number of employees of the company, **(d)** market share and **(e)** quantity of frozen codfish produced in Portugal. In addition, to estimate the **material costs**, the considered variables were: **(a)** inflation in Iceland, **(b)** inflation in Norway, **(c)** average importation price of dry cod in Portugal, **(d)** average importation price of fresh cod in Portugal, **(e)** market share and **(f)** quantity of frozen codfish produced in Portugal. The last two mentioned variables were chosen to try to predict the quantity with which the company in study operates. This quantity may relate both to the material costs, since it depends on the quantity of raw material they buy, and to the operating revenue, affecting in particular the quantity they sell. The other variables mentioned are supposed to explain the variation of the prices at which they buy and sell. Finally, the **cost of employees** might depend on the: **(a)** average salary in Portugal, **(b)** minimum salary in Portugal, **(c)** unemployment rate in Portugal, **(d)** GDP per capita in Portugal, **(e)** inflation in Portugal and **(f)** the number of employees of the company.

The result of this step, consists in three regressions, one for each of the explained variables, in the following structure:

$$DV_i = \beta_{i,0} + \sum_{k=1}^{n_i} \beta_{ij} \cdot IV_{i,j} + \epsilon_i \tag{4.6}$$

Where i distinguishes the DV in cause (from 1 to 3), $\beta_{i,0}$ is the intercept (constant term) of the regression i, $\beta_{i,j}$ are the slope coefficients correspondent to each IV j of the regression i, n_i is the number of IVs used in each regression i and ϵ_i is the error term of the model i.

Lastly, to investigate the reliability of the results and validate the regressions, the following conditions were verified, as suggested by Montgomery et al. [56]:

1. Near linear relationship between the DV and the IVs.

2. VIF values below 10 units to ensure there is no multicollinearity.

3. Uncorrelated and normally distributed errors, with mean equal to 0.

4.2.2 Data collection

Regarding the data collected to develop the model and the multiple linear regressions, several sources were consulted. First, the company's past results were reviewed in their financial reports, gathering the values from 2010 to 2019 of all the variables previously presented in Figure 4.1 and the number of employees the company had each year. Also, the sales of their five main competitors were extracted from the financial reports of those companies, to calculate the market share of the company in study. This was made simply by diving the sales of the company in study by the sum of the sales of its industry, in this case approximated to the company and its main competitors.

The remaining variables were consulted in statistics and data bases from different web-sites, detailed in Table 4.2.

Table 4.2: Data collection sources.

Variable	Source
GDP per capita in Portugal	PORDATA [76]
Inflation in Portugal	PORDATA [77]
Quantity of frozen codfish produced in Portugal	GPP [78]
Inflation Iceland	Macrotrends [79]
Inflation Norway	Macrotrends [80]
Average importation price of fresh cod in Portugal	GPP [78]
Average importation price of dry cod in Portugal	GPP [78]
Average salary in Portugal	PORDATA [81]
Minimum salary in Portugal	PORDATA [81]
Unemployment rate in Portugal	Statista [82]

The variables **inflation in Portugal**, **inflation in Iceland** and **Inflation in Norway** contain a consumer price index that, assuming a value of 1 in 2008, will have the following values:

$$Inflation_{year_i,country_j} = Inflation_{year_{i-1},country_j} * (1 + \% \, of \, change \, in \, the \, CPI), \quad i = 2009 \, to \, 2019 \tag{4.7}$$

Where CPI means consumer price index. The value for 2008 was established noting that it will not impact the results of the simulation because this variable will be used in a MLR. So, the values of the explanatory variables are adapted in the regression by the slope coefficients β and adjusted by the the constant term, being the relationship between the values important, unlike their scale.

4.2.3 Variables Prediction

Having the MLRs defined, the next step is to predict the values of each input variable for the next 10 years, which is the time frame on which this investigation is focused. As it will be presented in Chapter 5, the variables that turned out to be the inputs of the MLRs are the inflation in Portugal, the inflation in Iceland and the quantity of codfish produced in Portugal (CodPT).

The prediction of some of the variables was made using the expertise of the company's managers, culminating in the following assumptions:

- The **number of employees** will decrease, let us assume to 450 employees, and then stabilize due to the automation that is being implemented in their plants.
- The **CodPT** is expected to continue increasing at the same pace of the previous years. For that, a linear regression was calculated with the values from 2014 to 2018.
- The total value of the brand and goodwill amortization together with the reevaluations of their properties' value results in approximately $1.5M$€ of **depreciation and amortization** per year.
- The **financial expenses and revenues** are expected to continue decreasing and then stabilize in approximately 2 years. So, the estimation of these variables was made by decreasing the values at the same pace as the previous years, and then maintaining it the same as 2023 until 2029.
- The **other operating costs** are expected to remain the same as the past years.

Regarding the remaining input variables, the **corporate income tax rate** was considered to remain the same as the previous years, which corresponds to 21% in mainland Portugal, according with PWC [83]. Besides, according with Banco de Portugal [84], the consumer price index (CPI) in Portugal will increase 0.7% in 2021, 0.9% in 2022 and 1% in 2023. For the following years, let us assume a constant yearly increase of 1% of the CPI. This way, equation 4.7 was used to compose the rest of the array. Regarding the inflation in Iceland, the predictions of variation of the CPI from Central Bank of Iceland [85] were used. These correspond to average variations of 3.9% in 2021, 2.7% in 2022 and 2.5% in the following years with an associated uncertainty defined by a standard deviation of 1%.

4.2.4 Risk Modelling

The model was developed using the most predictable course of the variables. For example, the demand for codfish is not expected to decrease suddenly and the inflation rates are not likely to change more that 2% in a year. Nevertheless, some of these variables might have unexpected abrupt changes. This way, the importance of modelling extreme events arises. For that, the top identified risks of the register previously developed were implemented in the model, considering the opinion of the company's experts, who had participated in the evaluation of the probability and impact of the risks, assigning values from 1 to 5 of the scale previously presented in Table 4.1.

Regarding the modelling of the impacts and probabilities, first, Table 4.3 shows the implemented distributions used to model the probability of the risks. The probability is modelled by the number of possible occurrences of the risk per year. For simplification purposes, most of the levels of the scale are modelled considering the average period of the range and the Bernoulli distribution. For example, for an event that occurs once in every 5 to 15 years, it was considered a probability of occurrence once every 10 years, resulting in a yearly probability of $p = \frac{1}{10}$. Regarding the number of occurrences in a very high probability case, there is at least one event per year. So, considering that the occurrence of many events is less probable than the occurrence of a smaller amount of events, a Poisson distribution was used to model the remaining number of events that might happen beyond the one already predicted.

Additionally, Table 4.4 contains the implemented distributions to model the impact of the risks for each classification of the scale. Most categories were modelled with an uniform distribution, since it was assumed that the probability of losing each of the values inside the range was the same. The only exception is for the losses above $5M€$, where it was assumed a Pareto distribution, that will allow a higher probability for losses closer to $5M€$, and increasingly lower probabilities of much higher losses. This distribution is characterized by its shape and scale parameters. The scale parameter corresponds to the first possible value of the distribution, corresponding to the $5M€$, and, choosing a shape parameter of 2, the average loss is set to $10M€$, which was considered an acceptable value.

Table 4.3: Probability distributions implementation.

Scale	Probability	Implemented Distribution
1 (Very Low)	Once in periods over 15 years	**Bernoulli distribution** Probability per year: 0.05
2 (Low)	Once in every 5 to 15 years	**Bernoulli distribution** Probability per year: 0.1
3 (Medium)	Once in every 3 to 5 years	**Bernoulli distribution** Probability per year: 0.25
4 (High)	Once in every 1 to 3 years	**Bernoulli distribution** Probability per year: 0.5
5 (Very High)	At least once a year	1 unit + **Poisson distribution** λ: 1

Table 4.4: Financial impact distributions implementation.

Scale	Financial Impact	Implemented Distribution
1 (Very Low)	Losses below 100K €	**Uniform distribution** Minimum: 0 € Maximum: 100 000 €
2 (Low)	Losses between 100K € and 500k €	**Uniform distribution** Minimum: 100 000 € Maximum: 500 000 €
3 (Medium)	Losses between 500K € and 1M €	**Uniform distribution** Minimum: 500 000 € Maximum: 1 000 000 €
4 (High)	Losses between 1M € and 5M €	**Uniform distribution** Minimum: 1 000 000 € Maximum: 5 000 000 €
5 (Very High)	Losses above 5M €	**Pareto distribution** Scale parameter: 5 Shape parameter: 2

Lastly, the risks were integrated in the model by multiplying the impact by the number of occurrences and implementing it in the company's final results.

4.3 Mitigation Strategies

After analysing the main risks the company is exposed to, six possible mitigation strategies were defined by resorting to strategies presented in the case studies of the existing literature. Also, the impact of investing more money in determined areas of the company is also analysed as a mitigation strategy. For example, the company might invest in marketing, research and development (R&D), security, expansion to new markets, among others, and decrease its risk exposure to decreases in the demand, cyber attacks and unfavourable macroeconomic conditions. Based on these, a mitigation register was developed, containing the identified mitigation strategies and a brief description of their implementation and impact.

To implement the mitigation strategies in the model, it is necessary to estimate the implementation cost of that strategy and its impact in the company's results. The cost of the strategies was estimated by reviewing additional literature and available statistical sources. Relating the impact of the chosen strategies, it can be defined as a variation in the sales, costs or changing a specific risk. In particular, the strategies might contribute to reducing the impact, the probability or completely eliminating a previously modelled risk.

4.4 Utility Function

Having defined all the elements of the model, the net profit estimation is achieved. Nevertheless, to compare the added value the expected results provide to the company, it is important to define their utility function $u(x)$. As it will be further explained, this utility function was implemented in the model, calculating the utility of the net income in each iteration. As a result, after each simulation, a utility curve is obtained, containing the probability distribution of the utilities simulated. This way, several scenarios can be analysed, and the utility provided by each of them compared, enabling the conclusion of which scenario provides a greater level of utility to the company.

Regarding the function calculation, the company's risk profile was estimated using the exponential utility function, as suggested by Kirkwood [32]. To calculate the risk tolerance coefficient, the most simple approach proposed by Howard [37] was used to establish some reference values. In this regard, the values of the total sales and total equity were collected from the company's financial statements of the past decade. Subsequently, the values for risk tolerance coefficient the company had in each year were calculated by assuming a risk tolerance of 6% of the company's total sales, which should be approximately the same as one sixth of the company's total equity.

Nevertheless, for a more exact calculation, other methods were taken into account, allowing a comparison of the results and contributing to study the reliability of each method. In that sense, a survey was developed to determine the risk tolerance coefficient of the company, using 3 different methods presented in the literature. Later, the answers from the company's managers were collected. The following section describes the methods used to develop the survey and how the computation of the risk tolerance was made based on the answers.

Having the results of the four methods, the risk tolerance coefficient was set to a range with the lowest value obtained as its lower limit and the highest value as the upper limit.

4.4.1 Risk Tolerance Survey and Computation

The risk tolerance survey is divided in 3 sections. The first one corresponds to Neapolitan and Jiang's [36] method, where the decision-makers are asked to decide on the maximum value of X they would accept in a 50-50 gamble of winning X or losing $X/2$, as presented in Figure 4.2. The chosen value of X corresponds to the risk tolerance coefficient ρ.

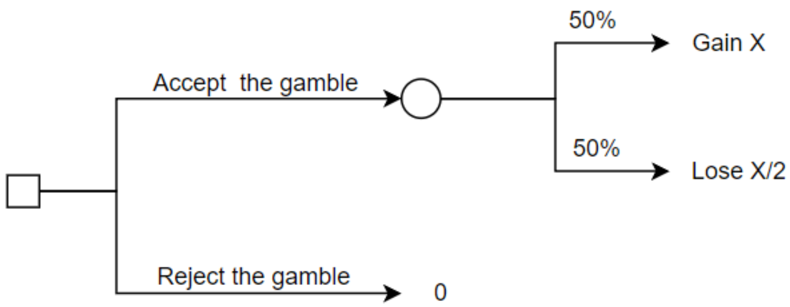

Figure 4.2: Method 1 of the survey.

The second one is the method suggested by Delquié [35], shown in Figure 4.3, where the decision-makers have to indicate the maximum value of money they are willing to lose to have a chance of winning an arbitrary large amount of money. In this case, let us consider the large amount of 10^{100}€ and the probability $p = 0.5$, which corresponds to an equal chance of gaining 10^{100}€ or losing L, the maximum acceptable loss. The risk tolerance coefficient is then computed by:

$$\rho = -\frac{L}{ln(0.5)} \tag{4.8}$$

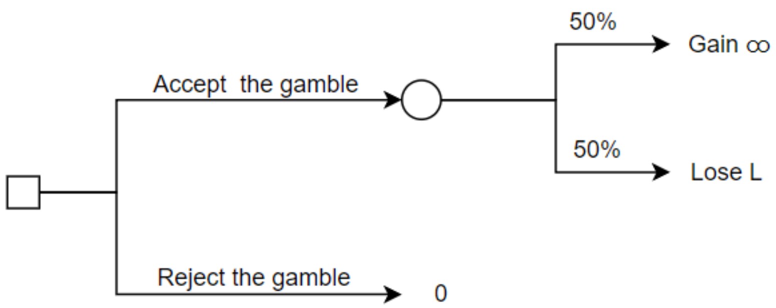

Figure 4.3: Method 2 of the survey.

Regarding the third section of the survey, Walls' [38] method was used. In this regard, the first step is to identify some typical decisions faced by the managers of the company in study. So, the survey was adapted to the codfish processing industry, where managers have to decide on what quantities to buy at a determined price. Table 4.5 shows 5 scenarios where the company has the opportunity to buy a determined quantity of codfish at a certain price that, after being processed and sold, will result in a known gain ($X_{success}$) or loss ($X_{failure}$), whose probabilities are also known ($P_{success}$ and $P_{failure}$). In each scenario, the decision-makers have to decide the percentage of the available quantity they would buy, knowing that selecting 100% corresponds to buying the totality of the codfish, exposing themselves to the totality of the presented results, whereas selecting 50% would mean they could only gain 50% of the success outcome ($X_{success}$), but only risking to lose 50% of the failure outcome ($X_{failure}$) as well.

Table 4.5: Method 3 of the survey.

Decision	$P_{success}$	$X_{success}$	$P_{failure}$	$X_{failure}$	Percentage of codfish (PoC)
1.	10%	100M€	90%	-0.1M€	□0% □25% □50% □75% □100%
2.	50%	50M€	50%	-0.5M€	□0% □25% □50% □75% □100%
3.	90%	100M€	10%	-1M€	□0% □25% □50% □75% □100%
4.	70%	3M€	30%	-3M€	□0% □25% □50% □75% □100%
5.	70%	100M€	30%	-10M€	□0% □25% □50% □75% □100%

Afterwards, the computation of the risk tolerance coefficient in this method is performed by using Microsoft Excel. For each of the five decisions, a table was created, as exemplified in Table 4.6. In this table, ρ_1 to ρ_{10} correspond to possible values of risk tolerance, organized from the highest value (on the top) to the lowest one (on the bottom). The columns will then correspond to the possible values o percentage of codfish (PoC) the managers may chose (from 0 to 100%). Each cell contains the value of the certainty equivalent (C_x) calculated using the risk tolerance coefficient ρ of the respective line and the percentage of codfish chosen PoC of the respective column.

Table 4.6: Certainty equivalent computation example for a decision of Method 3.

$\rho\backslash PoC$	0%	25%	50%	75%	100%
ρ_1	$C_X(\rho_1, 0\%)$	$C_X(\rho_1, 25\%)$	$C_X(\rho_1, 50\%)$	$C_X(\rho_1, 75\%)$	$C_X(\rho_1, 100\%)$
ρ_2	$C_X(\rho_2, 0\%)$	$C_X(\rho_2, 25\%)$	$C_X(\rho_2, 50\%)$	$C_X(\rho_2, 75\%)$	$C_X(\rho_2, 100\%)$
ρ_3	$C_X(\rho_3, 0\%)$	$C_X(\rho_3, 25\%)$	$C_X(\rho_3, 50\%)$	$C_X(\rho_3, 75\%)$	$C_X(\rho_3, 100\%)$
ρ_4	$C_X(\rho_4, 0\%)$	$C_X(\rho_4, 25\%)$	$C_X(\rho_4, 50\%)$	$C_X(\rho_4, 75\%)$	$C_X(\rho_4, 100\%)$
ρ_5	$C_X(\rho_5, 0\%)$	$C_X(\rho_5, 25\%)$	$C_X(\rho_5, 50\%)$	$C_X(\rho_5, 75\%)$	$C_X(\rho_5, 100\%)$
ρ_6	$C_X(\rho_6, 0\%)$	$C_X(\rho_6, 25\%)$	$C_X(\rho_6, 50\%)$	$C_X(\rho_6, 75\%)$	$C_X(\rho_6, 100\%)$
ρ_7	$C_X(\rho_7, 0\%)$	$C_X(\rho_7, 25\%)$	$C_X(\rho_7, 50\%)$	$C_X(\rho_7, 75\%)$	$C_X(\rho_7, 100\%)$
ρ_8	$C_X(\rho_8, 0\%)$	$C_X(\rho_8, 25\%)$	$C_X(\rho_8, 50\%)$	$C_X(\rho_8, 75\%)$	$C_X(\rho_8, 100\%)$
ρ_9	$C_X(\rho_9, 0\%)$	$C_X(\rho_9, 25\%)$	$C_X(\rho_9, 50\%)$	$C_X(\rho_9, 75\%)$	$C_X(\rho_9, 100\%)$
ρ_{10}	$C_X(\rho_{10}, 0\%)$	$C_X(\rho_{10}, 25\%)$	$C_X(\rho_{10}, 50\%)$	$C_X(\rho_{10}, 75\%)$	$C_X(\rho_{10}, 100\%)$

To calculate each certainty equivalent presented in Table 4.6, the following equation was used:

$$C_X(\rho, PoC) = -\rho \ln (P_{success} \times e^{\frac{X_{success} \cdot PoC}{\rho}} + P_{failure} \times e^{\frac{X_{failure} \cdot PoC}{\rho}}) \tag{4.9}$$

Where ρ is the risk tolerance coefficient of the respective line of the table, PoC the percentage of codfish of that column of the table, $P_{success}$, $X_{success}$, $P_{failure}$ and $X_{failure}$ are the values defined in the Table 4.5. As mentioned before, 5 tables similar to Table 4.6 were computed, one for each decision. For example, when computing this table for decision 1, the value of $P_{success}$, $X_{success}$, $P_{failure}$ and $X_{failure}$ will correspond to 10%, 100M€, 90% and -0.1M€, respectively.

After simulating all the $C_X(\rho, PoC)$, the highest value obtained must be highlighted in each line of the table. In the example provided, $C_X(\rho_1, 100\%)$ corresponds to a greater value than the other $C_X(\rho_1, PoC)$ of that line. As a result, its value was highlighted. This way, given the chosen percentage of codfish PoC by the company's managers, one can conclude that their risk tolerance coefficient corresponds to the one in the same line of the value highlighted. The risk tolerance is, hence, the one for which the chosen PoC leads to the highest certainty equivalent. For example, assuming that the managers chose a PoC of 75% in this decision example, it can be concluded that their risk tolerance coefficient is a value between ρ_4 and ρ_2.

Finally, having simulated ρ for the different decisions, resulting in five different tables similar to Table 4.6, the results must be matched to verify their consistency and to conclude about the risk tolerance coefficient value. The risk tolerance coefficient is within the range of values that are simultaneously obtained in the 5 computations of the decisions. For example, if decision 1 results in a risk tolerance range between 5 and 10 million euros, whereas decision 2 results in a range of 8 to 12 million euros, the conclusion that can be taken from the combination of these two decisions is that the risk tolerance coefficient is somewhere between 8 and 10 million euros.

4.5 Net Income Distributions Comparison

In order to estimate the company's net income, a determined number of iterations was run where, for each iteration, the @Risk software assigns different values to the variables that were modelled with uncertainty. For example, while in some iterations we might verify the occurrence of specific risky events, in others, different risky events might occur or even none at all. As a result, a net income value is estimated for each iteration, resulting in a distribution curve by the end of the simulation. This curve represents a distribution of all the net income values obtained, according with the frequency of occurrence of each value in all iterations.

For a larger number of iterations, the model will provide more accurate results. On the other hand, the more iterations the more time is required to run the simulation. So, this number was set to 5000, being high enough to provide precise results during an acceptable simulation time.

As previously mentioned, during each iteration the utility of the simulated net income is also calculated:

$$u(Net\,Income) = 1 - e^{-\frac{Net\,Income}{\rho}} \tag{4.10}$$

Where ρ corresponds to the risk tolerance coefficient calculated by the methods explained in the previous section and $Net\ Income$ corresponds to the calculated income in the present iteration. By the end of a simulation, 5000 iterations were run, enabling the results of two different curves — the net income curve, having the different net income values that occurred during the simulation associated with their happening frequencies, and the utility curve, having the different utilities calculated during the simulation and respective frequencies.

In this case, as the risk tolerance coefficient calculation results were different across all four methods, a range was defined comprising all the coefficients obtained. Hence, the utility output just mentioned was calculated twice, using two values of risk tolerance — the lower and the upper values of the uncertain risk tolerance range. This way, it is possible to analyse the two extreme scenarios, and understand how the decision results would change depending on a higher or lower risk tolerance inside the identified range.

In total, 23 simulations were run. First, to present the results of the net income curves, 9 simulations were run, one for each year between 2021 to 2029, calculating the predicted net income for each year. Together with these results, the 5% VaR was calculated. This value consists in the possible loss the company may have each year with a 5% probability. For a better understanding, Figure 4.4 presents an example of a normal distribution with mean 0 and standard deviation of 10. This distribution represents the frequency of the possible net incomes of a company in a simulation. To measure the VaR, the vertical lines observed in the Figure were adjusted so that the area on the left side of the left line corresponds to a 5% probability. Observing the net income value in that point, where the line is located, one may conclude that the company's 5% VaR is 16.46, meaning that the company may lose this amount of money with a 5% probability in year of the simulation.

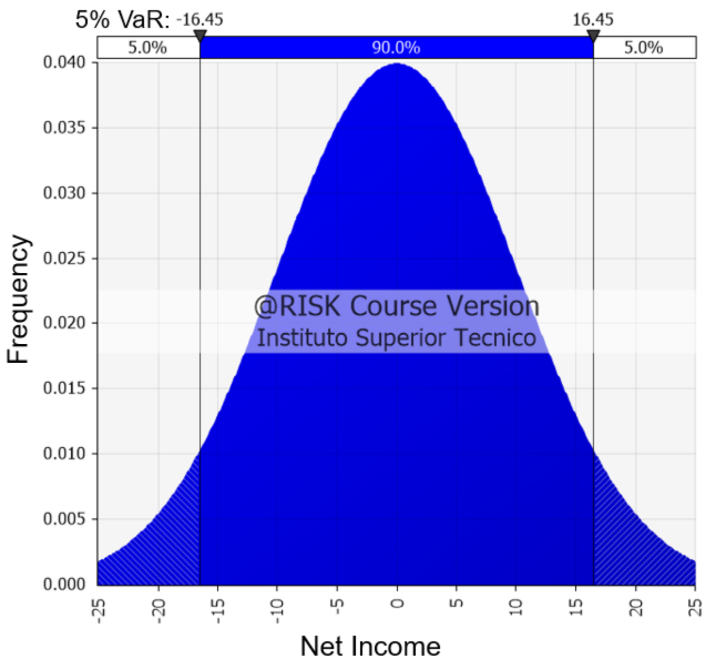

Figure 4.4: 5% VaR of a normal distributed example of net incomes.

Later, the utility distributions were calculated for the years of 2021 and 2029. The first provides more accurate results, as the risk tolerance coefficient was calculated with the survey answers given in this year (2021), revealing the current risk tolerance of the company. The second provides the results for the year of 2029, which gives a long term perspective for decision-making. For each of these two years (2021 and 2029), two utility distributions were also outputs of the model, using the lower and the upper values of the identified risk tolerance range. Additionally, 7 other simulations were run for each of the two years, corresponding to different scenarios — one representing the scenario where the company would adopt all the identified mitigation strategies, and the others, corresponding to the situations where the company would adopt only one of the six identified mitigation strategies. The objective is to study the impact that each mitigation strategy has on the company's utility. This way, the strategies must be simulated separately, so it is possible to understand which strategies contribute to increase the utility and which strategies will deteriorate it.

A summary of the ran simulations and outputs collected from each simulation is presented in Figure 4.5. As may be observed, the simulation number **1** corresponds to simulating the company's results in 2021. This simulation provides the results of the net income distribution, which allows the estimation of the future profits of the company and the calculation of the 5% VaR, and also provides the results of the utility distributions considering the two risk tolerance coefficients, extremes of the identified risk tolerance range. Afterwards, simulations **2** to **8** were ran by iteratively changing the year to provide the net income distributions for each of the years from 2022 to 2028. Similarly to simulation **1**, simulation **9** was also used to obtain not only the net income, but also the utility distributions. Finally, simulations **10** to **16** and **17** to **23** correspond to the scenarios with the implementation of different mitigation strategies for the years of 2021 and 2029, respectively. Each of these simulations has two outputs — the utility distributions for each of the two risk tolerance coefficients.

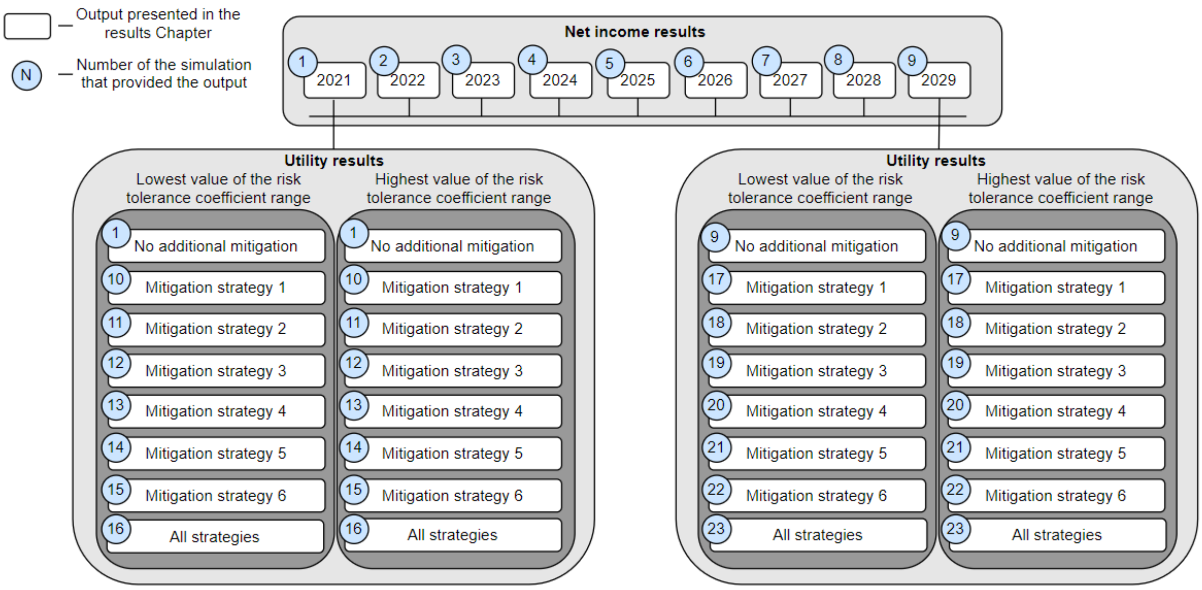

Figure 4.5: Summary of the simulations that were run and the main outputs that will be presented.

As it was observed, for both 2021 and 2029, eight scenarios are modelled for each risk tolerance values, showing the company's future results with and without the mitigation strategies. As a result, the utility results can be compared, enabling the conclusion of whether a mitigation strategy is worth to implement, improving the utility provided to the company.

The expected value of the utility is calculated by the software, corresponding to the mean value of the obtained utility distribution:

$$E[u] = \frac{\sum_{i=1}^{5000} u_i}{5000} \tag{4.11}$$

Where u_i corresponds to the simulated utility value in the iteration i. The 5000 utility values are summed, and then divided by the total number of iterations, resulting in the expected value.

The values of expected utility values were compared across the different scenarios, for 2021 and 2029 and the two risk tolerance coefficients. If, for example, the implementation of the mitigation strategy 1 results in a greater expected utility value than the base scenario (with no additional mitigation strategies), it means that this strategy is beneficial to the company, contributing to improve their results, according with their risk preferences. On the other hand, if, for example, strategy 2 decreases the value of the expected utility, this strategy is not worth implementing, as it deteriorates the utility of the results.

In other words, the advantageous mitigation strategies are concluded by comparing the expected utility provided by the simulation of each mitigation scenario against the base scenario. So, the utility distribution curves with higher expected utility have stochastic dominance over the others. To help analysing the results, a graphical representation of the several utility curves will be presented in Chapter 5. For that, the output utility curves are first approximated to a known probability density function and, afterwards, a plot containing all the cumulative probability functions of the scenarios will be presented. Figure 4.6 shows an example of a utility output distribution (blue bars), that is approximated to a continuous distribution (black curve) by the fit tool of the software @Risk. The fit curve is then represented in its cumulative form, as presented in the right side of the Figure.

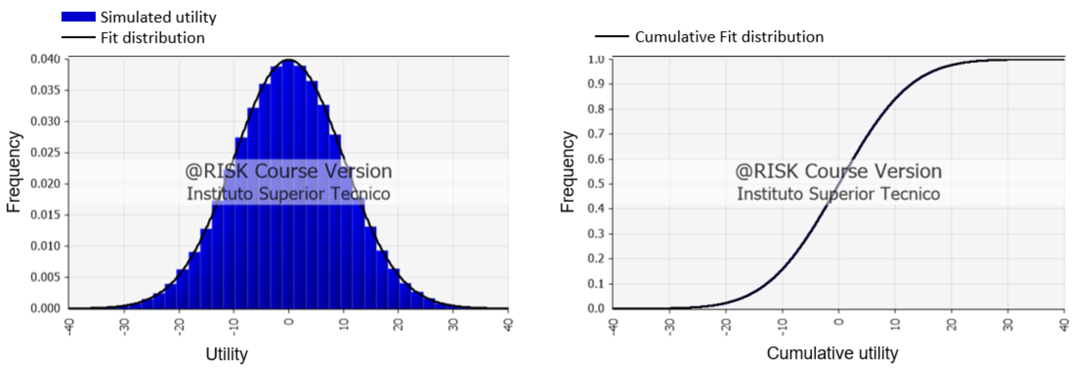

Figure 4.6: Fit distribution of the utility outcome example.

The obtained utility curves were then represented together in the same plot. The curves located on the right side of the base scenario (with no additional mitigation) curve have first order stochastic dominance over it, constituting good suggestions for the company to implement. The opposite applies to curves on the left side of the no additional mitigation scenario curve. In addition, if the curves cross, the second order stochastic dominance can be verified by analysing the area between the two curves in question, before and after they cross. Figure 4.7 exemplifies the previous statement. Assuming three different approximated cumulative utility curves, the green and the red one have first order stochastic dominance over the blue one. Since two of the curves cross, the areas A and B presented in the figure are analysed. Since area A is larger than area B, the red curve has stochastic dominance over the green one.

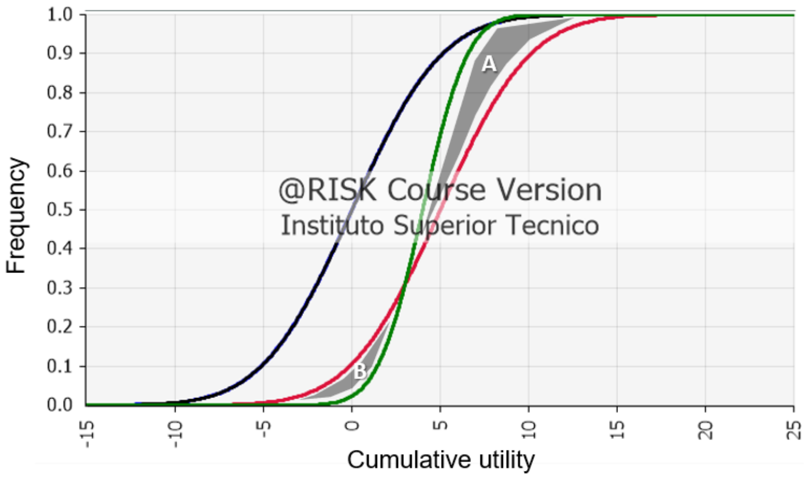

Figure 4.7: Graphical analysis of stochastic dominance.

4.6 Chapter Remarks

Figure 4.8 summarizes the methodology followed during this research. First, the context was defined, by resorting to analysis such as the SWOT and Five Forces of Porter, combined with a detailed characterization of the elements involved in the company and its supply chain. These analysis have triggered the risk identification, which resulted in the development of a risk register. To evaluate the risks, a financial impact and a probability scale were developed, classifying the risks from 1 to 5 in each of the two categories. According with these classifications, the risks' impact and probability were modelled with probability distributions.

Afterwards, these risks were implemented in a model predicting the future net incomes of the company. This model has several inputs, among them the operating revenue and material costs, which will be estimated by using multiple linear regression, trying to find the relationship between that variables with codfish prices, quantities and macroeconomic conditions.

Besides, the risk profile of the company was defined. As presented in Figure 4.8, a risk survey containing some risk tolerance coefficient calculation approaches was developed, and the found risk tolerance coefficient was then used in an exponential utility function.

Additionally, some mitigation strategies were identified and modelled, defining its implementation cost and impact in the company's results.

Finally, having all the elements modelled and present in the MCS model, the simulations may be run

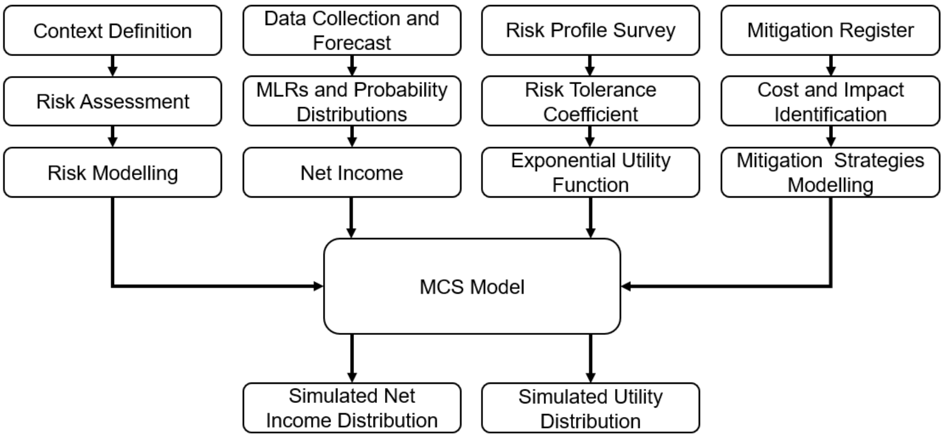

Figure 4.8: Summary of the implemented methodology.

for different scenarios, where the company adopts, or not, different mitigation strategies. The outputs of the model are the annual net income of the company, and the utility it provides. These results will be presented, together with the 5% VaR, which corresponds to analysing the simulated net income distribution, and verifying what is the possible loss the company may have with a 5% probability.

Chapter 5

Results and Discussion

This chapter provides the outcomes of the previously stated methodologies' application, as well as a discussion of the topics covered in each section. First, Section **5.1** presents the risk register with the evaluation and analysis of the risks. Afterwards, Section **5.2** includes the results of the MLRs and the list of the identified and characterized mitigation strategies. Subsequently, Section **5.3** presents the answers given to the risk tolerance survey by the company's decision-makers and includes the results of the risk tolerance coefficient computation through the different proposed methods. Finally, Section **5.4** includes the results of the future net income distributions for different years and using different mitigation strategies, comparing the desirability of the results using the expected utility of the expected net income outcomes.

5.1 Risk Assessment Results

This section will start by presenting the risk register, containing the identified and evaluated risks, graphically supported by the presentation of the risk matrices of the top 5 risks in the ranking, with higher value of the probability multiplied by the impact values, defined by the scales previously defined in Chapter 4.

5.1.1 Risk Register

Regarding the risk register, it contains all the identified risks, classified according with their impact and probability, and it is presented in Table 5.1. In each entry of the table, one can see the name and class of the identified risk, a brief description of the risk factors and the consequences these factors might trigger. Also, I_n corresponds to the impact of the risk, in the scale from 1 to 5, previously presented in Table 4.1, and, similarly, P_n denotes the assigned value of the probability scale. Finally, the last column indicates the ranking, allowing the table to be sorted from the risk with the highest impact times probability to the one with lowest.

Table 5.1: Risk Register.

Risk (Class)	Description	I_n	P_n	Rank
Sales decrease (Strategy)	Increased competition or changes in consumer preferences and trends might lead to a decrease in the company's sales.	5	3	15
Codfish price (Operations)	The company works mainly with one type of product, which is the codfish, and its price is dependent on the quotas defined by the governments of the fishing countries. This quotas are very volatile and, even though the company is able to pass the price changes to their customers, a significant change in the price can trigger a high reduction of the quantity demanded.	5	3	15
Reduced margins (Strategy)	Having low margins, periods of less favourable conditions can more easily lead their profitability to zero, or even to negative results.	5	3	15
Lack of new products (Strategy)	The continuous success of the company under study is subjected to their ability to forecast new trends, to innovate accordingly to those trends, and develop or adopt the necessary technology to launch new products.	4	3	12
Increase of the client's power (Strategy)	They sell their products to some retailers that might have increased power, resulting in lower margins to the company in study.	4	3	12
Dependence on large retailers (Strategy)	The company sells a large amount of their products to only a few retailers. This means that their results are dependent on the relationships with their long-term customers.	5	2	10
Global Demand decrease (Strategy)	Even though the demand for codfish and ready to cook products is increasing, changes in consumer preferences and trends might lead to a decrease in the codfish demand. Also, the animal food industry might be subjected to negative media coverage due to CO2 emissions derived from fishing.	5	2	10

Table 5.1: Risk register (continuation).

Risk (Class)	Description	I_n	P_n	Rank
Access to fish supply (Strategy)	Political, social and economic conditions of the countries where their suppliers are located might adversely affect their results.	5	2	10
Climate changes (Strategy)	Climate changes affect the quality of water, temperatures and levels, which might affect the quantity and health of the codfish. A dramatic reduction of the available fish resources would lead to an increase in its price, and to the appearance of more regulation.	5	2	10
Products reputation (Strategy)	Poor product quality, adverse publicity or other change in the consumers perception of the brand resulting in negative reviews of their products might negatively impact their results.	5	2	10
Stocks over costs (Operations)	Over-estimations might lead to the accumulation of stocks, increasing the inventory costs.	3	3	9
Changes in distribution costs (Operations)	Results might be affected by rises in transportation costs, including variations in the price of fuels.	3	3	9
Increase of the labour cost (Operations)	Government regulation might contribute to an increase in the labour cost.	3	3	9
Improvement processes (Operations)	The existing continuous improvement processes might not be enough to increase the workers efficiency more than the competitors.	3	3	9
CEO dependence (Human Resources)	The CEO is in charge of the majority of the company's strategic choices. This includes not just the risk of having centralized decision-making power, but also the risk of not being able to find a suitable replacement for his position in the company if he leaves.	4	2	8
Accidents at work (Operations)	If there is any accident at work, the company's results can be adversely affected by decreased reputation and compensation payments.	2	4	8

Table 5.1: Risk register (continuation).

Risk (Class)	Description	I_n	P_n	Rank
Production planning (Operations)	If the production planning is below optimal, due to the lack of proper methods, the company will lag behind competitors.	4	2	8
IT security and reliability (Information Technology)	Failures and breaches in IT technology and data security can cause a disruption on their operation, which can adversely affect their results.	4	2	8
Tax Changes (Legal and Governance)	The tax values might change in the countries they operate, affecting their results of operation and financial condition.	3	2	6
Failures in control and reporting (Legal and Governance)	Failures in effectively controlling and reporting could lead to unwanted risk exposure or inefficiencies in their operation.	3	2	6
Noncompliance of regulation (Legal and Governance)	The company is subjected to regulations relating to processing, packaging, storage, distribution, advertising, labelling, quality and safety of food products and environment, which can compromise their operation. For example, climate changes might lead to the development of new regulation that will affect the operation and transportation costs.	3	2	6
Subjective assumptions and estimates by managers (Human Resources)	Subjective assumptions made by managers might affect their financial figures, underestimate needed quantities, overestimate demand, etc.	2	3	6
Environmental reputation (Operations)	Their operation uses large quantities of water and codfish, and produces waste. For this reason, their operation might contribute to the decrease of the available resources and other environmental damages, affecting their reputation.	3	2	6
Employees qualification (Human Resources)	The business might be affected by the loss of some key personnel or the difficulties in attracting new and necessary talent with expertise in certain areas.	2	3	6
Failure in cold chain (Operations)	Failures in the cold chain might damage part of the codfish and lead to wasted product.	5	1	5

Table 5.1: Risk register (continuation).

Risk (Class)	Description	I_n	P_n	Rank
Expansion to new markets (Strategy)	Even if they locate good expansion possibilities, it can be difficult for them to successfully enter those new markets.	1	5	5
Outbreaks and natural disasters (Operations)	Events like pandemic outbreaks, fires, earthquakes and others, might cause a disruption in workforce or damage the facilities and stocks. This would affect the production levels and possibly increase the costs.	5	1	5
Risk of collusion (Legal and Governance)	If they collude with their competitors or with their buyers, the retailers, they can increase profits by combining prices and softening competition. On the other side, if the competition authorities find out, they will levy heavy fines. Furthermore, if the company's competitors collude, they will gain a competitive advantage over the company under study.	3	1	3

In fact, a broad research and context characterization has contributed very positively for the risk identification, as suggested by Gjerdum [15].

Let us note that the identified risks may be subjective, depending on the available information and brainstorming capacity, as studied by Sharma [49]. Therefore, other risks probably exist, and must be continually identified as the company's operation changes and evolves. Additionally, the expected probability and impact may also be subjective, relying on the expertise of the company's managers.

5.1.2 Risk Matrices

As observed in the previous section, the risks representing a higher threat to the company are: **(a)** sales decrease, **(b)** codfish price, **(c)** reduced margins, **(d)** lack of new products and **(e)** increase of the client's power. Figure 5.1 corresponds to the risk matrix of the first three risks, since they all have an impact of 5 and probability of 3. The other two risks have an impact of 4 and probability of 3, as represented in Figure 5.2. This visual analysis shows that all the identified risks are located in the orange and yellow part of the matrices, which means that there were not identified very critical risks, in the red part, nor very harmless risks, in the green part.

5.2 Model inputs and Distributions

In this section the final details for the construction of the model are set. Starting with the results of the MLRs, that were implemented in the model, and finishing with the identification and implementation

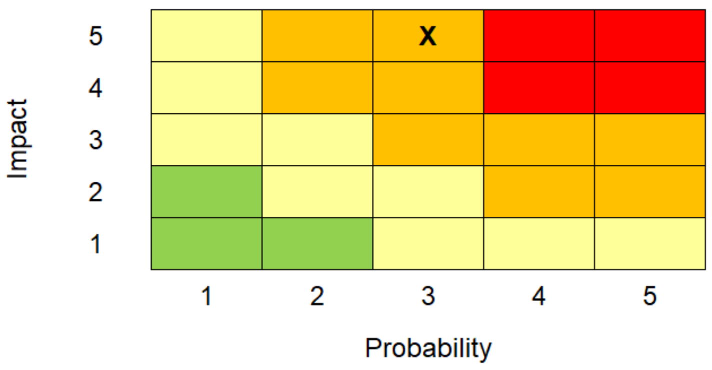

Figure 5.1: Risk matrix of the risks *Sales decrease*, *Codfish price* and *Reduced margins*.

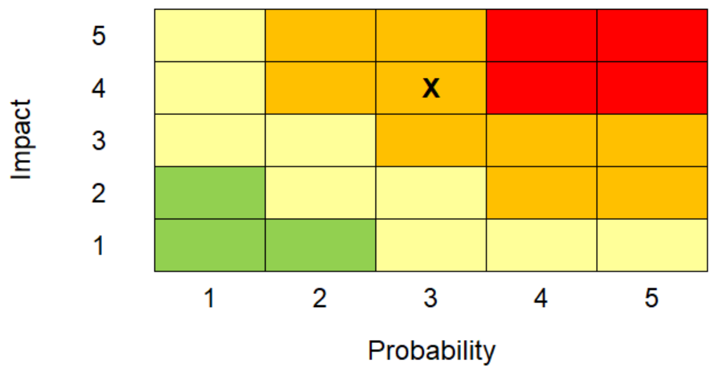

Figure 5.2: Risk matrix of the risks *Lack of new products* and *Increase of the client's power*.

results of the mitigation strategies' analysis.

5.2.1 Multiple Linear Regressions

The results for the MLRs have presented some constrains, including the very short number of observations and variables involved. The available data allowed the regressions to be estimated based on the past 10 years and, the more observations there were, the more accurate the results would be. Nevertheless, the regressions were successfully calculated for the variables operating revenue (OR), material costs (MC) and cost of employees (CE).

Operating Revenue

According with the stepwise method, the operating revenue (OR) depends on two of the possible identified variables. The first is the consumer price index in Portugal, which attempts to forecast the price changes of the company's products. The other is the quantity of codfish produced in Portugal (CodPT), a portion of which corresponds to the amount produced by the company in study. The variables of the regression are a limitation of the model. It is unrealistic to assume that the company's operating revenue is only dependent on the inflation of the country and the total quantity produced by all companies. It would make sense to integrate, for example, the company's market share, since the quantity they sell must be highly dependent on it. Nevertheless, this regression provides a general idea of the trend of the operating revenue values over the years.

The OR has a high correlation of 0.89 and a medium one of 0.46 with the consumer price index (defined by the Inf_{PT} variable, as previously explained) and CodPT variables, respectively. These two IVs have a low correlation of 0.10 between themselves. Table 5.2 contains the summary of this regression, where 92% of the operating revenue values are explained by the values of the independent variables. Table 5.3 contains the coefficients of the regression and presents a low value of VIF which will reinforce the fact there is no multicollinearity in this regression, as can also be concluded by the low correlation between the two IVs previously mentioned.

Table 5.2: Summary of the operating revenue MLR.

R	R^2	Std. error of the estimate
0.96	0.92	5.05E6

Table 5.3: Coefficients of the operating revenue MLR.

Independent Variables	Coefficients β_j	t	Significance	VIF
Constant	-3.43E8	-6.18	0.00	
Consumer Price Index Inf_{PT}	3.99E8	7.79	0.00	1.01
CodPT	2,163.98	3.38	0.01	1.01

Table 5.4 contains the data related with the regression's residuals. The mean residual was implemented in the regression to model the error term ϵ, which is defined by a normal distribution with mean 0 and standard deviation $4.4E6$€.

Table 5.4: Residuals of the operating revenue MLR.

Minimum residual	Maximum residual	Mean residual	Std. deviation
-1.02E7	5.07E6	0.00	4.45E6

Material Costs

The material costs (MC) are correlated with the consumer price index in Iceland, which relates to the price at which they buy, and with the quantity of codfish produced by the Portuguese companies, to which the quantity bought and produced by the company under study is related. Once again, the quantity of codfish produced by all the Portuguese companies is not enough to accurately estimate the quantity the company buys and the price at which they buy depend on several factors besides the inflation in Iceland. Hence, it would make sense that this regression incorporated the average price of codfish and the company's market share, for example. A possible reason for the market share not being correlated with their sales and bought quantities is that it was not calculated correctly. In this case, it was calculated by using the sales of the company in study and its five main competitors. So, a possible explanation is that the market was not well defined, existing other relevant players, and, as a result, the market share values were not calculated correctly.

The MC have a medium correlation of 0.64 and 0.53 with the inflation in Iceland (Inf_{IS}) and CodPT variables, respectively. These two IVs have a low correlation of -0.17 between themselves. Table 5.5 shows the summary of the regression, which explains 80% of the DV, and Table 5.6 contains information about the coefficients of the regression. Similarly to the previous case, there is no multicollinearity and the residuals were modelled.

Table 5.5: Summary of the material costs MLR.

R	R^2	Std. error of the estimate
0.89	0.80	9,223.37

Table 5.6: Coefficients of the material costs MLR.

Independent Variables	Coefficients β_j	t	Significance	VIF
Constant	1.71E7	0.74	0.48	
Consumer Price Index Inf_{IS}	1.11E8	4.22	0.00	1.00
CodPT	2,602.89	3.20	0.02	1.00

Table 5.7: Residuals of the material costs MLR.

Minimum residual	Maximum residual	Mean residual	Std. deviation
-1.15E7	7.64E6	0.00	5.68E6

Cost of Employees

The CE turned out to be simple linear regression, with only one IV, the number of employees. This variable has a high correlation of 0.88 with the DV. Tables 5.8, 5.9 and 5.10 contain the results of this regression, including the coefficients and the residuals information.

Table 5.8: Summary of the cost of employees LR.

R	R^2	Std. error of the estimate
0.88	0.78	1,06E6

Table 5.9: Coefficients of the cost of employees LR.

Independent Variables	Coefficients β_j	t	Significance
Constant	1.17E6	1.56	0.16
Number of employees	11,559.35	5.26	0.00

Now it is important to verify the accuracy of the results by the requirements previously set in Chapter 4. For the first one, medium correlations were observed between the DV and each IV, which does not correspond to the ideal solution, where all these correlations would be high. For the second condition, all

Table 5.10: Residuals of the cost of employees LR.

Minimum residual	Maximum residual	Mean residual	Std. deviation
-8.18E5	2.24E6	0.00	9.95E5

the VIF values are much below 10 units and the correlations between the IVs are low, meaning that there is no multicollinearity. Regarding the last condition, Figure 5.3 contains the standardized errors of the two calculated MLRs, allowing a comparison with the standardized normal distribution, which consists in the diagonal represented in the plots. In fact, the plotted points are approximately following the expected distribution. Finally, the errors should be uncorrelated. Figure 5.4 includes the partial regression plots of each DV for each related IV, which correspond to scatter plots of the residuals of two regressions (one estimating the DV with all the IVs excluding the one under consideration, and other regression of the IV in question being predicted by the other IVs of the initial regression). If the points are uniformly distributed in the plot area, it means the errors are uncorrelated. Observing these plots, one may conclude that there are no plotted points in the top left extreme, and neither in the bottom right extreme. This observation consists in another limitation of the model, revealing a certain linear correlation, especially in the first plot, where the CPI in Portugal is used to estimate the operating revenue.

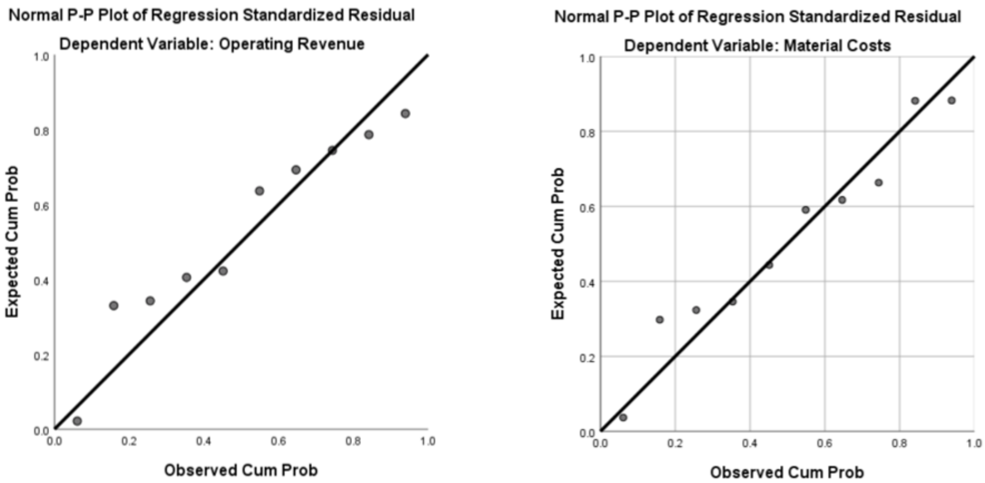

Figure 5.3: Standardized errors comparison with standardized normal distribution for the two MLRs calculated.

Summarizing, the implemented equations in the model, reflecting the Excel file cells, were the following:

$$OR = -3.43E8 + 3.98E8 \times Inf_{PT} + 2163.98 \times CodPT + RiskNormal(0, 9.95E5) \tag{5.1}$$

$$MC = 1.71E7 + 1.11E8 \times Inf_{IS} + 3.26E4 \times CodPT + RiskNormal(0, 5.68E6) \tag{5.2}$$

$$CE = 1.17E6 + 1.16E4 \times Number\,of\,Employees + RiskNormal(0, 9.95E5) \tag{5.3}$$

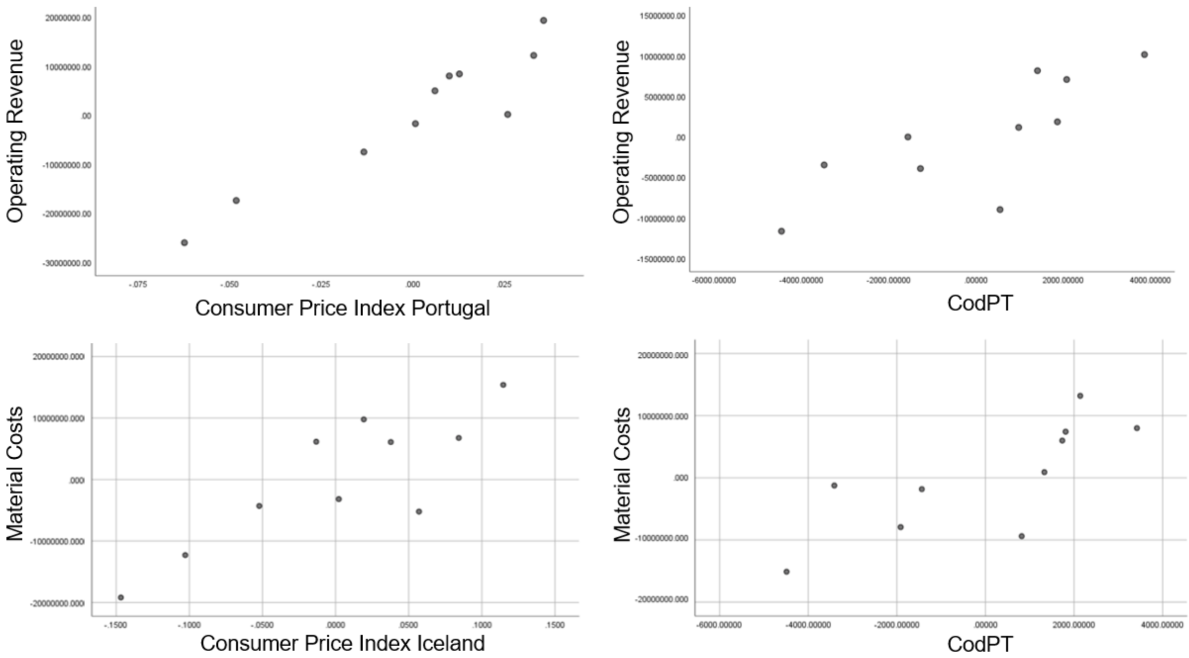

Figure 5.4: Partial regression plots for each IV of the two DVs of the MLRs calculated.

Additionally, the same software was used to calculate the linear regression of the variable CodPT per year, used to predict the values of this variable for the years of 2020 to 2029, resulting in the following equation:

$$CodPT_{year_i} = CodPT_{year_{i-1}} + 1572.05 + RiskNormal(0, 442.69) \tag{5.4}$$

5.2.2 Top risks modelling

Combining the information from Tables 4.3 and 4.4, which contain the implemented probability and impact distributions of the risks for each assigned scale value, with Table 5.1, which presents all the risks including their assigned scale value, the risks modelling was achieved.

Summarizing the results, as the 5 first risks in the ranking had the same value of 3 in the probability scale, the probability of all these risks was modelled with a Bernoulli distribution with a annual probability of 0.25 as shown in Figure 5.5. Regarding the impact, the first three risks in the ranking had a classification of 5 in the impact scale, resulting in a Pareto distribution with a scale parameter of 5 and a shape parameter of 2 represented in the left side of Figure 5.6, while the next two risks in the ranking had an impact classification of 4, correspondent to an uniform distribution varying between 1 and 5 million euros, as presented in the right side of Figure 5.6.

5.2.3 Mitigation Strategies

Additionally, some mitigation strategies were identified, and its impact in reducing the top 5 risks in the register was modelled. First, the strategies will be described and, afterwards, the explanation of how

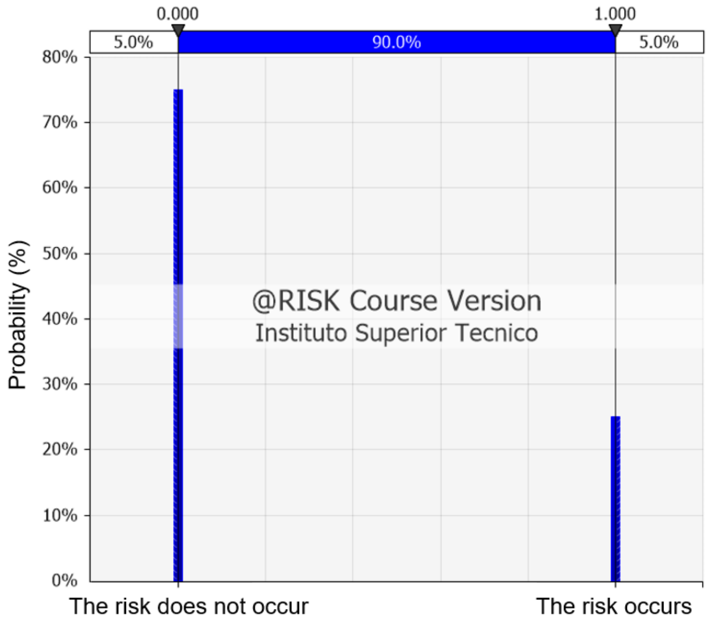

Figure 5.5: Modelled probability of the top five risks in the risk register.

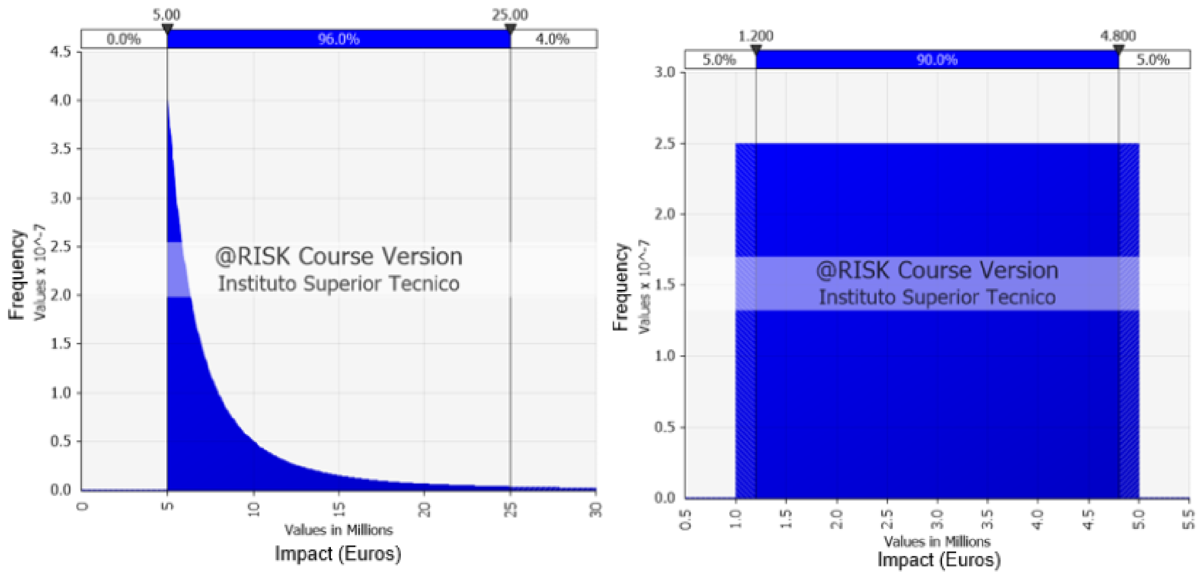

Figure 5.6: Modelled impact of the top five risks in the risk register.

their impact and implementation cost was defined will be provided.

Register

The identified mitigation strategies for the top five risks of the ranking are presented in Table 5.11, together with a brief description of each strategy and how it may contribute to reduce a certain risk.

Modelling

To model these strategies, several assumptions had to be made. These assumptions are subjective and, when using this model for decision-making, the company should study in detail the impact of the

Table 5.11: Mitigation strategies register.

Mitigation Strategy	Description
Marketing campaign	Marketing campaigns may contribute to product differentiation and increase the consumers purchase intention, increasing the quantities sold and, as a result, the company's sales.
Investing in R&D	Investing in R&D is another way of differentiating the products and innovating, increasing the sales of the company, and automatizing and improving the processes, decreasing the company's costs.
Hedging	Hedging contributes to reduce the impact of commodities' price volatility.
Supplier contracts negotiation	Setting prices and quantities in contracts with the suppliers may be beneficial for both parties, since the buyer locks in a favourable price and the seller guarantees future sales.
Export to new countries	Expanding to new countries reduces the macroeconomic risks specific to a country or a group of countries. Also, it increases the number of costumers of the company, contributing to a possible sales' increase.
Selling directly to consumers	This strategy reduces the risk associated with the company's clients, which are not the final consumers. A way of selling directly to the end consumers is online sales.

different decisions they want analyse. This section contains the description of the assumptions made and the respective sources that enabled the modelling of the mitigation strategies.

First, regarding the marketing campaign, Nabeel [86] has performed a study about the impact of television advertisements using answers from 400 respondents, and has concluded that the commercials contribute to an increase of the consumer purchase intention if they meet some specifications. For example, the responses indicate that when the commercials highlight the quality of the product and involve celebrities, the purchase intention improves. Moreover, Blondeau and Blanc [87] calculated an average value of return on investment (ROI) for the television commercials, using 85 campaigns from 5 different sectors, including the food one, and concluded that, for each euro invested in television advertisement, the value of sales would increase 4.9€. This value was modelled considering its uncertainty, assuming a triangular distribution so that the most likely value is the 4.9, but taking into account that the marketing campaign may be unsuccessful, having a ROI of zero. Furthermore, the average cost of producing a 10 second commercial in Portugal is 3000€, while the cost of airing it on the two most watched channels in Portugal is 480€.

In addition, investing in R&D contributes to developing new products, improving the existing ones, and automatizing the company's processes. An increase in the research capital would possibly decrease the likelihood of the risk **lack of new products**. However, predicting the ROI of research capital is not an easy task [88]. Therefore, the modelling of this mitigation strategy will have a high level of uncertainty associated. An annual investment of 1 million euros in developing new products and analysing the market and consumer trends was assumed. Additionally, it was assumed that this investment can have unpredictable effects in reducing the risk in question. For that reason, the risk impact was multiplied by a value between 0 and 1, with uniform distribution, where 1 means the total harm of the risk and that the investment had no positive impact, and 0 means that the risk was totally eliminated by the investment.

Moreover, by analysing other commodities, it is feasible to identify a highly correlated portfolio to invest and mimic the codfish price, allowing an hedging mitigation strategy. In this situation, the company would require additional funds to invest in this portfolio, raising its interest costs. Let us assume that the interest will double every year, since they will require roughly the same amount of money to buy the codfish and the correlated portfolio. When prices are lower than the expected the firm must hedge to lock in that value, as suggested by Wojakowski [67], so that when the codfish prices are higher, they can sell their correlated commodities' stocks, receiving a fixed amount of money that compensates the difference paid. The benefit of this technique is that it reduces the company's costs' uncertainty. As a result, the impact will be simulated by removing the modelled risk **codfish price**. Alternatively, the company could agree on prices with its suppliers, with no cost associated, as it benefits both parties, guaranteeing sales to the producers.

Every year, the company's management spends between 5 and 20 thousand euros on expenditure attempts. Let us assume that, if they expanded to a new country, their other operating costs would rise by 3.75 million euros due to the additional facilities, transportation, tax and compliance costs associated with the new country, and so on. This value was over estimated to nearly one-fourth of the existing other operating costs, as the company already sells in mainly 4 countries but the production process in Portugal is responsible for the vast bulk of these costs. The effect of expanding may contribute to increase the company's revenue by accessing a larger range of potential customers and increasing the quantity sold, as well as help to differentiate the macroeconomic risk associated to a given region. As a result, the modelling of the mitigation approach will result in a reduction of the risk **reduced margins**.

An e-commerce website can cost up to 50 thousand euros to design and 30 thousand euros each year to maintain [89]. Furthermore, half of the Portuguese population shops online [90]. Assuming that the additional transportation expenses are charged to the consumers, and that the website would only reach 25% of the company's consumers, it is reasonable to expect that half of these consumers would begin purchasing their products online. As a result, the company would rely less 12.5% of their sales on the retailers, decreasing the impact of the risk **increase of the client's power**.

Finally, to summarize the values just mentioned, Table 5.12 details the implemented costs and impact distributions in the model for each mitigation strategy.

5.3 Risk Tolerance

This section gives the results of the risk tolerance coefficient computation, which are employed in the exponential utility function, which determines the utility of the company's future net incomes.

Using Howard's [37] method, the company's risk tolerance was calculated using their total sales (TS) and total equity (TE) values, as previously explained. Table 5.13 shows the results of this calculation in each of the years from 2010 to 2019.

Table 5.12: Mitigation strategies modelling summary.

Mitigation Strategy	Cost	Impact
Marketing campaign	3480€	$3480 \times \alpha$€ with $\alpha \in [0, 5]$
Investing in R&D	$1M$€	Reduction of the impact of the risk **lack of new products** to between 0 and 100% of its current value
Hedging	≈ Financial Expenses	Elimination of the codfish price risk
Supplier contracts negotiation	0€	Elimination of the codfish price risk
Expansion to new countries	$3.75M$€	Reduction in the **reduced margins** risk probability from 0.25 to 0.1
Selling directly to consumers	80000€	Reduction of the impact of the risk **increase of the client's power** to 87.5% of its current value

Table 5.13: RT coefficient in different years according with Howard's [37] method.

	ρ (€)	
Year	$0.06 \times TS$	$\frac{TE}{6}$
2010	6.6E6	4.0E6
2011	7.6E6	4.2E6
2012	8.2E6	4.7E6
2013	8.9E6	4.9E6
2014	7.8E6	5.6E6
2015	7.7E6	6.1E6
2016	8.7E6	6.7E6
2017	8.5E6	7.3E6
2018	9.1E6	8.3E6
2019	9.3E6	9.1E6

Using this method, two conclusions can be taken straight away. The first one is that the risk tolerance of the company has been increasing over the past years. This makes sense, since they have been expanding their business, increasing their costs, revenues and profits. So, their tolerance to lose money is expected to grow together, since the same amount of money starts representing a smaller and smaller percentage of their traded volume. The second conclusion is that, even though the two formulas to calculate the risk tolerance provide very different results in some years (from 2010 to 2013), the risk tolerance coefficient was around $9M$€ in 2019.

5.3.1 Survey answers and computation

Additionally, the risk survey answers from the managers of the company were collected, resulting in significantly different results, when comparing the several methods.

Method 1

Regarding the first method of the survey, the company's managers have answered that they would accept a gamble with a 50% chance of winning X and 50% chance of losing $X/2$ for values of X equal or below $8M$€, risking to lose a maximum of $4M$€. In this method, this value of $8M$€ corresponds to the risk tolerance coefficient.

Comparing this result with the expectations set by Howard's [37] formulas, the value is close to the expected one, of $9M$€. Combining the two methods, one can conclude that the company's risk tolerance is between 8 and 9 million euros.

Method 2

Moving on to method 2, the company's decision-makers claim to be willing to bet $10M$€ for a 50% chance of winning $10^{100}M$€. The computation of the risk tolerance is made by applying equation 4.8 presented in Chapter 4. In this case, it will lead to a result of $14.43M$€ for the coefficient.

This value is significantly above the ones calculated in the previous methods. By claiming a willingness to lose $10M$€ for a chance to win a very large amount of money, the managers show a vast tolerance to risk. Inclusively, they were willing to lose more money than their annual profits for this chance to win $10^{100}M$€.

The results of this method have no consistency with the previous ones. Combining the results, one can conclude that the company's risk tolerance coefficient lies somewhere between 8 and 14.5 million euros. For now, two of the methods point to a lower value within this range, while only one method points to a higher value.

Method 3

The third method for the risk tolerance coefficient computation is presented in Figures 5.7 to 5.11. Each figure is composed by one image and one table. On the left side, the images show the results of the computation, by applying equation 4.9 on each cell of the spreadsheet, using the value of ρ of the respective line and the value of PoC of the respective column of the cell. On the right side, the table summarizes the variables used for the computation ($P_{success}$, $X_{success}$, $P_{failure}$ and $X_{failure}$), and the percentage of codfish chosen by the company's decision-makers when answering the survey.

Figure 5.12 condensates the results of the decisions. For example, in Figure 5.7 one can see that in the column of $100\%\,PoC$, which was the one chosen in that case, the highlighted values start at $19M$€. This means that, considering this answer, the risk tolerance coefficient of the company is higher than $19M$€. So, a bar starting in 19 units was made in the figure to represent graphically this result. The same reasoning and representation was made for decisions 2, 3 and 4. Regarding decision 5, the company's

RT\PoC	0%	25%	50%	75%	100%
19,000,000.00	0	1419517.3	1800924.5	1886297.7	1890977
18,000,000.00	0	1380241.9	1722906.4	1790637	1788801.9
13,000,000.00	0	1135666.7	1288985.6	1290203.6	1269032.6
12,000,000.00	0	1074785.6	1193758	1186768.6	1164008.4
8,000,000.00	0	779045.36	791179.04	767809.44	742880.85
7,000,000.00	0	690767.68	686913.19	662506.51	637523.13
1,000,000.00	0	80360.516	55360.516	30360.516	5360.5157
100,000.00	0	-14463.95	-39463.95	-64463.95	-89463.95

Decision 1	
$P_{success}$	0.1
$X_{success}$	100M €
$P_{failure}$	0.9
$X_{failure}$	-0.1M €
PoC chosen	100%

Figure 5.7: Certainty equivalent computation for decision 1 of the method 3 of the survey.

RT\PoC	0%	25%	50%	75%	100%
10,000,000.00	0	4314883.6	5911321.5	6332477.7	6367583
9,000,000.00	0	4134507.8	5459887.9	5730469.8	5705471.6
7,000,000.00	0	3659727.8	4414655.8	4445820.8	4346880.2
6,000,000.00	0	3343488.3	3820313.2	3773012	3657556.3
4,000,000.00	0	2480775.4	2515341.3	2397279.8	2272575.6
3,000,000.00	0	1910156.6	1828778.2	1704431.7	1579441.4
500,000.00	0	221573.59	96573.59	-28426.41	-153426.4
100,000.00	0	-55685.28	-180685.3	-305685.3	-430685.3

Decision 2	
$P_{success}$	0.5
$X_{success}$	50M €
$P_{failure}$	0.5
$X_{failure}$	-0.5M €
PoC chosen	100%

Figure 5.8: Certainty equivalent computation for decision 2 of the method 3 of the survey.

RT\PoC	0%	25%	50%	75%	100%
13,000,000.00	0	18910421	27226933	28843286	28884263
12,000,000.00	0	18491923	25623698	26686745	26607161
9,000,000.00	0	16562371	19931819	19955370	19722183
8,000,000.00	0	15575100	17791163	17665122	17420444
5,000,000.00	0	10982517	11011077	10762914	10512925
4,000,000.00	0	8895581.6	8710222	8460340.2	8210340.4
1,000,000.00	0	2052585.1	1802585.1	1552585.1	1302585.1
100,000.00	0	-19741.49	-269741.5	-519741.5	-769741.5

Decision 3	
$P_{success}$	0.9
$X_{success}$	100M €
$P_{failure}$	0.1
$X_{failure}$	-1M €
PoC chosen	100%

Figure 5.9: Certainty equivalent computation for decision 3 of the method 3 of the survey.

RT\PoC	0%	25%	50%	75%	100%
7,000,000.00	0	265322.65	457929.35	573728.86	610152.05
6,000,000.00	0	259372.03	433049.32	515962.81	505588.67
5,000,000.00	0	250964.99	397757.83	434147.72	358533.9
4,000,000.00	0	238195.61	343975.2	310270.8	139373.81
3,000,000.00	0	216524.66	252794.33	104530.36	-211375.8
2,000,000.00	0	171987.6	69686.904	-281821.3	-811860.4
1,000,000.00	0	34843.452	-405930.2	-1071618	-1801794
100,000.00	0	-629602.8	-1379603	-2129603	-2879603

Decision 4	
$P_{success}$	0.7
$X_{success}$	3M €
$P_{failure}$	0.3
$X_{failure}$	-3M €
PoC chosen	100%

Figure 5.10: Certainty equivalent computation for decision 4 of the method 3 of the survey.

RT\PoC	0%	25%	50%	75%	100%
31,000,000.00	0	13946340	21986092	25142013	25308932
30,000,000.00	0	13847259	21608088	24448116	24381206
22,000,000.00	0	12724904	17632131	17812117	16144211
21,000,000.00	0	12524795	16985718	16840981	15024820
13,000,000.00	0	9928564.5	10217881	8098566.1	5645234.2
12,000,000.00	0	9406129.5	9164851.3	6918776.1	4444749
5,000,000.00	0	3472410.9	1019669.2	-1480137	-3980136
100,000.00	0	-2379603	-4879603	-7379603	-9879603

Decision 5	
$P_{success}$	0.7
$X_{success}$	100M €
$P_{failure}$	0.3
$X_{failure}$	-10M €
PoC chosen	50%

Figure 5.11: Certainty equivalent computation for decision 5 of the method 3 of the survey.

managers have chosen a PoC of 50%, resulting in an highlighted area for all the risk tolerance coefficient values between 13 and $21M$€. Analysing this figure, it is possible to conclude that the results of the 5 decisions overlap for the range from 19 to $21M€$.

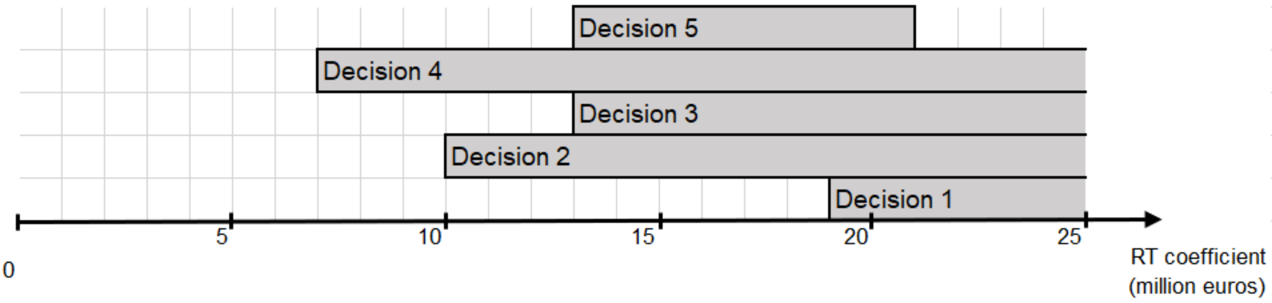

Figure 5.12: RT results of the 5 decisions of the survey's method 3.

Walls [38] suggests that the form must be filled by several members of the company and, in this situation, there was only one survey response, reflecting the typical decisions performed by the company's decision-makers, which constitutes a limitation in the application of this method.

5.3.2 Risk Tolerance Coefficient Methods Discussion

To conclude, the different methods provided very different results regarding the risk tolerance of the company in study, between 8 and $21M€$.

Howard's [37] method is very simple to implement, not requiring any subjective view of the company's managers for specific decisions or gambles, and the results it provides using the TS and using the TE are consistent with each other for the last 5 years calculated. His formulas assume a constant proportion between the sales and the equity of the company, which corresponds to a limitation. Nevertheless, in this case, that proportion was roughly reached in 2015. Considering that the company's business has been steadily expanding together with the estimated risk tolerance coefficient, one may assume that the coefficient is currently slightly greater than it was in 2019 and that it will likely continue to rise in the coming years. Given that this simulation seeks to study the company's future performance, it seems appropriate to use greater values of risk tolerance when simulating the utility curve of the prospective income of the next years.

Regarding the risk tolerance definition provided by Neapolitan and Jiang [36], the results of this gamble seem to provide more conservative results, when comparing with any of the other methodologies. On the other hand, Delquié's [35] gamble results in higher risk tolerance values. One may conclude that when gambling to win an arbitrary amount of money, the willingness to lose money increases more than the expected, compared with a situation of winning twice the bet amount. Considering that the company's risk tolerance is in the range between the values reached through this gambles, it is possible to conclude that the simpler approach by Howard [37], that was initially tested using companies of the oil and chemicals industry, also applies to the codfish processing industry.

The last method used, developed by Walls [38], also suggests an higher risk tolerance coefficient than the other methods. Considering only Decisions 2, 3, 4 and 5; the result for the coefficient would be between 13 and 21 million euros, including lower values consistent with Delquié's [35] approach.

Nevertheless, Decision 1 has changed these results since the company's managers have shown a 100% willingness to lose $100K€$ with a 90% probability, for the 10% chance to win $100M€$. This way, this methodology added a valuable insight to the equation, exposing a much higher tolerance to risk than the initially predicted.

Let us note that all the methods of the survey reflect the managers perception of the company's risk tolerance, which may not correspond exactly to the real value.

For the next steps, it makes sense to consider two scenarios of risk tolerance coefficient values and compare the results provided by each scenario. Recalling the methodology to evaluate the mitigation strategies, if both coefficients provide the same decision it is not important to specify the value of the coefficient within the range to conclude weather the mitigation strategy is recommended or not. Given the results, let us assume a risk tolerance range between 8 and 21 million euros.

5.4 Future Results Calculation and Comparison

This section analyses eight scenarios to present the findings of the net income curves and utility comparison. The first one is the projected outcome if the company continues to operate as is, without implementing any of the indicated mitigation techniques. In addition, a scenario modeling all of the mitigation techniques at the same time is shown. Finally, the remaining scenarios correspond to the addition of one mitigation approach at a time, with each of these scenarios modeling only one mitigation strategy.

As two of the mitigation strategies, hedging and negotiating prices with the suppliers, have the same impact of eliminating the codfish price risk, it does not make sense to simultaneously implement the two strategies. For that reason, the scenario that models all the mitigation strategies excludes the hedging one, as it has a higher cost than the supplier negotiation and the same impact. Nevertheless, this scenario will still be denoted by modelling all mitigation strategies in the rest of this dissertation.

5.4.1 Net Income and VaR Results

The simulation was ran for the 9 years, from 2021 to 2029, and the net income results are bell shaped curves, similar to the normal distribution. Figure 5.13 shows the obtained distributions for the years of 2021 and 2029. As can be verified, the obtained ranges are very wide, with low precision. As a result, the company's future results will very likely be included in the range. Nonetheless, analysing the average values of these distributions, one may conclude that these values do not show consistency with the company's past results. For a deeper analysis, the minimum, maximum and mean values of the simulated net incomes are presented in Table 5.14.

As presented in Table 5.14, the minimum and maximum net income values are far apart from each other, leading to possible net income ranges of roughly 55 million euros each year. This range is not acceptable when using the results to assist in decision-making, being too wide to enable any conclusion. Regarding the mean values, the average net income of the years between 2021 and 2024 is negative,

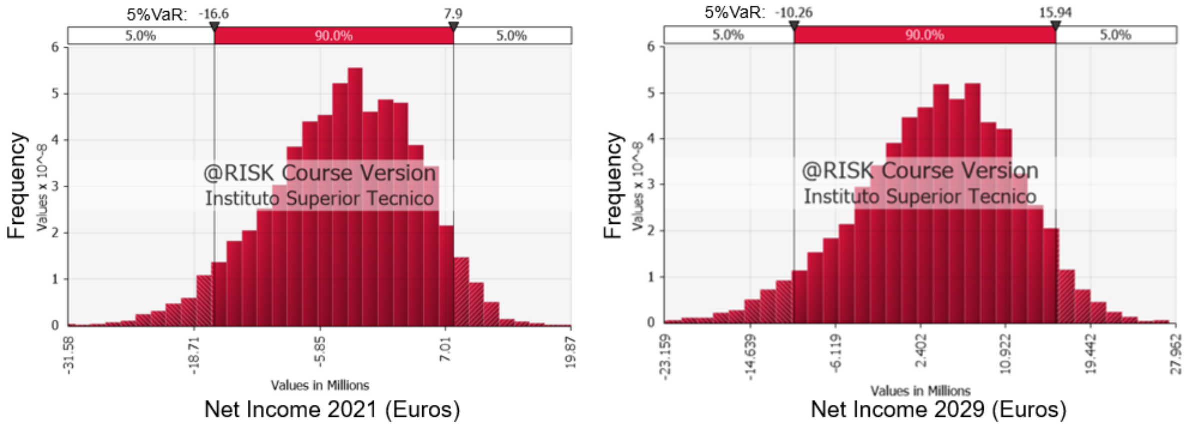

Figure 5.13: Simulated net income for the years of 2021 and 2029.

Table 5.14: Simulated net income for the years from 2021 to 2029.

	Simulated Net Income (€)			
Year	Minimum	Maximum	Mean	5%VaR
2021	-3.67E7	1.80E7	-3.38E6	1.66E7
2022	-3.46E7	2.27E7	-2.71E6	1.60E7
2023	-3.56E7	2.36E7	-1.78E6	1.56E7
2024	-3.78E7	2.19E7	-8.97E5	1.45E7
2025	-2.95E7	2.48E7	3.44E4	1.37E7
2026	-3.27E7	2.36E7	9.26E5	1.30E7
2027	-3.26E7	2.53E7	1.85E6	1.26E7
2028	-3.10E7	2.58E7	2.92E6	1.09E7
2029	-2.94E7	2.73E7	3.95E6	1.03E7

which is not consistent with the positive results the company has had in the past years. Despite the limitations found during the estimation of the material costs and the operating revenue, presented in Section 5.2, the simulation of the operating costs and revenues led to very plausible results for the year of 2021. Figure 5.14 shows the simulated operating values, where the operating revenue has an average value of 176 million euros, whereas the operating costs have an average value of 168 million euros. Possibly, during the modelling of the top 5 risks in the register, the risks' probability was overestimated, lowering the average results more than the reasonable. This overestimation is due to the subjectivity associated with the risks modelling, and consistent with the limitations of simulating future results found by Crum and Rayhorn [53], since these authors have also verified the same limitation during their simulations. As they point out, forecasting future results is very subjective and uncertain independently on the methodology used, not being a particular disadvantage of MCS.

In conclusion, the low values of average simulated net income do not correspond to realistic predictions of the company's future results. Nonetheless, these values have captured the growing tendency of the company's results, estimating a net income increase of 7 million euros in 8 years, when comparing 2029 results with 2021 ones.

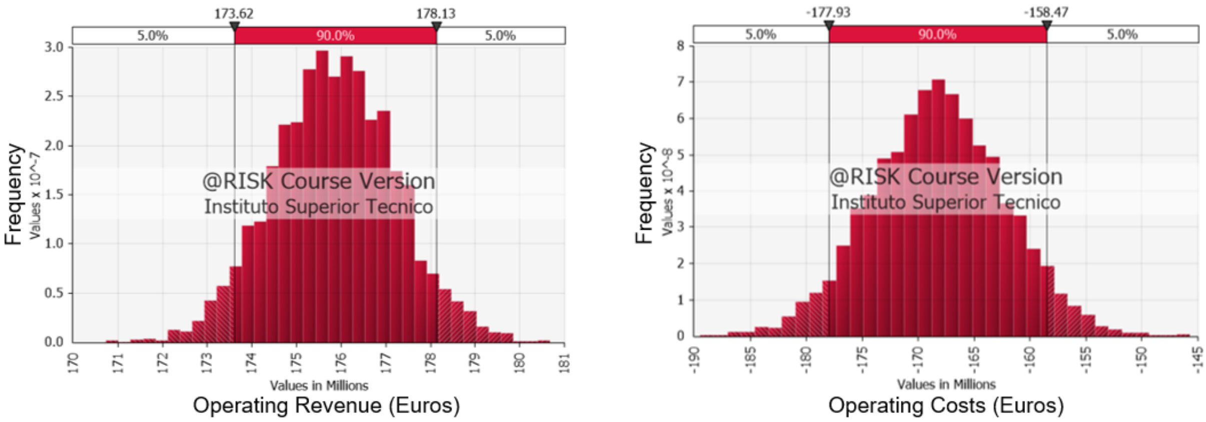

Figure 5.14: Simulated operating revenue and operating costs for the year of 2021.

Additionally, Table 5.14 also contains the 5% VaR information. In 2021, the company is risking a 5% chance of losing at least 16 million euros, which may correspond to a low probability, but is a very significant loss, that would very likely completely destroy the business of the company under study. In 2029, the model predicts a decrease in this value to roughly 10 million euros, which is still higher than what would be acceptable in a healthy business, possibly not reflecting the reality.

5.4.2 Utility Results for 2021

Moving to the utility results, first, the results for the year of 2021 are presented in this section. Two utility outputs were calculated in the model, using the two extreme values of the possible risk tolerance coefficient range:

$$u_8 = 1 - e^{-\frac{Net\,Income}{8E6}} \tag{5.5}$$

$$u_{21} = 1 - e^{-\frac{Net\,Income}{2.1E7}} \tag{5.6}$$

Where u_ρ is the utility provided using the risk tolerance coefficient ρ and $Net\,Income$ is the simulated net income in each iteration. Figure 5.15 presents the calculated utility for the year of 2021 using the two risk tolerance coefficients — 8 and 21 million euros, in the left and right side of the Figure, respectively. This utility is associated to the net income results presented in the previous section for 2021.

The expected utility value corresponds to the mean result of the simulation. For example, Figure 5.15 contains the distribution of the utilities calculated in the 5000 iterations of a simulation and, by calculating the expected value ($E(u) = \frac{\sum_{i=1}^{5000} u_i}{5000}$) of this distribution, the expected utility is concluded.

The model was ran for the two risk tolerance coefficients and the 8 mitigation scenarios — the first simulation corresponds to base scenario, represented in Figure 5.15, 6 simulations correspond to individually implementing each of the 6 identified mitigation strategies and, lastly, all the mitigation strategies were simultaneously implemented. Table 5.15 summarizes the expected utility results of these simulations. All of the presented expected utility results correspond to negative values, as it was

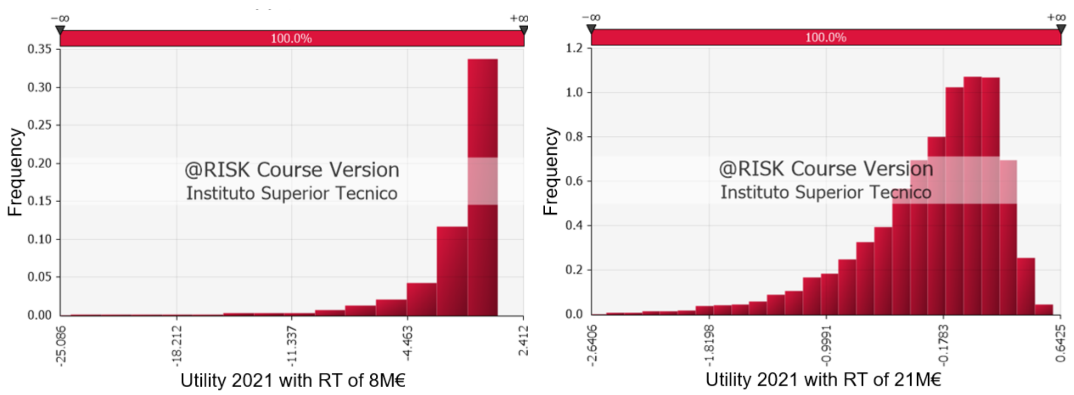

Figure 5.15: Expected utility for the year of 2021 with no additional mitigation strategies using two different risk tolerance coefficient values.

expected, since the simulation results have also provided negative expected incomes for the year of 2021, as previously presented in Table 5.14. However, let us note that the expected utility does not correspond to the utility of the expected income, which, in this case, corresponds to -0.53 for a risk tolerance coefficient of 8 million euros ($u(E[Net\,Income]) = 1 - e^{3.38/8} \approx -0.53$). Conversely, the expected utility is estimated by calculating all the utility values iteration by iteration and, afterwards, calculating the expected value of all these values. As observed in Table 5.15, the expected utility with no additional mitigation strategy is lower than -0.53, corresponding to a value of -1.52, as the exponential utility function calculates very low values of utility for the extreme cases of loss. For example, in 2021, the minimum simulated net income corresponded to -37 million euros. During the iteration that led to this value, the simulated utility corresponded to -101 ($u(-37E6) = 1 - e^{37/8} \approx -101$), contributing to decrease the expected utility of that simulation. Nevertheless, the negative values can be compared and it can be concluded that the implementation of some decisions is more beneficial than the implementation of the others, providing greater values of utility.

Table 5.15: Expected utility using the two risk tolerance coefficient for different scenarios for 2021.

Scenario	Risk Tolerance Coefficient $8M€$	Risk Tolerance Coefficient $21M€$
No additional mitigation	-1.52	-0.26
Marketing campaign	-1.45	-0.25
Investing in R&D	-1.70	-0.29
Hedging	-1.19	-0.22
Supplier contracts negotiation	-0.80	-0.14
Expansion to new countries	-2.03	-0.37
Selling directly to consumers	-1.56	-0.26
All mitigation strategies	-1.327	-0.27

As can be verified in the Table 5.15, for a risk tolerance coefficient of $8M€$, the mitigation strategies that provide a greater utility to the company when put in practice are the marketing campaign, hedging and the supplier contracts negotiation. Additionally, investing in R&D, expanding to new countries and selling directing to the consumers decrease the expected utility. The results have shown that the added benefit of these strategies do not compensate for their costs, resulting in less utility for the company. Similarly, analysing the results for a risk tolerance coefficient of $21M€$, the same conclusions can be taken. In this case, the company would be indifferent between selling directly to the consumers and not applying this strategy. So, the mitigation strategies of performing a marketing campaign, hedging and negotiating supplier contracts are recommended, independently of their risk tolerance coefficient, knowing this coefficient value is somewhere between 8 and 21 million euros. In this case, there is no need for further specification of the risk tolerance coefficient, since the identified range is narrow enough to provide a basis for decision-making on the advantageous mitigation strategies.

Still analysing the values in Table 5.15, its last line contains the results when all the mitigation strategies were simulated simultaneously. If the company has a risk tolerance value closer to 8 million euros, they would benefit from applying all the mitigation strategies at the same time. On the other hand, if having a higher tolerance to risk, they are more willing to take risks, and less in need to apply the mitigation strategies. As a result, when considering a risk tolerance of 21 million euros, applying all the strategies is not beneficial anymore, contributing to a decrease in the provided utility.

Moving on to the graphical representation, the fit tool of @Risk was used to approximate each utility curve to a probability distribution. All the simulated utility distributions were approximated to minimum extreme value distributions, with different parameters, since it was the best fit suggested by the tool. The cumulative probability functions obtained are represented in Figure 5.16. Each of the represented functions corresponds to an approximation of the results of each utility simulation.

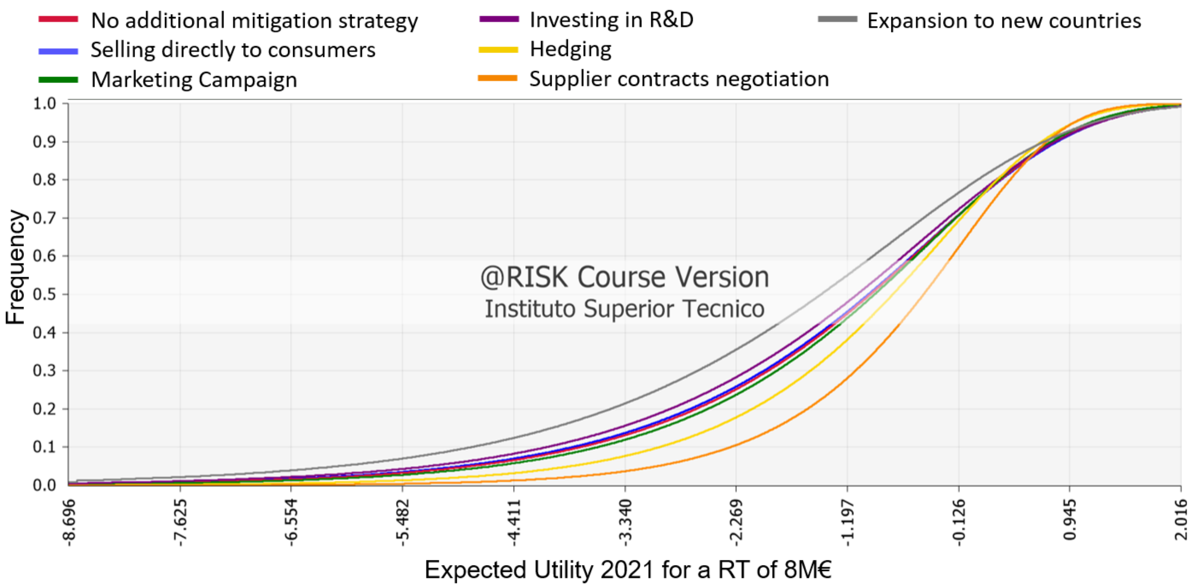

Figure 5.16: Cumulative distribution functions of the utility simulations for a risk tolerance coefficient of 8M€ in 2021.

This figure enables the same conclusions, but in a more direct way. The red, green and blue curves are very close to each other, meaning that the strategies of performing a marketing campaign and selling directly to the consumers do not change significantly the utility provided by the scenario without implementation of additional mitigation strategies. On the other hand, the orange and yellow curves, corresponding to the hedging and the supplier contracts negotiation strategies, are mainly located on the right side of the other curves, before crossing them. This means that these two strategies have second order stochastic dominance over the others. Contrarily, the scenarios including the strategies of expanding to new countries and investing in R&D are dominated by the other simulation scenarios.

Similarly, Figure 5.17 maintains the same stochastic relation between the scenarios for a risk tolerance coefficient of $21M€$. In this case, the grey curve is dominated in first order by the remaining curves, whereas the orange curve has first order dominance over all the others. Comparing this figure with Figure 5.16, one may notice that the curves are closer to each other. This is due to the fact that, having a higher tolerance to risk, the mitigation strategies will not affect the utility of the company as much as they would if the company was less tolerant to risk.

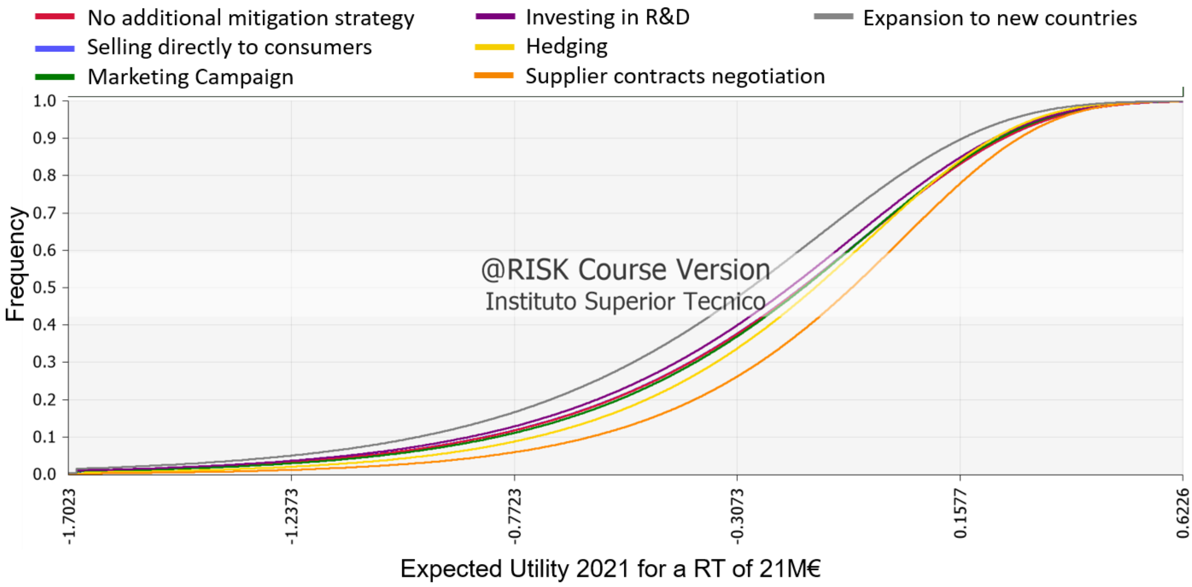

Figure 5.17: Cumulative distribution functions of the utility simulations for a risk tolerance coefficient of 21M€ in 2021.

5.4.3 Utility Results for 2029

Similarly to what was done for 2021, the utility function curves were calculated for the 8 scenarios and the expected utility values are detailed in Table 5.16. Analysing these values for both of the risk tolerance values, similar conclusions may be taken, reinforcing the fact that there is no need to narrow down the identified risk tolerance coefficient range of possible values. For both coefficients, the strategies of performing a marketing campaign and selling directly to consumers have very little impact in the company's expected utility. The strategies that improve the utility of the results are hedging and supplier contracts negotiation, whereas expanding to new countries and investing in R&D deteriorate the expected utility. Also, the scenario modelling all the mitigation strategies reinforces that a more risk averse company benefits more from mitigating risks than a more risk tolerant one.

Once again, the utility curves were approximated to distributions for the graphical simultaneous representation and all the fit results were approximated to minimum extreme value distributions. Figures

Table 5.16: Expected utility using the two risk tolerance coefficient for different scenarios for 2029.

Scenario	Risk Tolerance Coefficient $8M€$	$21M€$
No additional mitigation	-0.06	0.11
Marketing campaign	-0.05	0.11
Investing in R&D	-0.14	0.08
Hedging	0.08	0.14
Supplier contracts negotiation	0.23	0.19
Expansion to new countries	-0.26	0.03
Selling directly to consumers	-0.08	0.11
All mitigation strategies	0.04	0.10

5.18 and 5.19 present the cumulative plots of the approximated utility distributions. These graphical representations emphasize the benefit of hedging and supplier contracts negotiation, the small impact in the utility provided by the strategies of selling directly to the consumers and performing a marketing campaign and the decrease in the utility when expanding to new countries and investing in R&D.

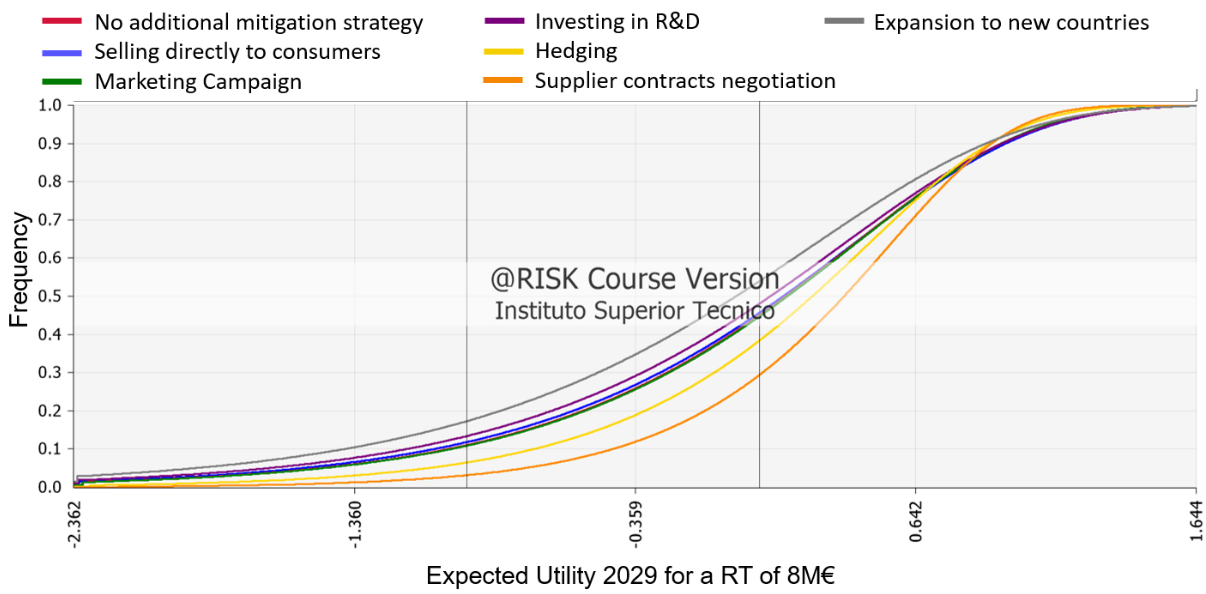

Figure 5.18: Cumulative distribution functions of the utility simulations for a risk tolerance coefficient of 8M€ in 2029.

Analysing the results from a short and long term perspective (for 2021 and 2029, respectively), and for the two extremes of the risk tolerance coefficient possible values range, it can be concluded that it would be beneficial for the company to negotiate supplier contracts and to hedge. These two mitigation strategies were modelled having the same impact, reducing the price risk, but with different costs. As a result, the most expensive strategy, hedging, provides less utility than the other. This way, it is recommended that the company tries to negotiate with the suppliers and set price contracts. Nevertheless, if the suppliers do not seem to be interested in fixing prices with the buyers, and want to sell according with the variation of the government codfish quotas, the company may consider to invest

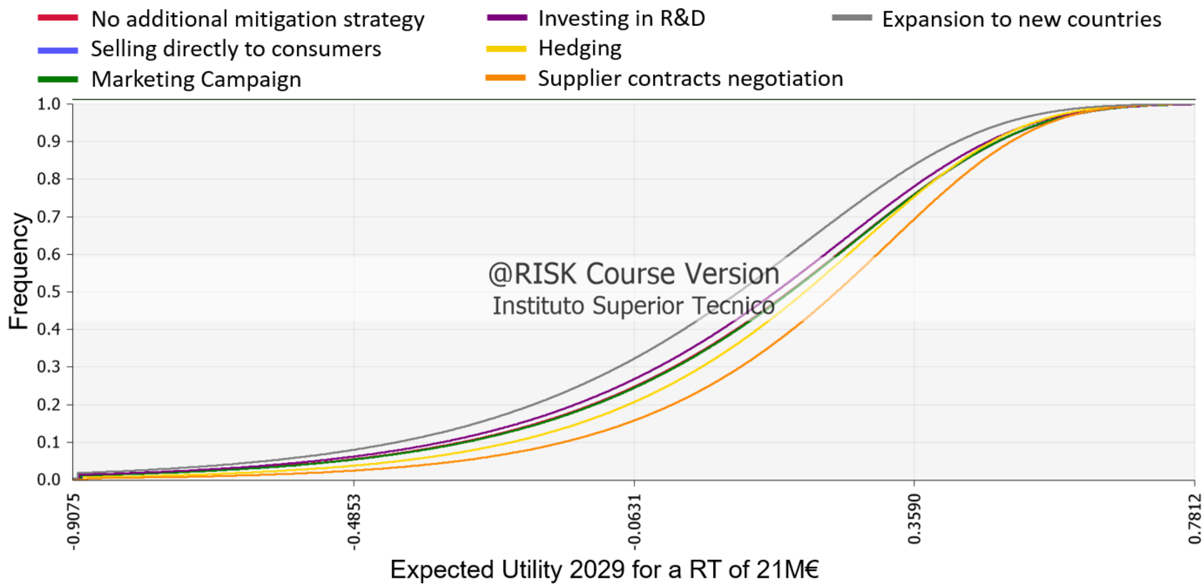

Figure 5.19: Cumulative distribution functions of the utility simulations for a risk tolerance coefficient of 21M€ in 2029.

in a commodity portfolio with a high correlation with the codfish price.

In particular, by analysing the prices of several commodities available at Tridge [17], some medium-high correlations are found. For example, the monthly exportation price of codfish in Iceland has correlations of 0.55, 0.67, 0.58 and 0.63 with the prices of onion, peanut, rice and pork, respectively. Ultimately, more prices need to be analysed and a portfolio must be created. A possible way to do it is using MLRs to try to predict the codfish price using the prices of other commodities.

5.5 Model Limitations

The constructed model provided an idea of the company's future outcomes, based on pricing and codfish consumption trends. Furthermore, it has provided a practical foundation for decision-making, allowing the comparison between different decisions, when their impact can be modelled. However, the results are imprecise and have certain limitations.

First, the variables utilized in the MLRs correspond to a limited set of subjectively chosen possibilities that may have strong correlations with historical records of the dependent variable simply by chance, which may not be confirmed in future years. Additionally, there may be better variables to explain the behavior of the dependent variable, that were not identified. Also, some of the required conditions suggested by Montgomery et al. [56] were not fully met, as previously detailed.

Moreover, the future values of the inputs were estimated by resorting to various entities, whose predictions may be uncertain. Also, the risk identification is limited to the known and predictable events. In turn, the modelling of these risks is susceptible to the expert opinion of the company's managers, resulting in an ambiguous estimate of the most likely impacts and probabilities.

As a result, all variables and relationships were modelled with a level of uncertainty, resulting in a wide range of annual projected results. Hence, because of the imprecise range of outcomes, this model is insufficient for forecasting sales, costs or revenues.

Additionally, for this case study, the risk tolerance coefficient calculation approaches have proven to be imprecise, resulting in highly diverse outcomes depending on the methodology used. Nonetheless, the range of probable values offered by the available approaches was adequate to choose the best strategies, among those identified. These strategies, on the other hand, are merely samples of conceivable decisions that might be modelled, having subjective impacts and costs. The goal of this study is to provide a foundation for additional decisions to be modelled and implemented, thereby assisting firm managers with decision-making.

Chapter 6

Conclusions

Risk management contributes to increase the value of the companies, by analysing the businesses' risks and opportunities and allowing a better understanding of their operation. It also enables a more structured decision making, by improving the communication and the implementation of prevention and control practices among the company's processes. Having said this, risk management can be a valuable tool for organizations, as the company of this case study, which have had positive results so far, but is exposed to a variety of uncertainties related with their operation, such as the relationship with their customers, decrease in the demand for codfish and abrupt increases in the codfish price.

During the risk identification of the research, the detailed context of operation characterization has triggered the identification of several risks, which is consistent with the findings of Gjerdum [15]. Additionally, to measure the impact and probability of the risks, the development of scales was crucial, being a recommendable strategy, as suggested by Curtis and Carey [12]. Using these scales enabled the quantification of the impact and probability, providing the needed values to implement the definition of risk provided by Mitchell [29], in which the risk corresponds to the impact multiplied by the probability of the risk. By measuring these two variables in equally sized scales, from 1 to 5, it is implicit that neither of the variables has more weight than the other when calculating the risk.

Regarding the developed MCS model, it allowed the calculation of the company's VaR, as proposed by Alexander et al. [50]. Contrarily to the initial computational efforts concerns, cautioned by Cheung and Powell [52], the computational time of each simulation was around 15 seconds for the 5000 iterations, which corresponds to significantly fast simulation. However, the reliability of the forecasts have been questioned, since the distributions of the inputs may be subjective. In this case, the risks, mitigation strategies and forecast of the variables were made by resorting to the expertise of several entities, which may be subjective. Nevertheless, as Crum and Rayhorn [53] already studied, every forecasting method has subjectivity and uncertainty associated. Therefore, one may conclude that using MCS is adequate when studying the risk exposure of a company.

A very significant limitation of the model, was the MLRs found. These regressions did not meet the necessary requirements and not enough correlations were found to explain the dependent variables. In this case study, the available information was restricted to the total values of sales and material costs, without the quantities bought and sold specification, neither the prices at which they buy and sell each year. It was concluded that the available variables could not be predicted with accuracy by the macroeconomic, market prices and quantities variables. Possibly, better regressions could be found to explain the variables: **(a)** price at which the company buys codfish per year, **(b)** quantity of each product sold per year and **(c)** tonnes of codfish they buy each year. Eventually, higher correlations could be found, and these variables would be estimated using MLR. Later, they would integrate the model, and the operating costs and revenues would be calculated by using the variables, multiplying, for example, the quantities sold by the price of each sold product.

As a result of the subjectivity of the forecasts and weakness of the MLRs found, the net income forecast results were a very wide range of values, with a negative average for some of the years. These results were not consistent with the company's positive results of the past years. Additionally, the 5% VaR calculation showed a 5% possibility of the company losing at least 16 million euros in the current year.

As expected, negative incomes provide negative utility to the company in study. Thus, the utility values are lower than the expected as well. Nonetheless, the utility analysis allows a comparison between different values of utility, independently if these values are all smaller than expected. As a result, the utility analysis proved to be a great approach for decision-making, enabling the conclusion that the company would benefit from mitigating the risk associated with the volatility of the codfish price. The utility results have proven that, for this context, a more risk averse company benefits more from mitigating risks than a more risk tolerant one, having more added utility from doing so.

The utility analysis was made through the use of an exponential utility function. In agreement with the findings of Kirkwood [32], the exponential function was appropriate and assisted with the computation of the company's utility. This function uses the risk tolerance coefficient, which was computed by using several methods. The methods have provided different results. In particular, the methods proposed by Howard [37] and Neapolitan and Jiang [36] lead to close conservative results, being the first method easier and faster to implement. In addition, the method suggested by Delquié [35] has resulted in higher risk tolerance values. As this method consists in a gamble where the decision-maker may win an arbitrarily large amount of money, he may tend to answer higher values than what they would be willing to lose, mistaken by the opportunity of winning a significantly large amount of money. As a result, this method provided a more risk tolerant result. Finally, the method proposed by Walls [38] contained several decisions which lead to different risk tolerance computations. Most of the computations resulted in consistent results with the previous method, with the exception of one decision, which have shown an even higher risk appetite.

To conclude, this dissertation studied the application of several methods of simulation and risk profile estimation to a specific case study. Therefore, it has contributed to study the adaptability of the different risk management frameworks for the codfish processing industry and to verify the accuracy of the used methods, as the case of the risk profile estimation ones.

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