Master thesis

Creating a decision framework for managing an EUR/USD exposure using system dynamics and scenario planning.

Name: Jesper Sonsma

Student number: s1065165

Address: Tweede Oude Heselaan 125

Phone: +31648770229

E-mail: jesper.sonsma@ru.nl

First supervisor: prof. dr. H.J. Meurs

Second supervisor: dr. B.H. Hoorani

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Preface

Before you lies the final result of six year of studying and for now the final chapter of my academic career, my master thesis. This feels not only like the final threshold towards my master's degree but also a closure of my entire academic journey. From secondary school to commercial economics at the university of applied sciences in Utrecht to hopefully getting my master's degree in business administration at the Radboud University. I am happy that I can now put into practice the things I have learned in these past years and therefore I am very much looking forward to my first step in my professional career.

I would like to thank Henk Meurs for his supervision and constructive feedback during this thesis trajectory. This has been of great help and kept me motivated during this period. Finally I would like to thank my participants who took the time to speak with me, and who were so open about their knowledge and experiences.

I hope you enjoy reading my thesis.

Jesper Sonsma

Nijmegen, 22-06-2022

Abstract

This master thesis aims to provide a decision framework for financial decision-makers who are managing a large EUR/USD exposure. The EUR/USD market involves a high degree of uncertainty, which makes the decision-making process of finding a appropriate hedging strategy difficult. This study provides insights in how to deal with this uncertainty and what the financial impact is of a EUR/USD fluctuation on the most important financial figures. This research started from a qualitative constructed system dynamics model based on the existing literature and insights from the researcher. The results of this model shown that there are multiple feedback loops in this system that influence the behaviour of the system (currency risk). Two important feedback loops present in this model involves the hedging of the currency risk via external hedging instruments, which causes an balancing as well as an reinforcing effect in this system.

To ultimately improve the decision-making process an interactive dashboard is built in this study where financial decision-makers can find an robust strategy regarding different EUR/USD scenarios, in line with step 2 of the robust decision-making framework of Marchau et al. (2019). Results of this interactive dashboard shows a robust strategy involves a mixed strategy of two external hedging instruments (spots and options) to benefit from an increase of the EUR/USD rate and protected from a decrease of the EUR/USD rate and thus potential losses. This research also concludes that a few business characteristics such as percentage profit margin, international activity and diversification of markets partly determines the degree of sensitivity to the EUR/USD rate.

Financial managers can use the findings of this research by means of the interactive dashboard to involve more people in the decision-making process. And in addition, by visually showing the impact of a change in the EUR/USD rate on the business results for creating shared understanding for joint action.

In future research the built interactive dashboard could be tested with real cases in order to see if the dashboard improves the decision-making process.

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Research title

Creating a decision framework for managing an EUR/USD exposure using system dynamics and scenario planning.

1.1 Introduction

On 23th of June 2016 the British pound fell overnight by 13.33% against the U.S. Dollar because of the Brexit vote that day. General Motors, which sold its products world-wide, stated in February 2017, that its fourth quarter net income for 2016 fell by more than 71% from the previous year, attributing most of the financial impact to the drop in the value of the British Pound after the Brexit vote (Shanker and Satir, 2019). Besides General Motors, there are numerous companies that are exposed to a currency risk. As global operations in multinational firms grow in popularity, the internal transactions of such firms are increasingly carried out internationally. This phenomenon makes profit and losses heavily dependent on the movements of currency exchange rates (Kim and Park, 2014). For many companies, currency management therefore plays an important role in risk management. According to Vohra and Fabozzi (2019) foreign-exchange (FX) risk is even recognized as one of the most important risks associated with foreign investing and the pricing of international assets.

A sudden change in currency exchange rates thus could have major consequences for an internationally operating company and according to Kim and Park (2014) it is not uncommon to see radical changes in currency exchange rates. The problem with the management of EUR/USD exposure is that the exchange rate is unpredictable, due to the high degree of uncertainty involved. This study focuses on foreign operating Dutch companies exposed to a EUR/USD risk. Internationally operating Dutch companies outside the EU zone often deal with US dollars. For example, when a Dutch company imports goods from the United States, payment is usually in US dollars. All other costs and revenues of the Dutch company are in Euros, so at some point the Dutch company has to buy US dollars to pay its suppliers. This is also called currency risk, which refers to the risk that a certain company takes when it carries out transactions in foreign currencies. This risk has to deal with a possible change in the exchange rate of a currency.

This study elaborates on the financial consequences on the profit margin of products of different EUR/USD scenarios. Not to predict the future but to be prepared when they occur, to

achieve this scenario planning in combination with system dynamics will be used to understand the bandwidth of risk effects of the different scenarios. System dynamics is a theory developed to understand the structure and behaviour of complex system (Forrester, 1987). As mentioned, sudden changes in the EUR/USD exchange rate could have financial consequences for a firm, in this study system dynamics is used to improve the decision-making process of EUR/USD management. System dynamics emphasize the importance of investigating systems from the inside while also approaching problems with a comprehensive outlook and aiming to grasp the complexity of causal interconnections (Király & Miskolczi, 2019). The findings from the theory of system dynamics will be translated into a decision framework (interactive dashboard) for financial decision-makers in order to make more informed decisions about a EUR/USD exposure.

In addition to developing a decision tool, this study also looks at sector differences. Dominguez and Tesar (2006), El-Masry and Abdelsalam (2007), Doukas et al. and Dornbush (1987), among others, claim that the degree of sensitivity to the EUR/USD exchange rate is largely determined by a number of company characteristics. This study investigates by means of field research which characteristics play a role in this and what impact this has on a EUR/USD hedging strategy.

This study is written from a business perspective on how organisations could improve the decision-making process to find an robust currency strategy. The actors in this decision-making process are usually the CFO, the financial manager or the treasurer of a large internationally operating company. Insights from this study can be used to engage the decision-makers in the process of risk management and help them understand the consequences of an currency rate fluctuation. Macro-economic topics play a role in this study, but this is not the focus of this study. This study is written from a business perspective on how organisations could improve the decision-making process to find an robust currency strategy.

1.1.1 Research objective

The main research objective is how an internationally operating Dutch company can deal with different identified EUR/USD exchange rate scenarios in order to protect these companies from potential losses due to a fluctuation in the EUR/USD exchange rate. To achieve the research goal, an interactive dashboard is built using the program Python based on the findings of a qualitative system dynamics model that is built in this study. This interactive dashboard provides a visualisation of the financial impact on the profit margin of products when a fluctuation in the EUR/USD exchange rate occurs. To find a strategy that is robust to all scenarios, the theoretical framework of Robust Decision-Making (RDM) is used. The integration of the interactive dashboard, system dynamics model and RDM helps the financial decision-maker to make more informed decisions regardless of the high uncertainty in the EUR/USD market. Another research objective is to find out whether the degree of sensitivity to a sudden change in the EUR/USD exchange rate differ per sector and which company characteristics determine this difference.

1.1.2 Research questions

This study focuses on designing a decision framework for the management of an EUR/USD exposure to ultimately improve the decision-making process on finding a robust EUR/USD hedging strategy. The research questions of this study are stated below.

Research question 1: *What is the financial effect of a change in the EUR/USD exchange rate on the profit margin of a product?*

To further support research question 1, a few sub questions have been formulated.

- Sub question 1: *Which hedging instruments can be used to manage the EUR/USD risk?*
- Sub question 2: *Which strategy is the most robust regarding the different identified scenarios?*

Research question 2: *To what extent does sensitivity to the EUR/USD rate differ between sector?*

To further support research question 2, a few sub questions have been formulated.

- Sub question 1: *What characteristics of a sector explain the degree of sensitivity to a change in the EUR/USD exchange rate?*

1.1.3 Hypothesis

The following hypothesis is derived from the conceptual model and the research question:

- Hypothesis 1: *"A change to a lower EUR/USD exchange rate leads to a lower profit margin per product over time"*

1.1.4 Outline of thesis

The first chapter of the thesis is the introduction chapter where the central topic will be introduced to the reader. Then the literature review of the core concepts will be presented, which can be seen as the body of knowledge of this thesis. The literature review will be summarised in a conceptual model, following the conceptual model is the methods section. In this section the research strategy and collected data will be presented. The next chapter is about the simulation model that is built, followed by the results section. This section will also consist of the validation and practical relevance of the simulation model. The thesis will be rounded off with a discussion and conclusion section. Figure 1 visualises the thesis outline.

Figure 1: Thesis outline

2.1 Theoretical background

Figure 2 gives an overview of the different concepts and their relations with each other. The green concepts can be seen as the core concepts of this study and are therefore of great importance. The orange concepts are intended more as support for the core concepts. This study examines the financial implications for a product's profit margin following a currency fluctuation and whether sensitivity to the EUR/USD exchange rate differs by sector. Therefore first of all the phenomenon of currency risk will be explained in order to subsequently discuss the consequences of a currency risk and the degree of sensitivity to a change in the exchange rate. Because this market is very uncertain the theoretical concept of uncertainty will also be explained. Furthermore it will be examined how, by means of scenario planning and robust decision-making, strategies can be developed to prepare companies as well as possible for these risks.

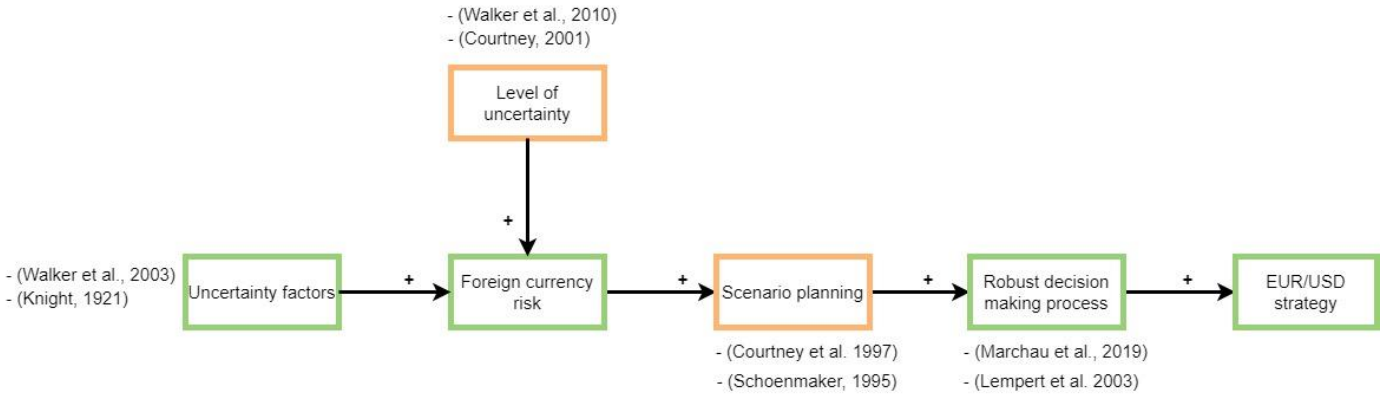

Figure 2: concepts of study

2.1.1 Foreign currency risk

According to Adler and Dumas (1984) exposure can be defined as the amounts of foreign currencies which represent the sensitivity of the future, real domestic-currency (market) value of any physical or financial asset to random variations in the future domestic purchasing powers. Related to this study it is of importance to define foreign currency exposure. Foreign currency exposure can be defined as the extent to which the value of the company would be affected by unforeseen changes in exchange rates (Eun and Resnick, 2004, p. 284). Companies can hedge their EUR/USD exposure with hedging instruments. In this paper the focus will be on external hedging instruments. External hedging instruments are used to protect against the possibilities of losses occurring as a result of exposure to foreign risk (Tijhaar, 2013, p. 377). To illustrate how the EUR/USD exchange rate can affect an organisation financially, here is an example. Imagine that the United States is an important export market for your organisation

and that the euro suddenly depreciates sharply against the US dollar (as it did before). Ultimately, this means that your company's products may be priced out of the US market, as the euro price of US imports will rise following the fall in the euro (Eun & Resnick, 2014).

2.1.1.1 Consequences of change in currency exchange rate

According to Dominguez and Tesar (2006) it is widely believed that changes in currency exchange rate have important implications for financial decision-making and for the profitability of firms. One of the main reasons for adopting the euro was to protect companies from the uncertainty of the change in relative prices of the products on offer due to currency exchange rate fluctuations (Dominguez & Tesar, 2006). This indicates the acknowledgment of potential financial consequences for a sudden change in the exchange rate. However, a change in the exchange rate does not necessarily have to have negative consequences, if the exchange rate moves in the "right" direction it will be beneficial for the profit margin of a product because the relative price changes. An important aspect that determines part of the foreign currency risk is the type of contract between a company and its customer. In this case, we assume two types of contracts: fixed price contract and spot price contract. According to Polinsky (1987), the price can be fixed in advance, which is called a fixed price contract, or both parties can agree on the price that applies to the product on the date of delivery on the spot market, which is called a spot price contract. If a company has fixed price agreements with the other party for a long period of time, a sudden change in the exchange rate (into the “wrong” direction) can have a large impact on the profit margin, because the change in the exchange rate cannot be passed on to the other party. This study will go further into depth what the consequences are for a change in the EUR/USD exchange rate for the profit margin of a product and if those consequences differ per sector.

2.1.1.2 Sensitivity to exchange rate fluctuation

It is worth distinguishing between firms that are more financially affected when prices fluctuate. According to Dominguez and Tesar (2006), it is mainly the smaller companies that are susceptible to this, because larger companies often have more opportunities and resources to hedge these risks. But it is mainly the number of international operations that determine whether a company is sensitive to fluctuations in the exchange rate. El-Masry and Abdelsalam (2007) argues that in general terms the more international activities you have as a company the more sensitive you are to foreign currency exchange rate fluctuations. The study by Doukas et al. (2001) also stated that the more international activities a company has, the more it is exposed

to foreign currency risk. Not only the size of a company and the amount of international activities are important here, but also the sector in which a company operates. According to Dornbush (1987), the sensitivity to exchange rate fluctuations is not the same in all sectors. Industries such as rubber and plastic, stone, clay and glass has relatively low foreign involvement and thus relatively low foreign currency exposure (Doukas et al. 2001). Sapir and Sekkat (1985) show that the degree of sensitivity to exchange rate fluctuations is also related to the type of product traded.

2.1.2 Uncertainty

Decision-making under (deep) uncertainty is one of the core concept of this research paper. The part that makes managing EUR/USD exposure difficult is the great uncertainty that hangs over this market. Therefore, it is important to further explain the theoretical concept of uncertainty. The level of the exchange rate of the EUR/USD is unpredictable and thus highly uncertain. Despite the uncertainty financial decision-makers still need to make decisions about which strategy to follow based on this uncertainty. To find a way to deal with this kind of uncertainty, we first need to define uncertainty. When uncertainties occur, decision-makers open themselves up to risk, it is important to make a distinction between uncertainty and risk. According to Knight (1921) the term 'risk' is used to describe decision situations in which probabilities are available to guide choice and the term 'uncertainty' is used to describe decision situations in which information is too imprecise to be summarised by probabilities. Uncertainty in this study refers to uncertainty factors that play a role in the decision-making process when dealing with currency risk. "With respect to decision-making, uncertainty refers to the gap between available knowledge and the knowledge decision-makers would need in order to make the best policy choice" (Marchau et al., 2019, p. 2). To dive deeper in the concept of uncertainty the following concepts of uncertainty are briefly described: nature of uncertainty, and the level of uncertainty.

2.1.1.1 The nature of uncertainty

According to Walker et al. (2003) there are two types of uncertainty: epistemic uncertainty and variability uncertainty. Walker et al. (2003) defines them as follows:

- Epistemic motivation: the uncertainty due to the imperfection of our knowledge, which may be reduced by more research and empirical efforts.

- Variability uncertainty: the uncertainty due to inherent variability, which is especially applicable in human and natural systems and concerning social, economic, and technological developments.

Variability uncertainty plays a role in this paper, because uncertainty in currency exchange rates does not occur due to the imperfection of our knowledge (epistemic motivation) but through inherent variability (variability uncertainty). To explain further the relevance of the phenomenon variability uncertainty Walker et al. (2003) give the example of tossing a coin; one knows that in ½ of the cases the outcome will be heads, but it is unpredictable what specific value the next toss will have. The same is true for the EUR/USD exchange rate, the exchange rate will rise or fall but you do not know in which direction it will behave. Therefore the phenomenon variability uncertainty is applicable in this study.

2.1.1.2 Level of uncertainty

Then there remains the question of how uncertain a situation is. According to Courtney (2001) uncertainty is not an all-or-nothing phenomenon but there are certain levels that can distinguish uncertainty. Walker et al. (2010) made a framework based on different levels of uncertainty. Defining the levels of uncertainty is crucial to determine which approach to use for dealing with (deep) uncertainty. The framework is based on the different levels of uncertainty distinguished by Courtney (2001):

- Level 1: A Clear Enough Future
- Level 2: Alternate Futures
- Level 3: A Range of Futures (multiple plausible outcomes)
- Level 4: True Ambiguity (unknown future)

Within the concept of uncertainty, another distinction can be made, namely deep uncertainty. According to Lempert et al. (2006), uncertainty in the absence of knowledge about probability distributions and outcomes is also called deep uncertainty. This article will focus on level 3 of uncertainty, which Courtney (2001) defines as a range of futures. Levels 1 and 2 are not applicable in this article because the future of the EUR/USD exchange rate is not clear and we certainly cannot predict the future with probabilities that are characteristics of level 1 and 2 uncertainty according to Courtney (2001).

2.1.1.3.1 Uncertainty level 3

As mentioned, uncertainty describes situations where information is too imprecise to be summarised in probabilities. Level 3 uncertainty is known as a range of futures that could happen, several plausible outcomes can be found (Courtney, 2001). According to Courtney et al. (1997), there are three analytical tools to deal with level 3 uncertainty:

- Latent-demand research
- Technology forecasting
- Scenario planning

This study will further explore the phenomenon of scenario planning and robust decision-making, which will be described in the following sections of the theoretical background.

2.1.3 Scenario planning

Organisations today are more dependent on change and adapt relatively quickly to new circumstances. According to Chermack et al. (2001), uncertainty is becoming an important factor that business leaders and planners must take into account. In such a rapidly changing business environment, the ability to adapt quickly to major changes can mean the difference between a thriving business and bankruptcy. According to Courtney et al. (1997), scenario planning is an analytical tool to deal with uncertainty.

Porter (1985) states that scenario planning can be defined as an internally consistent view of how the future might turn out - not a forecast, but one possible future outcome. Scenario planning is known for its ability to capture a whole range of possibilities in rich detail. By identifying basic trends and uncertainties, a series of scenarios can be created to compensate for the usual errors in the decision-making process (Schoenmaker, 1995). Step 2 of the RDM process consists of the evaluation of strategies across futures, also known as scenario planning. The different scenarios and outcomes are simulated via an interactive dashboard. This dashboard will help the financial decision-maker to understand the strategy outcomes for different scenarios.

This study deals with scenarios consisting of one specific dimension, scenarios based on a change in the EUR/USD exchange rate. With this dimension, there is an opportunity to think critically about the financial implications of a sudden change in this dimension and the risk to an organisation's foreign exchange strategy that this entails. The scenarios in this case study are used as described by (Schoenmaker, 1995) to compensate for the usual errors in the

decision-making process and to improve the decision-making process. The identified scenarios for this study are visualised in part 2.1.9.1.

2.1.4 Robust decision making (RDM)

According to Marchau et al. (2019) there are five analytical approaches for supporting decision making under uncertainty, *Robust Decision Making (RDM), Dynamic Adaptive Planning (DAP), Dynamic Adaptive Policy Pathways (DAPP), Info-Gap Decision Theory (IG), Engineering Options Analysis (EOA).* This study will go further in depth on robust decision-making. "Robust decision making is a set of concepts, processes, and enabling tools that use computation, not to make better predictions, but to yield better decisions under conditions of (deep) uncertainty" (Marchau et al., 2019, p. 16). According to Lempert et al. (2003) robust decision-making is combining the best capabilities of humans and computers to address decision problems under conditions of uncertainty. A robust decision-making process is applicable in this paper because it involves (deep) uncertainty. It is impossible to predict the exchange rate of the EUR/USD. Figure 4 shows the robust decision-making process in more detail (Marchau et al., 2019, p 31).

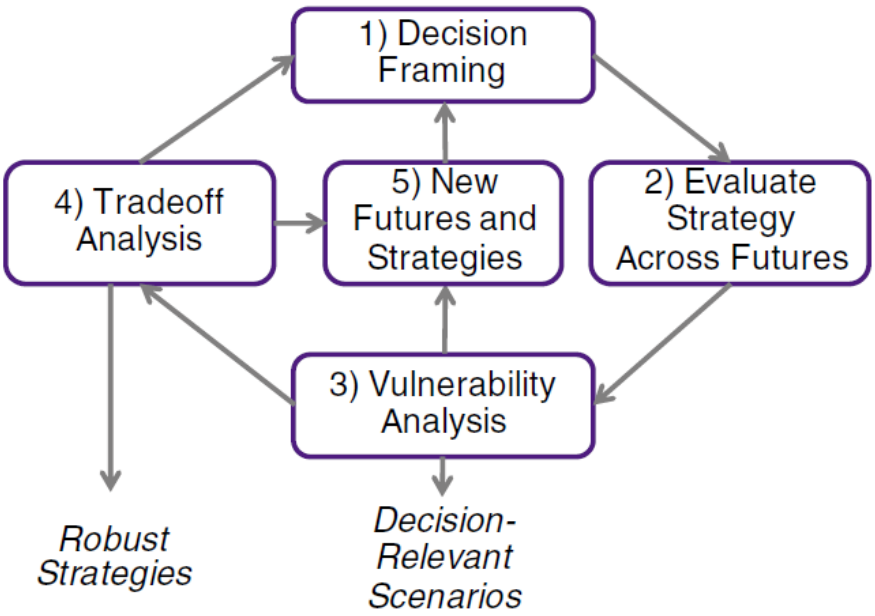

Figure 3: RDM process

This study will mainly focus on step 1 (determining the decision framework) and step 2 of the process (evaluating the strategy for the different future scenarios). Due to time constraints and relevance, the other steps of the RDM process will not be considered in this paper. The emphasis lies on the first two steps, because they involve the decision framing and the

evaluation of strategies across scenarios. In step 1, this study will mainly focus on constructing the qualitative system dynamics model in order to understand the relationships between variables and to identify crucial feedback loops. In step 2, this study focuses on identifying strategies that are most robust in each scenarios by means of the interactive dashboard.

2.1.5 Simulation modelling

Since scenario planning deals with possible future outcomes, simulation tools have played an important role in the world of scenario planning. According to (Eid et al., 1997), simulation techniques have been used to evaluate the impact of scenarios in scenario-based planning. In this paper, the system dynamics methodology is used to create the simulation model. "The system dynamics simulation plays a key role in this regard and is able to capture the long-term relationship between different events" (Geum et al., 2014, p. 42). Understanding the long-term relationship between different events is crucial in this research, namely to understand the financial consequences and risks of different scenarios on an organisation's operations.

2.1.5.1 System dynamics

System dynamics is all about systems. "A system is a set of things - people, cells, molecules, or whatever - that are connected in such a way that over time they produce their own pattern of behaviour" (Meadows & Wright, 2009, p. 2). A stock is the basis of any system. According to Meadows & Wright (2009), stocks are the elements of the system that you can see, feel, count or measure at any given moment. Stocks can only change over time due to inflows and/or outflows. Figure 4 shows a visual representation of a stock-and-flow Diagram.

Figure 4: stock and flow diagram

If a system shows you consistent behaviour over a longer period of time, there is probably a mechanism that creates that consistent behaviour. Those mechanisms are known as feedback loops (Meadows & Wright, 2009). “A feedback loop is a closed chain or causal connections from a stock, through a set of decisions or rules or physical laws or actions that are dependent

on the level of the stock, and back again through a flow to change the stock" (Meadows & Wright, 2009, p. 27) In the world of system dynamics there are two kind of feedback loops:

- Balancing feedback loops
- Reinforcing feedback loops

According to Meadows & Wright (2009, p. 27-28) balancing feedback loops are equilibrating or goal-seeking structures in systems and are both sources of stability and sources of resistance to change. Reinforcing feedback loops are self-enhancing, leading to exponential growth or to runaway collapses over time and are found wherever a system element has the ability to reproduce itself or to grow as a constant fraction of itself (Meadows & Wright, 2009, p. 30-31).

2.1.6 Contribution to existing literature

Decision-making on the management of foreign exchange risk has been examined in several studies, such as Ferguson's (1985). However, there is little known literature on the foreign exchange market decision-making process using simulation models. This study combines robust decision-making and scenario planning to make better informed decisions despite the uncertainty of the EUR/USD currency market. This study focuses mainly on the financial consequences of a fluctuation in the EUR/USD exchange rate for the profit margin of a product. In addition, the sectoral dependence of this phenomenon is examined. The combination of these different concepts is unique and will therefore contribute to the existing literature.

2.1.7 Practical relevance

On 4 February 2022 the EUR/USD exchange rate was 1.1464, one month later on 2 March the EUR/USD exchange rate was 1.1106 (IMF, 2022), a drop of 3.5 cents. For companies with large EUR/USD exposure, these small changes can have large financial consequences. In fact, if a company has an annual EUR/USD exposure of 10.000.000, a 3.5 cent drop in the exchange rate will already result in a depreciation of 300.000 euros. So understanding the financial consequences of different scenarios of the EUR/USD exchange rate could be useful for many foreign trading companies with a large EUR/USD exposure.

2.1.8 Management relevance

This study is mainly of interest to financial advisors who advise in the field of risk management of foreign currencies. Insights from the interactive dashboard and system dynamics model can

be used as visual support to indicate to clients the consequences of an exchange rate fluctuation on, for example, the profit margin. According to Black (2013) boundary objects (visual representations) facilitate shared understanding for joint action. In this way, advisors can bring decision-makers into the process in a more understandable way and create more support for the advised choices. In addition, financial decision-makers of large internationally operating companies can also use this interactive dashboard to make more informed decisions about how to deal with the EUR/USD risk they are facing.

2.1.9 Conceptual model

The central topic of this study, EUR/USD exposure plays a central role in this conceptual model. The starting point of the conceptual model (see figure 5) is the stock *'EUR/USD exposure'*, this stock will increase via the inflow *'dollar need'* and decrease via the outflow *'hedged exposure'.* The dollar need is heavily influenced by the amount of orders: the more orders a company has, the more it would have to buy in dollars to meet customer demand. The outflow hedged exposure depends on the variable *'ratio of the hedged exposure'*. This is the place in the system where financial decision-makers can adjust the amount of risk they want to take. This can be seen as the strategy employed to manage the EUR/USD exposure with the use of the different external hedging instruments. If they choose to hedge only 10% of their exposure for example, the organisation is heavily dependent on changes in the EUR/USD exchange rate. This is defined in the conceptual model as *'currency risk'*, referring to the risk of potential losses due to a change in the EUR/USD exchange rate. This could lead to reduced profit and less room to invest, which ultimately hampers growth and resulting in fewer orders. This is the first feedback mechanism present in this model, namely a balancing feedback loop (B1).

An organisation can also protect itself against price fluctuations outside the hedging instruments by looking at alternative products, for example. In this conceptual model this is shown as *'substitution products'* which reflects the extent to which an organisation is substitute products or raw materials. This variable is influenced by the variable *'investments'*. This is done in order to reduce currency risk, which is at the same time the second feedback mechanism, namely an reinforcing loop (R1).

A direct consequence of a change in the EUR/USD exchange rate is that this may lead to unexpectedly more expensive purchase costs, which leads to more marginal costs and this in turn results in a lower profit margin per product. The variable *'profit'* is influenced by the variable *''profit margin per product''*, as mentioned earlier, less profit gives less room for

investments which in this case results in less international activities. In the conceptual model this is visualised as "B2", referring to the second balancing feedback loop of the system.

In this conceptual model, there are also a number of exogenous variables that only influence variables but are not influenced themselves. The variables *'sector sensitivity'*, *'EUR/USD exchange rate'* and *'Demand from customer'* are exogenous variables in this case.

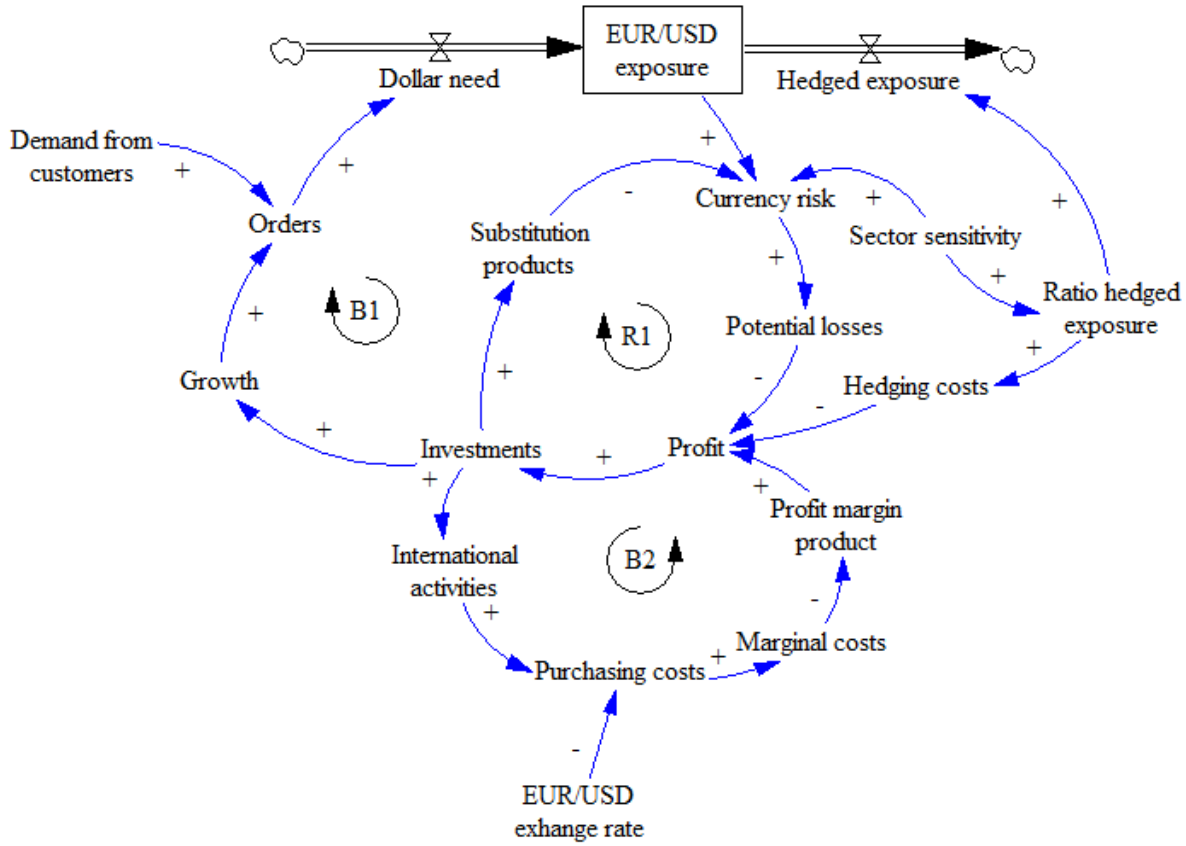

Figure 5: Conceptual model

Table 1: Overview of feedback loops

Name	Overview of feedback loops
B1	Currency risk→Potential losses → Profit → Investments → Growth → Orders → Dollar need → EUR/USD exposure → Currency risk
B2	Profit → Investments → International activities → Purchasing costs → Marginal costs → Profit margin product → Profit
R1	Investments → Sensitivity to rate movements EUR/USD → Currency risk → Potential losses → Profit → Investments

2.1.9.1 Scenarios

The purpose of the interactive dashboard is to get insight into the financial consequences on the profit margin of products of the different identified plausible scenarios. The purpose of the interactive dashboard is to get insight into the financial consequences of the different identified plausible scenarios. Those scenarios are based on a change in the variable EUR/USD exchange rate, this a relevant variable because it can be seen as an uncertainty that cannot be controlled by a company itself.

These scenarios will be used to find a EUR/USD strategy that is as robust as possible in each scenario, where it will also be examined which external hedging instruments can be used. In addition, it will be examined whether it is useful to adopt a strategy per sector or whether a generic foreign currency strategy will be enough. To determine the value of the variable *"EUR/USD exchange rate"* the data from the European Central Bank is used (ECB, 2021). Thus the value of the variable is based on historical data (see figure 6), where the first 2 scenarios are based on the highest and lowest measured EUR/USD exchange rate in history (1.5990 & 0.8252). The third and fourth scenarios are based on a 10% increase and decrease compared to the current rate (1.0878). Since a major change in the EUR/USD exchange rate does not happen overnight, the change in the exchange rate will be simulated over a period of 6 months in order to monitor the change over time.

Figure 6: EUR/USD exchange rate over the years

Table 2: Identified scenarios

Scenario name	**Change in elements***
Scenario 1	EUR/USD exchange rate: 1.5990
Scenario 2	EUR/USD exchange rate: 0.8252
Scenario 3	EUR/USD exchange rate: 1.19
Scenario 4	EUR/USD exchange rate: 0.97

*The above changes happen over a period of 12 months.

3.1 Methodology

3.1.1 Research Strategy

The research strategy used in this paper is a mixed methods research strategy. A mixed methods approach, uses quantitative and qualitative research methods, either simultaneously (independently of each other) or sequentially (findings from one approach inform the other), to understand a phenomenon of interest (Venkatesh et al., 2013). Harrison (2013) distinguishes four mixed method types: convergent, embedded, explanatory and exploratory. In this study an interactive dashboard is designed that can assist in the decision-making process of financial decision-makers. An explanatory approach were used to achieve the aim of the research. Explanatory research is a design type where quantitative research is followed by qualitative research (Harrison, 2013). Thus, this study used an explanatory mixed methods approach that translated insights from the system dynamics model into an interactive dashboard. This dashboard was validated by means of two interviews with experts in the field of foreign currency management and also to prove the practical relevance. In addition, the interviews examined whether the sensitivity for the EUR/USD rate is determined by the sector in which a company is located. In this study, the mixed methods approach has been used sequentially, with the quantitative data (interactive dashboard) being used as input for the qualitative study (interviews).

3.2 Methods of data collection

3.2.1 Quantitative

To build the interactive dashboard, data on the EUR/USD exchange rate is used; this archive data is taken from the public site of the International Monetary Fund (IMF) (IMF, 2022). The quantitative input for the dashboard is collected from an invented case describing the value of the variables used. This case mainly describes the cost structure of a company, the total EUR/USD exposure per year and all other relevant information that was needed to build the interactive dashboard.

3.2.1.1 System dynamics simulation model

A simulation model (interactive dashboard) is constructed based on the theory of system dynamics outlined in section 2.1.5. According to Barlas (1996), a model should not only reproduce/predict the behaviour, but also explain how the behaviour comes about, and possibly

suggest ways to change the existing behaviour. Hence, in this study, a mixed method is used combining qualitative and quantitative aspects into an interactive dashboard. The theory of system dynamics makes it possible to identify feedback loops that explains the behaviour of a system, in this case the management of foreign currency exposure. The system dynamics simulation model (interactive dashboard) will specifically address the financial implications of the various scenarios on the purchase price of products and how that affects the profit margin of products. These insights could be used by financial decision-makers to constructively arm and prepare for currency risks. In addition, this model serves as a boundary object (visual representation) to create understanding among various stakeholders for a EUR/USD strategy, according to the study by Black (2013).

3.2.2 Qualitative

Luna-Reyes and Andersen (2003) propose the formal incorporation of qualitative methods into the conceptualisation, formulation and assessment of system dynamics models. Because of the importance of including a qualitative perspective in model building, two disconfirmatory were taken with financial advisors. The objective of those interviews was to see if the behaviour of the interactive dashboard is representative. In addition, to see if there should be made a difference between different sectors and to see which sector factors explain any difference. There was room for the participants to make improvements to the dashboard in order to create a more representative and realistic behaviour.

3.2.2.1 Disconfirmatory interviews

The two disconfirmatory interviews to validate the structure and behaviour of the interactive dashboard were conducted with two financial advisors. These financial advisers are active in the field of risk management and are familiar with the implications and effects of the EUR/USD exchange rate. These interviews were semi-structured interviews with the topics discussed in the next section (3.2.2.2). The interviews were held in Dutch and recorded with the permission of the participant so that the interviews can be properly analysed. The interview guide used can be found in appendix 5.

3.2.2.2 Topics disconfirmatory interviews

The following topics were discussed in the two disconfirmatory interviews in order to validate the qualitative system dynamics model and interactive dashboard:

- Structure of the qualitative SD model: the participants were asked about the structure of the model in order to check the different relationships between the variables used in the model.
- Feedback loops: the participants were asked if they understood and agreed with the feedback loops.
- Behaviour of the interactive dashboard: the participants were asked about the behaviour of the build dashboard. In order to see if the behaviour of the results is realistic.
- Decision-making process: participants were asked whether the use of this dashboard will help the decision-making process for managing the EUR/USD exposure and in what way it helps this process.
- Difference by sector: Participants were asked if this model/dashboard can be used generically or if the behaviour of the model/dashboard differs by sector or type of product. In addition, the participants were be asked whether they agree with the sectors that are not very sensitive to price fluctuations according to Doukas et al. (2001) (see section 2.1.1.2) and whether there are other sectors that could be added.

3.3 Validation of the simulation model

"The ultimate goal of system dynamics model validation is to establish the validity of the model's structure" (Barlas, 1996, p. 188). The validation of the model will be carried out through the structure validity and the behavioural validity as proposed by Barlas (1996). The structure of the simulation model will be examined by an extreme condition test. According to Sterman (2000, p. 869) "models must be robust under extreme conditions. Robustness under extreme conditions means that the model must behave in a realistic manner, no matter how extreme the inputs or policies imposed on it may be". To investigate the structure of the system dynamics model and behaviour of the interactive dashboard, two disconfirmatory interviews were conducted to assess the SD model and the interactive dashboard. These interviews were used to increase users' confidence in the structure and behaviour of a model by using a systematically constructed process of disconfirmation (Andersen, et al. 2012). As mentioned earlier the interviews were conducted with financial advisors in the field of EUR/USD risk management. To help the respondents interact with technical, modelbased artefacts, an interactive interview is used. In addition to the validation of the simulation model, the practical relevance of the model was examined through the two disconfirmatory interviews

3.4 Research ethics

Research ethics is about setting standards for conducting research. Research should not harm research participants, research should lead to findings of good quality and findings contribute to the greater good (Denscombe, 2012, p. 122). This research involves more than minimal risks of research ethics, this research involves confidential information about the decision-maker's decision-making process. While conducting the two disconfirmatory interviews, it is discussed what the decision-making process of that particular decision-maker looks like and how he or she determines the foreign currency strategy. This information is confidential and should remain so in the interest of the decision-maker and the company he or she works for. In addition to ethics when doing research, ethics must also be observed when writing research. As a researcher, you have an ethical responsibility to write in a way that is accessible to the widest possible audience (Liebenberg, 2016). This research is written down in a way that is readable and understandable for a broad audience. This means putting yourself in the position of the reader to think critically about whether your written research is understandable to outsiders who are not so familiar with the subject.

4. Results

This chapter starts with the description of the constructed system dynamics model (section 4.1). Here you will find a description of the different variables and the identified feedback loops, which are important for the structure of the system. For the quantification of the model, a fictional case is described (appendix 1), namely a firm with a EUR/USD exposure. Paragraph 4.2 is about the quantification of the EUR/USD scenarios. Section 4.3 presents the financial implications of the scenarios and the consequences for the rest of the model. Section 4.4 and 4.5 are about different hedging strategies, to ultimately find a robust strategy. In section 4.6 the decision-making process is discussed and how the interactive dashboard improves this process. Section 7 of the results section is about the practical relevance of the interactive dashboard. In section 4.8 discusses the degree of sensitivity to the EUR/USD rate and whether this differs by sector. The final section (4.8) is about the validation of the two models.

4.1 Description of the system dynamics model

In section 2.1.4 the framework of robust decision-making is discussed. The system dynamics model is intended to frame the decision (step 1 RDM) by capturing key relationships between variables and identifying important feedback loops.

4.1.1 Stock and flow structure

The central stock in this model is the EUR/USD exposure. This stock can only fluctuate via the inflow and outflow. The inflow in this case is the so-called dollar need which is proportional to the number of purchasing costs per unit of time (months). The stock can only decrease via the outflow, in this case hedged exposure. Because when a company hedges exposure, it protect itself (partly) from a EUR/USD risk.

figure 7: stock and flow structure

4.1.2 Structure of the model

Within the theory of system dynamics, it is of great importance to identify feedback loops. According to Meadows & Wright (2009) a feedback loop consists of a closed chain of connections that are dependent on the level of the stock, and back again through a flow to change the stock. In figure 8, the basis of the model with two important feedback loops in the system is visualised. First of all, the higher the stock EUR/USD exposure, the higher the currency risk of a firm. Potential losses (due to currency risk) is in short explained by two variables; currency risk and EUR/USD exchange rate. In this case, when the EUR/USD rate decreases, the variable potential losses increase because the EUR is worth less than the USD and thus the firm is exposed to a risk. As a company, you can hedge against such risk by hedging your exposure. In this paper the focus will be on external hedging instruments, according to Tijhaar (2013, p. 377) external hedging instruments are used to protect against the possibilities of losses occurring as a result of exposure to foreign risk. The variable *hedged exposure per product* causes a change in the outflow *hedged exposure* and the variable *currency*

risk. Therefore, the variable *hedged exposure per product* is an important variable in the two feedback loops visualised in figure 8. The hedging strategy determined by the financial decision-maker of an organisation is represented by the variable *hedged exposure per product*. Simplistically, this strategy is formed by two input variables: *ratio hedged exposure per product, purchasing costs*.

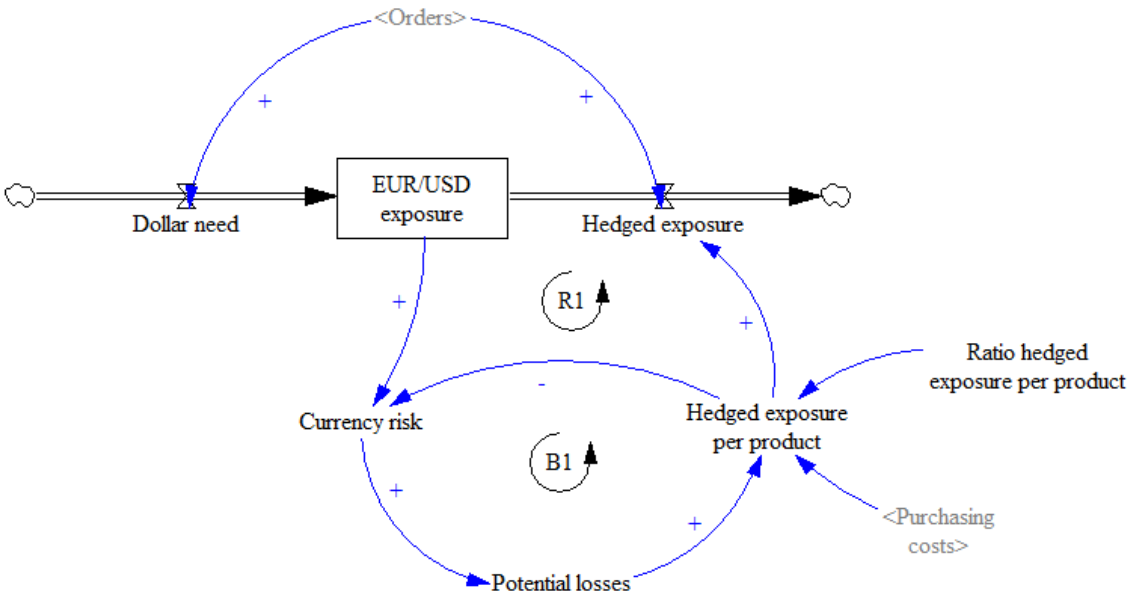

figure 8: Stock structure

According to Santillán-Salgado et al. (2019) it is widely accepted that fluctuations in currency exchange rates directly affect the input costs of firms engaged in multinational business activity, in figure 8 known as the variable *purchasing costs*. Mann (1986) argued that profit margins are a key link between the exchange rate and prices of traded goods. The profit margin of a product of an international operating firm is thus heavily dependent on fluctuations of the currency exchange rate, in this case the EUR/USD rate. The article of Lee (2014) stated that an active investment is necessary for firm growth and that the effect of profit on growth is likely to be positive in an environment that is conducive to investment and growth. In figure 9, the relationship between the variables *profit, investment and growth* can be explained as follows according to the study of Lee (2014). The more profit a firm makes, the more investments they could afford which ultimately leads to more firm growth. Figure 9 visualises the findings of Santillán-Salgado et al. (2019), Mann (1986) and Lee (2014), which leads to the third balancing feedback loop of the model.

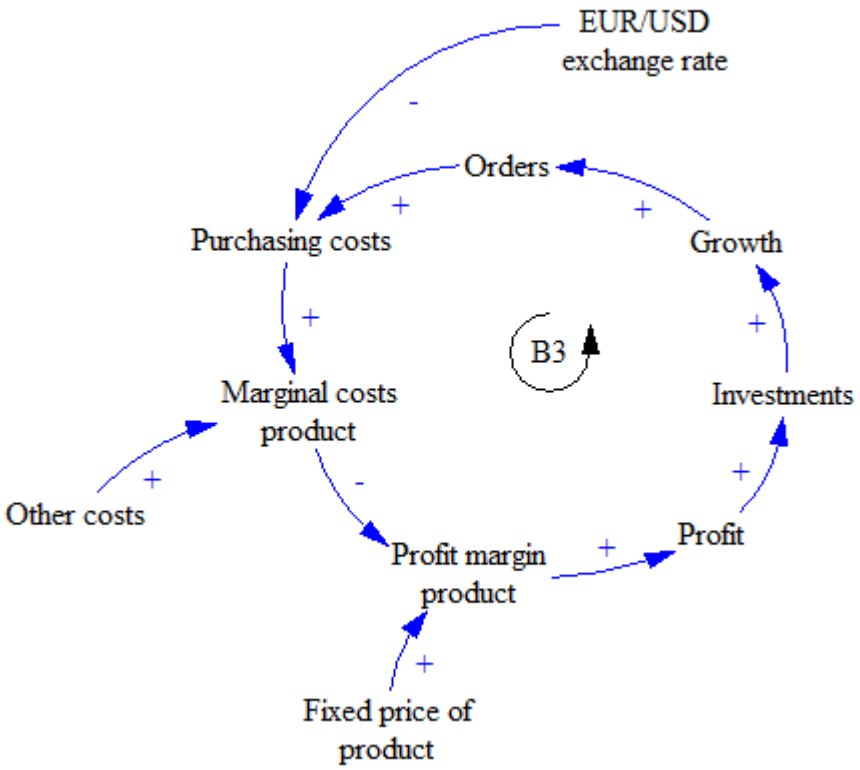

Figure 9: balancing feedback loop 3

Besides the use of external hedging instruments, there are other ways for firms to protect themselves from foreign currency risks. According to Levy & Sarnat (1970) diversification of international portfolios can reduce corporate risks, supported by the theoretical models of portfolio selection developed by Markowitz (1952). Currency risk can also be spread through diversification. For example, by not only being dependent on the EUR/USD rate but also, for example, by looking for suppliers who want to be paid in British pounds (GBP). Or to completely rule out the risk, to make price agreements in euros (EUR). As visualised in figure 10, more investments in diversification will lead to a lower currency risk as explained above. This loop is an reinforcing loop because a higher value of the variable *diversification* will in the end lead to an even higher value of the variable *diversification.*

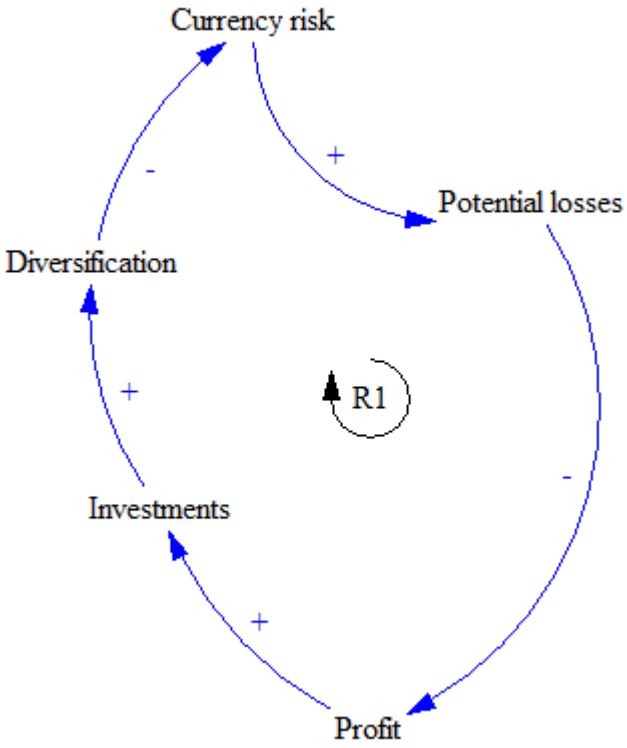

Figure 10: Reinforcing feedback loop 1

4.1.3 Overview of the whole model

Figure 11 shows the complete model for managing a EUR/USD exposure. The following sections describe the feedback mechanisms in more detail.

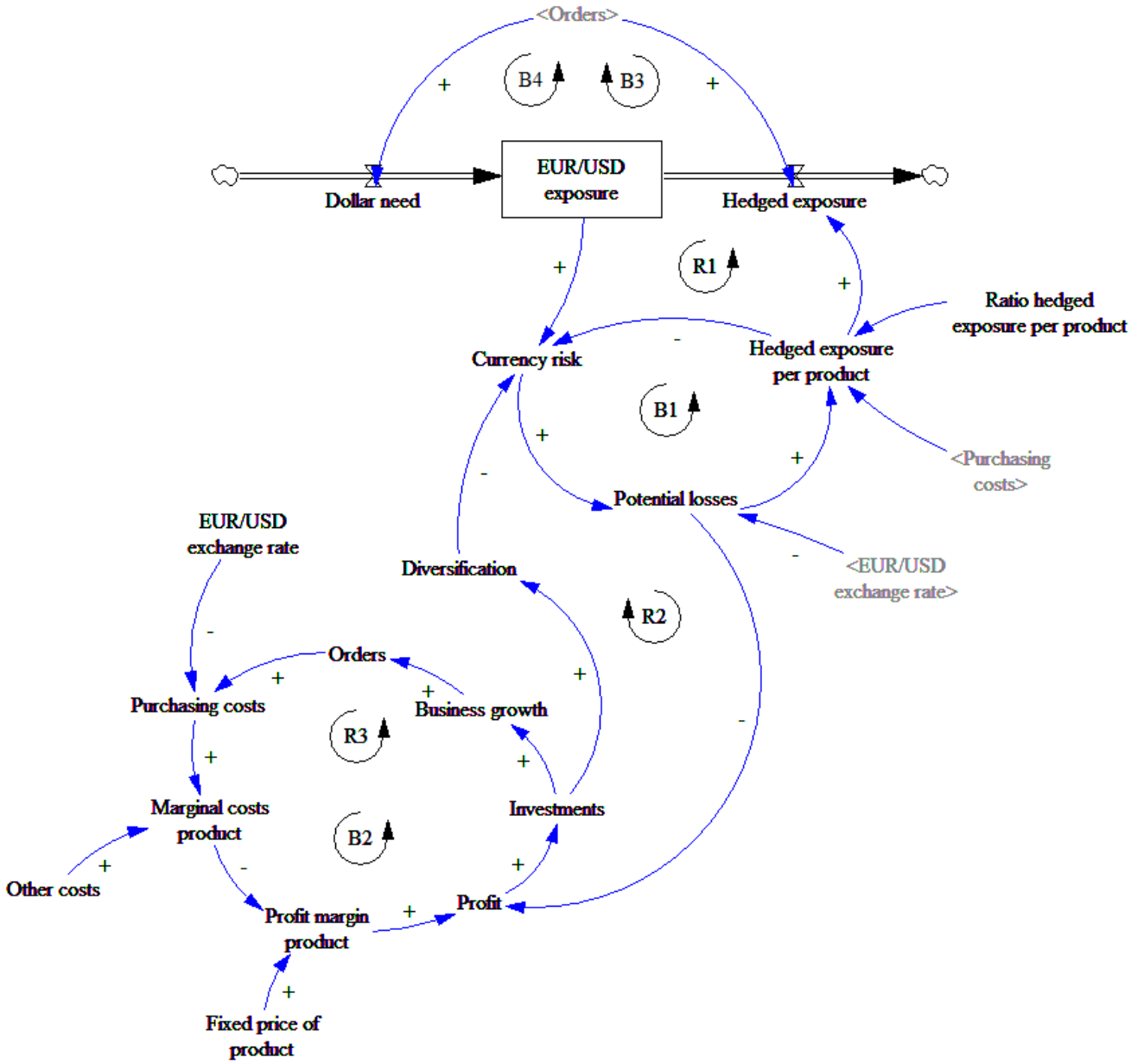

Figure 11: overview of the whole model

4.1.4 Feedback loops

According to Forrester (1961, p. 15) "*Systems of information-feedback control are fundamental to all life and human endeavour, from the slow pace of biological evolution to the launching the latest space satellite. Everything we do as individuals, as an industry, or as a society is done in the context of an information-feedback system".* So feedback loops are present in every system, so also for the management of a EUR/USD portfolio. According to Meadows and Wright (2009), the many feedback loops in a system move against each other, trying to make the stocks grow, die or balance with each other.

The above visualised model (figure 11), consists of 7 feedback loops, 2 reinforcing feedback loops and 5 balancing feedback loops which are described in table x.

Table 3: overview of feedback loops

Name	**Overview of feedback loops**
B1	Currency risk → Potential losses → Hedged exposure per product
B2	Orders → Purchasing costs → Marginal costs product → Profit margin product → Profit → Investments → Business growth
B3	Orders → Hedged exposure → EUR/USD exposure → Currency risk → Potential losses → Profit → Investments → Business growth
B4	Orders→ Dollar need → EUR/USD exposure → Currency risk → Potential losses → Profit → Investments → Business growth
R1	EUR/USD exposure → Currency risk → Potential losses → Hedged exposure per product → Hedged exposure
R2	Currency risk → Potential losses → Profit → Investments → Diversification
R3	Orders → Purchasing costs → Hedged exposure per product → Hedged exposure → EUR/USD exposure → Currency risk → Potential losses → Profit → Investments → Business growth

The primary symptom of a balancing feedback loop structure is that not much changes, despite outside forces pushing the system (Meadows & Wright, 2009). The counterpart of balancing feedback loops are reinforcing feedback loops, according to Meadows & Wright (2009) reinforcing loops is a vicious or virtuous circle that can cause healthy growth or runaway destruction, it generated more input to a stock the more that is already there (and less input the less that is already there). It is important to identify the different feedback loops in this model and to understand the dynamics behind them.

Balancing feedback loop 1 (B1) Is the feedback loop that describes well how the currency risk in this system remains the same, this is mainly caused by the variable *hedged exposure per product*. Because the more currency risk there is, the more potential losses a company will face, upon which a company will start to hedge this risk via the variable *hedged exposure per product*, with the result that the variable *currency risk* will decrease again (balancing effect).

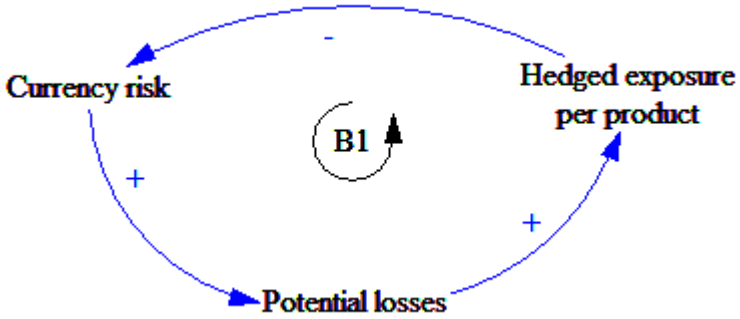

Figure 12: balancing feedback loop 1

Reinforcing feedback loop 1 is another important loop in this model, as it reflects a reinforcing effect of the hedging phenomenon. Organisations with large EUR/USD exposure are exposed to relatively high currency risk due to possible exchange rate fluctuations, which in turn results in potential losses. To counter this, an organisation may decide to hedge the currency risk, with the result that the stock EUR/USD exposure will decrease (reinforcing effect).As described in section 2.1.1, this document explicitly deals with external hedging instruments, whereby the variable *hedged exposure per product* can be seen as the hedging strategy of a company whereby a financial decision-maker can hedge more or less exposure based on the degree of uncertainty and the perceived risk.

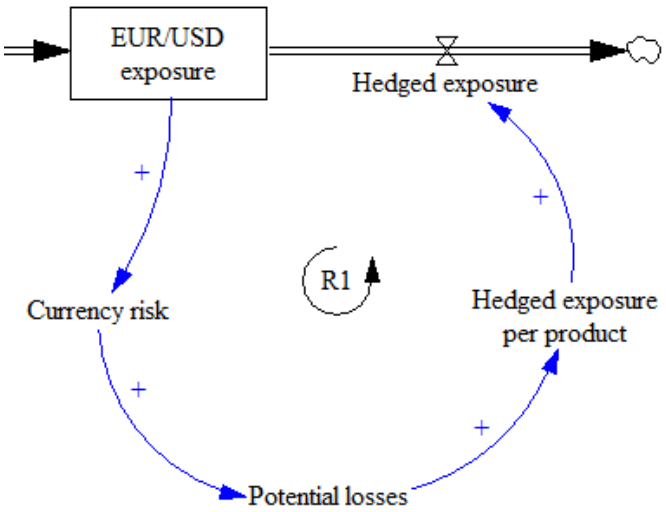

Figure 13: reinforcing feedback loop 1

4.2 Quantification of the model

The quantification of the system dynamics model was done using the program python. With this program, an interactive dashboard was built to support the decision-making process of financial decision-makers. The input for this dashboard is based on a case study (see appendix 1). The dashboard consists of three different parts: EUR/USD exchange rate scenarios, case study and hedging strategies. These three components are discussed in more detail below. The programming code used can be found in appendix 8.

4.2.1 Scenarios

One of the main questions of this study is what the financial impact is of a fluctuation in the EUR/USD exchange rate. To simulate this effect, four scenarios were drawn up: two extreme scenarios and two more obvious scenarios (see table x). In order to make the scenarios as realistic as possible, the four scenarios have been programmed with the program python according to the programming language found in appendix 2. It is important that these scenarios are as realistic as possible, as this forms the further basis of the results section. Each scenario contains a starting point and an end point between which 50 numbers in a linear direction (50 weeks) were chosen at random. The scenarios are represented in the qualitative system dynamics model as the variable *EUR/USD exchange rate*.

Table 4: the four scenarios

Scenario name	**Change in elements**
Scenario 1	EUR/USD exchange rate: 1.5990
Scenario 2	EUR/USD exchange rate: 0.8252
Scenario 3	EUR/USD exchange rate: 1.19
Scenario 4	EUR/USD exchange rate: 0.97

4.2.1.1 EUR/USD exchange dashboard scenarios

The first part of the dashboard consists, as mentioned, of the EUR/USD scenarios. The financial decision-maker can sketch various plausible scenarios here. This part of the dashboard creates a random scenario between an entered start and end point to get a realistic scenario. Figure 14 shows an example with the starting point of the EUR/USD rate of 1.06 and an ending point of the same rate of 1.15 over a 52-week period.

Graph 14: EUR/USD exchange rate scenario

4.3 Financial effect scenarios

To answer research question 1 (*What is the financial effect of a change in the EUR/USD exchange rate on the profit margin of a product?)*, we will have to look at the effect of a fluctuation in the EUR/USD exchange rate on the profit margin of a product. This has also been done using the fiction case study (appendix 1). To determine the financial effect on the profit margin, the part of the system dynamics model of figure 15 is simulated. In this case, it was assumed that no hedging strategy would be used and that all dollars needed would therefore be bought on "spot". It is assumed that the suppliers must be paid immediately each time in order to maximise the financial effect of a change in the EUR/USD exchange rate. The financial figures of figure 16 in section 4.3.1 are used as input for the calculations.

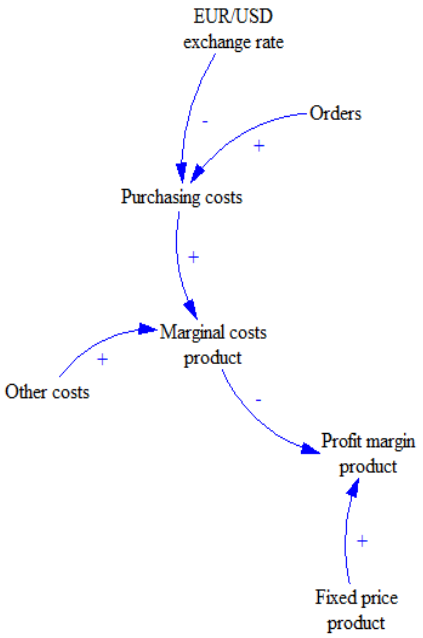

Figure 15: effect exchange rate on profit margin

4.3.1 Case study

The interesting thing about a EUR/USD exchange rate fluctuation is to see what effect it has on the various cost components of a company with a large EUR/USD exposure. As mentioned, a case study was created as input for the interactive dashboard. In this case, the key figures from figure 16 were used, which can be adjusted by the financial decision-maker.

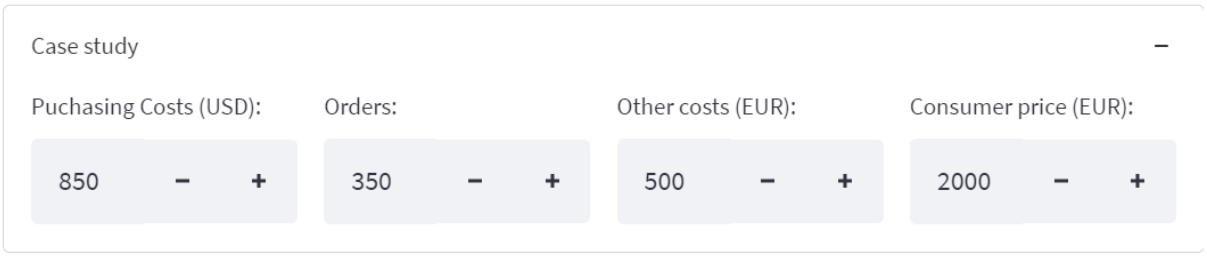

Figure 16: key figures case study

4.3.2 Positive effect

As the charts below show, scenarios 1 and 3 have a positive effect on a product's profit margin. Simply put, this is because the EUR/USD exchange rate rises; the EUR becomes more valuable against the USD.

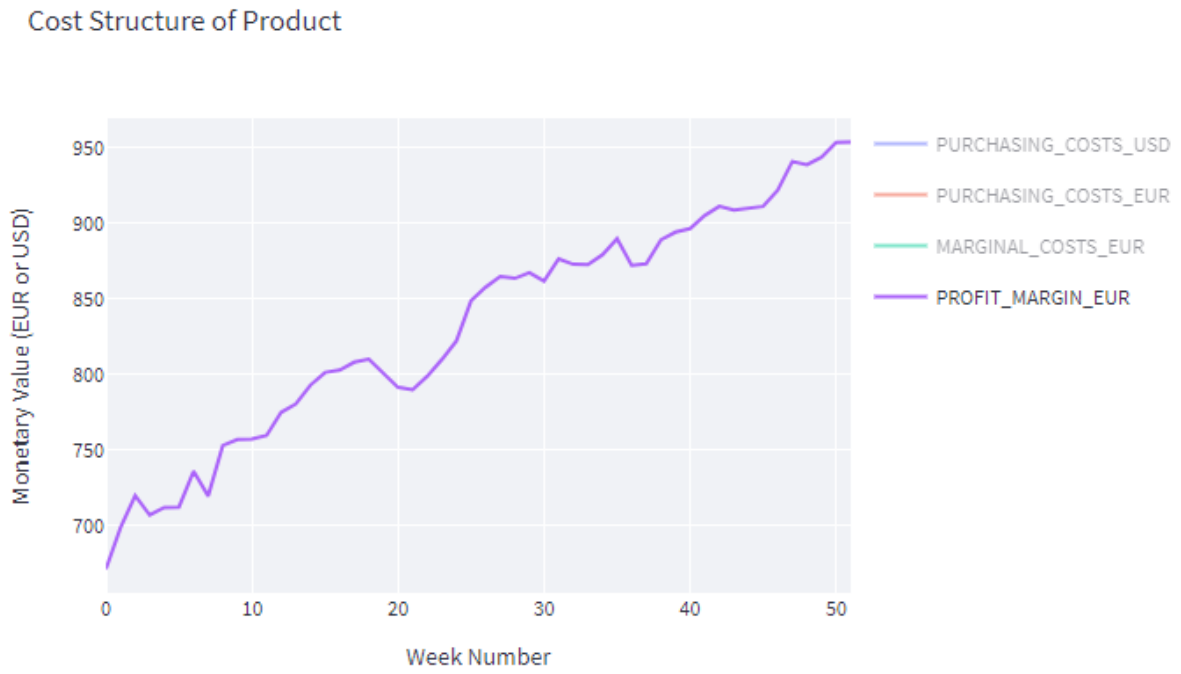

Figure 17: Profit margin of scenario 3

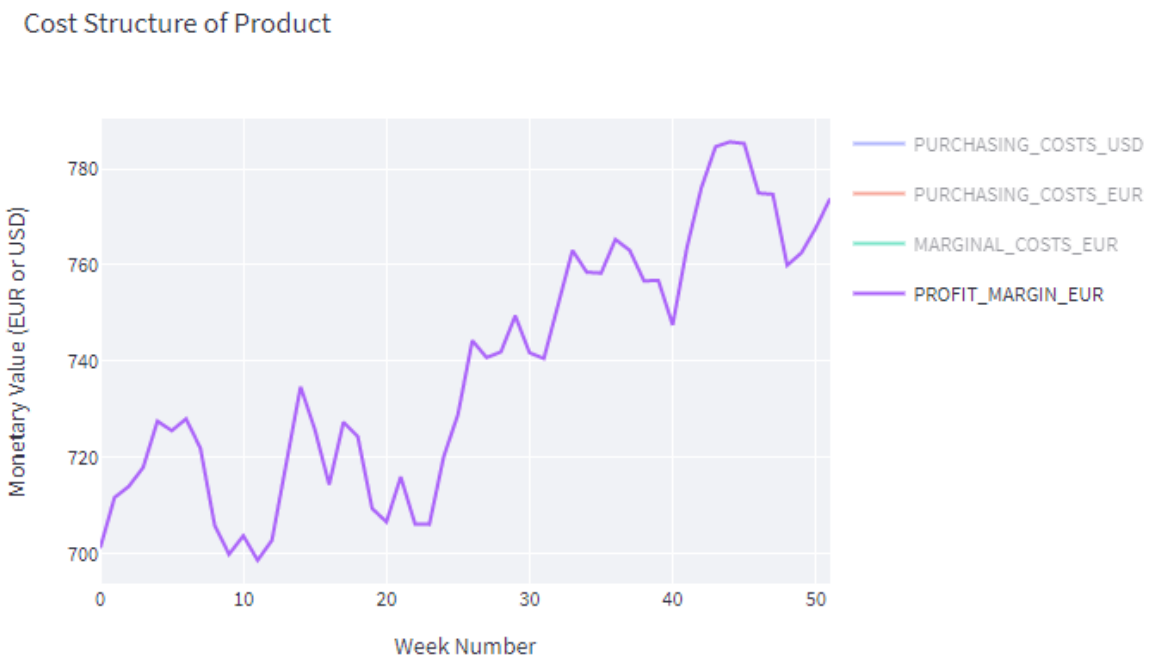

Figure 18: Profit margin of scenario 3

The strength of this effect depends on the growth of the EUR/USD exchange rate. The difference in growth is shown in tables 5 and 6. It can be seen that a relatively small growth of the EUR/USD exchange rate (scenario 3) yields a relatively larger increase in the profit margin than a relatively large growth of the EUR/USD exchange rate (scenario 1). This is demonstrated by the following calculation:

Table 5: the effect of scenario 1

EUR/USD rate	Growth in %	Profit margin	Growth in %
1,08	47,22	708,71	35,62
1,58		961,16	

Table 6: the effect of scenario 3

EUR/USD rate	Growth in %	Profit margin	Growth in %
1,069	10%	708,13	9,5
1,1768		775,41	

- *Scenario 1*, 35,62/47,22 = 0,75
- *Scenario 3*, 9,5/10 = 0,95

Thus, especially small changes in the EUR/USD exchange rate have a relatively large impact on the profit margin and, as the EUR/USD exchange rate rises further, the strength of this effect diminishes.

4.3.3 Negative effect

The graphs below show the effects of scenarios 2 and 4. These are the two scenarios where the EUR/USD rate falls over time, causing a negative financial effect on the product's profit margin. This effect therefore satisfies hypothesis 1 (*A change to a lower EUR/USD exchange rate leads to a lower profit margin per product over time*), namely that a trend towards a lower level of the EUR/USD over time causes a smaller profit margin.

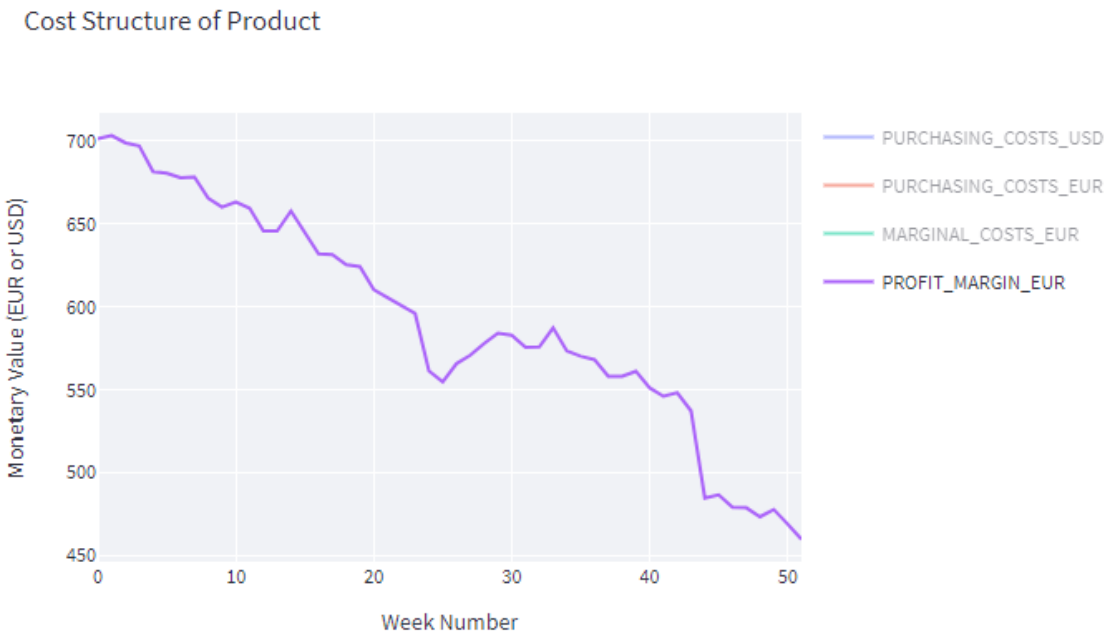

Figure 19: Profit margin of scenario 2

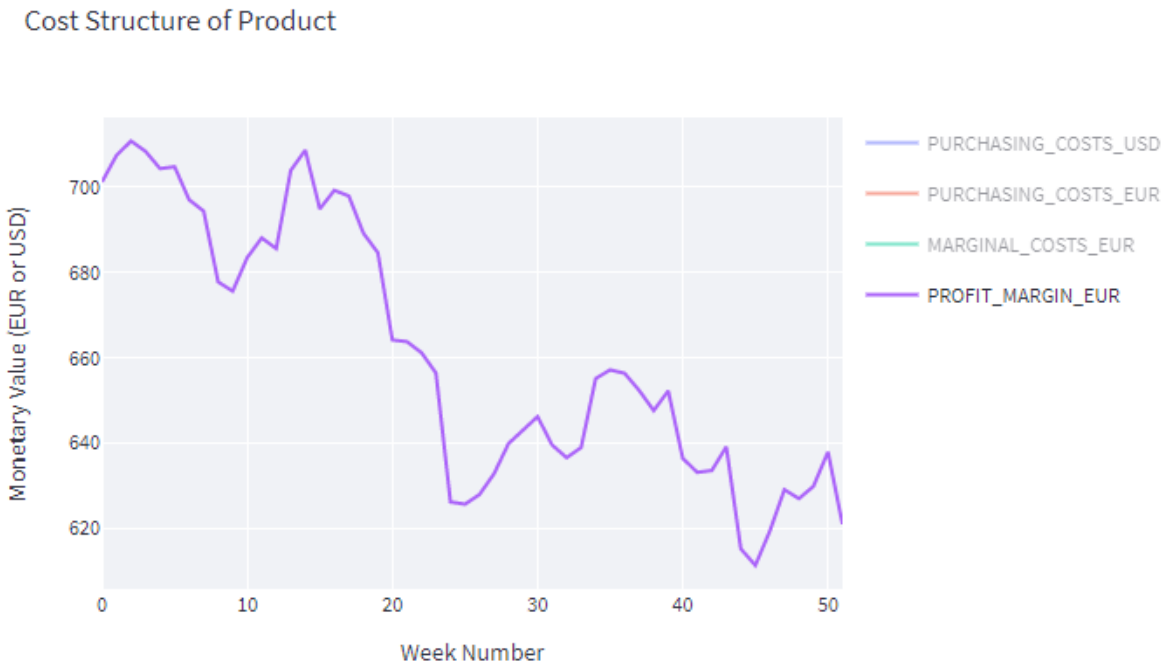

Figure 20: Profit margin of scenario 4

4.3.5 Consequences for the rest of the model

The above effect also affects other variables in the qualitative system dynamics model, as the variable *profit margin product* is embedded in feedback loops. The variable *profit margin product* is part of the balancing feedback loop 2, as shown in figure 21. This loop is crucial for the growth of a firm and any fluctuation will have a balancing effect on it. In other words, if for example the variable *purchasing costs* rises, it will fall again over time due to the dynamics of the feedback loop.

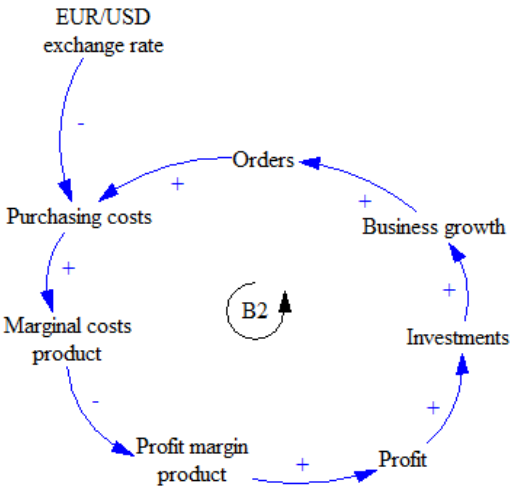

Figure 21: Balancing feedback loop 2

Apart from the fact that the effect is embedded in a balancing feedback loop of the model, the effect of the different scenarios on purchasing costs is also present in a reinforcing feedback loop. This loop is shown in the figure below (figure 22).

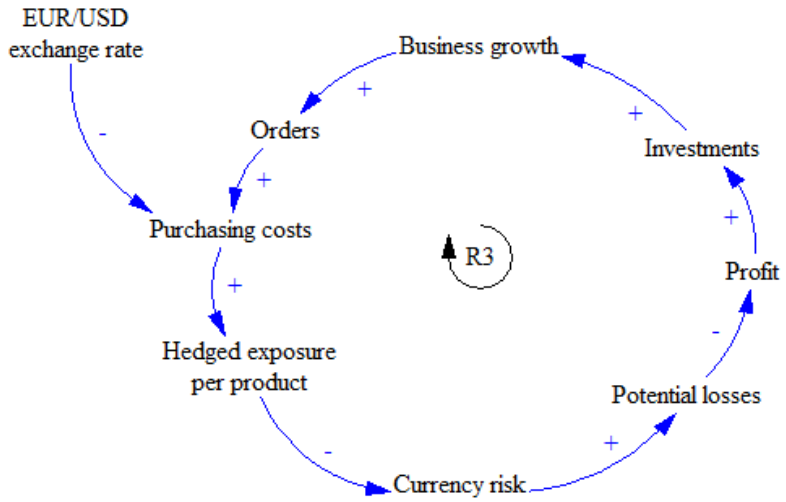

Figure 22: Reinforcing feedback loop 3

A change in the EUR/USD exchange rate can trigger this loop. A rise in the EUR/USD exchange rate will increase a firm's purchasing costs, which will ultimately lead to an increase in orders, which in turn will result in even more purchasing costs.

4.4 Hedging strategies

The results in section 4.3 are based on the so-called "spot strategy", which according to Eun & Resnick (2014) involves an agreement between two parties (bank and firm) to immediately buy a currency (USD) and sell a currency (EUR) at the rate of that moment. To answer sub-questions 1 and 2, it is useful to examine which external hedging instruments could be applicable and what the effect of these instruments could be on the currency risk.

- Sub question 1: *Which hedging instruments can be used to manage the EUR/USD risk?*
- Sub question 2: *Which strategy is the most robust regarding the different identified scenarios?*

4.4.1 External hedging instruments

In order to answer sub question 1 a number of external hedging instruments have been analysed. This analysis compares the external hedging instruments spots, forwards and options to find a robust strategy for hedging a EUR/USD exposure regarding the above formulated scenarios. To provide clarity on what these external hedging instruments entail and how they can reduce currency risk, they are briefly explained below.

4.4.1.1 Spots

As mentioned earlier, a spot purchase involves an agreement between two parties (bank and firm) to immediately buy a currency (USD) and sell a currency (EUR) at the rate of that moment (Eun & Resnick, 2014). This instrument is particularly useful when an enterprise needs a USD cash flow at very short notice. A risk of a spot transaction is that it does not protect the company against future exchange rate fluctuations (Eun & Resnick, 2014). Especially in currency markets where a high degree of volatility plays a role, this can be a risk to which a company exposes itself.

4.4.1.2 Forwards

According to Eun & Resnick (2014), forward contracts are the most common way to hedge currency risk. A forward contract is an agreement between two parties (bank and company) to exchange one currency for another at a fixed price at a certain time in the future (Eun &

Resnick, 2014). Forward contracts can therefore be used to hedge a company against a potential unfavourable price movement. The disadvantage of this instrument is that you, as a company, do not gain any financial benefit from favourable price movements.

4.4.1.3 Options

A shortcoming of forward contracts is that you do not profit from favourable price movements, you only hedge the risk of possible losses. According to Eun & Resnick (2014), external instrument options do allow a company to benefit from favourable price movements. The difference between forwards and options is that you have the choice of either lifting the option (the predetermined rate) or executing the transaction at the current rate. This instrument does come with a cost, according to Eun & Resnick (2014) €0.02 per dollar is a common price for this instrument.

4.4.1.4 Financial overview external hedging instruments

To give an indication of how these external hedging instruments work, here is a brief overview of how much dollars a company will receive from a € 10,000,000 transaction (see table x) at different exchange rates.

Table 7: Financial overview spot transactions

Spots		
Exchange rate (EUR/USD)	**Euros**	**Dollars**
0,90	€ 10.000.000	$ 9.000.000
1,00	€ 10.000.000	$ 10.000.000
1,10	€ 10.000.000	$ 11.000.000
1,20	€ 10.000.000	$ 12.000.000
1,25	€ 10.000.000	$ 12.500.000

Table 8: Financial overview Forwards

Forwards*		
Exchange rate (EUR/USD)	**Euros**	**Dollars**
0,90	€ 10.000.000	$ 11.000.000
1,00	€ 10.000.000	$ 11.000.000
1,10	€ 10.000.000	$ 11.000.000
1,20	€ 10.000.000	$ 11.000.000
1,25	€ 10.000.000	$ 11.000.000

* The price for the futures contract has been set by the bank at 1.10 (EUR/USD)

Table 9: Financial overview options

Options*					
Exchange rate (EUR/USD)	**Exercise decision**	**Euros**	**Gross dollars**	**Option costs**	**Net dollars**
0,90	Exercise	€ 10.000.000	$ 11.000.000	$ 210.000	$10.780.000

1,00	Exercise	€ 10.000.000	$ 11.000.000	$ 210.000	$10.780.000
1,10	Neutral	€ 10.000.000	$ 11.000.000	$ 210.000	$10.780.000
1,20	Not exercise	€ 10.000.000	$ 12.000.000	$ 210.000	$11.780.000
1,25	Not exercise	€ 10.000.000	$ 12.500.000	$ 210.000	$12.290.000

* When the option contract was established, the EUR/USD exchange rate was 1.10

4.4.2 Defined hedging strategies

Before the most robust strategy based on the different scenarios can be identified, it is important to define the strategies. It was decided to look at the individual effect of the instruments and at a mixed strategy between the different external hedging instruments. In the table below, the strategies are further elaborated, here percentages are used.

Table 10: EUR/USD hedging strategies

Strategies	Spots	Forwards	Options
Strategy 1	100%	0%	0%
Strategy 2	0%	100%	0%
Strategy 3	0%	0%	100%
Strategy 4	40%	60%	0%
Strategy 5	40%	0%	60%
Strategy 6	40%	30%	30%

4.5 EUR/USD hedging strategy dashboard

In order to review the different hedging strategies, an interactive dashboard was created with the three above mentioned hedging instruments (spots, forwards, options). The financial decision-maker of an internationally operating company with a EUR/USD exposure can determine which hedging strategy is appropriate for a given scenario. These will be discussed below in order to ultimately answer sub-question 2: *"Which strategy is the most robust with respect to the different scenarios identified?"*

4.5.1 Hedging strategies

As can be seen in section 4.3, just as Dominguez and Tesar (2006) claim, a fluctuation in the EUR/USD exchange rate can have many financial consequences for a company. In this case scenario 1 and 3 has a positive financial effect on a product's profit margin, but if the exchange rate moves in the "wrong" direction (the dollar gains against the euro) it has a negative financial effect on a product's profit margin (scenario 2 and 4). In that case, it is useful for a company to hedge against this risk. According to Eun & Resnick (2014), this currency risk can be hedged by using external hedging instruments, which are explained in more detail in Section 4.4.1. Figure 23 shows the part of the qualitative system dynamics model that is simulated within the interactive dashboard. These strategies are implemented in the dashboard so that a financial decision-maker can see the effect of a particular hedging strategy right away (see figure 24). The costs of a hedging strategy are also included in the dashboard, in this case a company pays €0.02 per dollar to a bank or broker for a transaction. Other costs are charged for spot transactions and forward contracts. For spot transactions, a price of €0.005 per dollar is taken into account. For forward contracts, a price of €0.008 per dollar is taken into account.

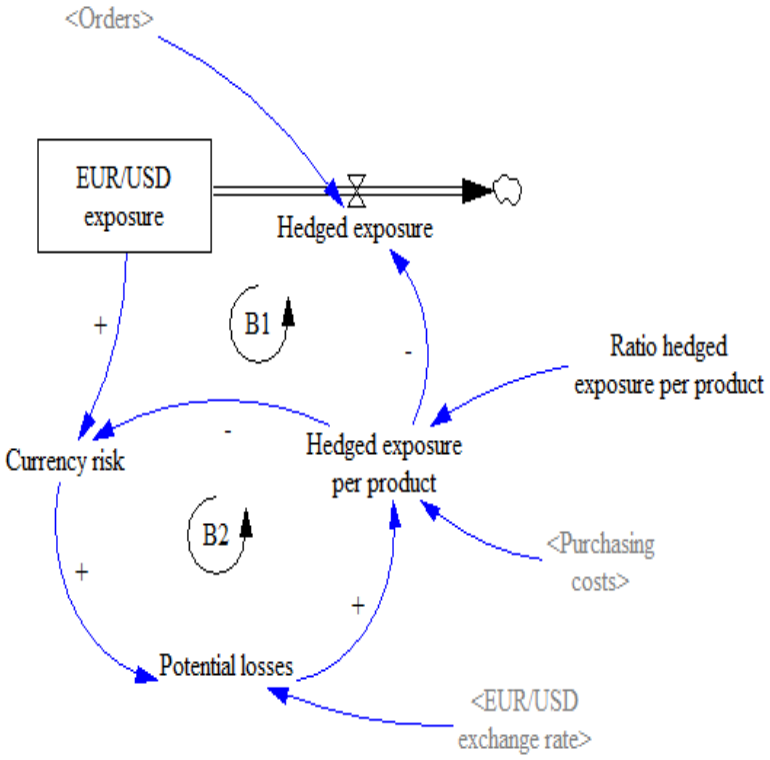

Figure 23: Hedging strategy SD model

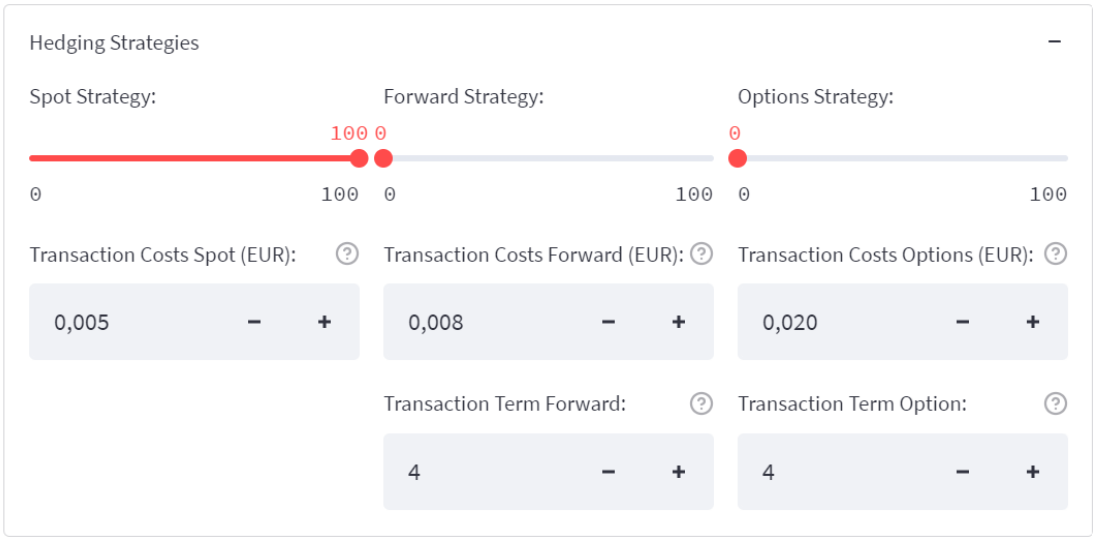

Figure 24: Hedging strategies

4.5.2 Robust strategy

The purpose of the RDM process framework (section 2.1.4) is to find a strategy that is robust under different scenarios. Step 2 of the RDM process framework is about evaluating strategies across futures, in this case scenarios. This section discusses which strategy is the most robust in order to ultimately answer the sub-question *"which strategy is the most robust with respect to the different scenarios identified?"*.

In scenarios where the EUR appreciates against the USD (EUR/USD rate rise), a 100% spot strategy is always the best choice. Because if you use a hedging instrument in this case, you cover yourself against a negative exchange rate fluctuation that will not occur in this case. Unfortunately, this decision is not as easy as it seems because of the high degree of uncertainty, because what if the EUR/USD exchange rate does fall? If this happens, your company is immediately very vulnerable and this can have major financial consequences, as explained in section 2.1.1.1 of the theoretical background and therefore a 100% spot strategy is not a robust strategy at all.

Table 12 shows the average financial result of the profit margin, see appendix 3 for the calculation of the averages. It is evident that strategy 3 (100% option strategy) and strategy 5 (40% spot and 60% option) are the two best strategies on paper. Although strategy 3 gives a better financial result, it is wise to choose strategy 5 because the 40% spot strategy allows you to profit even more from a sudden rise of the EUR/USD exchange rate.

Table 12: Average financial results strategies

Strategies	Average result strategy
Strategy 1	703.65
Strategy 2	710.69
Strategy 3	729.73
Strategy 4	716.01
Strategy 5	723.30
Strategy 6	717.20

To answer sub question 2 (which strategy is the most robust with respect to the different scenarios identified?), a robust strategy in this case is therefore a combination of a spot strategy (to take full advantage of a rise in the EUR/USD exchange rate) and an option strategy (to hedge against a fall in the exchange rate).

4.6 Decision-making process and EUR/USD dashboard

A central topic of this research is the decision-making process under uncertainty. The dashboard seeks to provide support in this decision-making process, to provide, as Marchau et al. (2019, p. 16) state, not to make better predictions, but better decisions under conditions of (deep) uncertainty. In order to include uncertainty in the decision-making process of a financial decision-maker, it is necessary to include the forecast of a financial decision-maker in a certain bandwith. Here the interactive dashboard comes again into play, the financial decision-maker provides an expected value of the EUR/USD exchange rate for each quarter of the coming year with a percentage deviation, so that an upper and lower bound can be created (see appendix 4). As a result, the exchange rate with bandwidth is visualised (see figure 25). This projected exchange rate is then applied to the financial figures so that the decision-maker knows in which bandwidth your profit margin for example will fall, see figure 26. In this way, a financial decision-maker can also test hedging strategies and thus know within what range the financial results will lie. Figure 26 shows the financial results of the above-formulated most robust strategy: 40% spot and 60% options. In this manner, a decision-maker can make an informed decision on a one-year hedging strategy at t=0 and test different strategies against different EUR/USD exchange rate scenarios in order to arrive at the most robust strategy according to the decision-maker. This thus mainly addresses step 2 of the RDM process as outlined by Marchau et al. (2019, p 31), which is also explained in section 2.1.4 of the theoretical background.

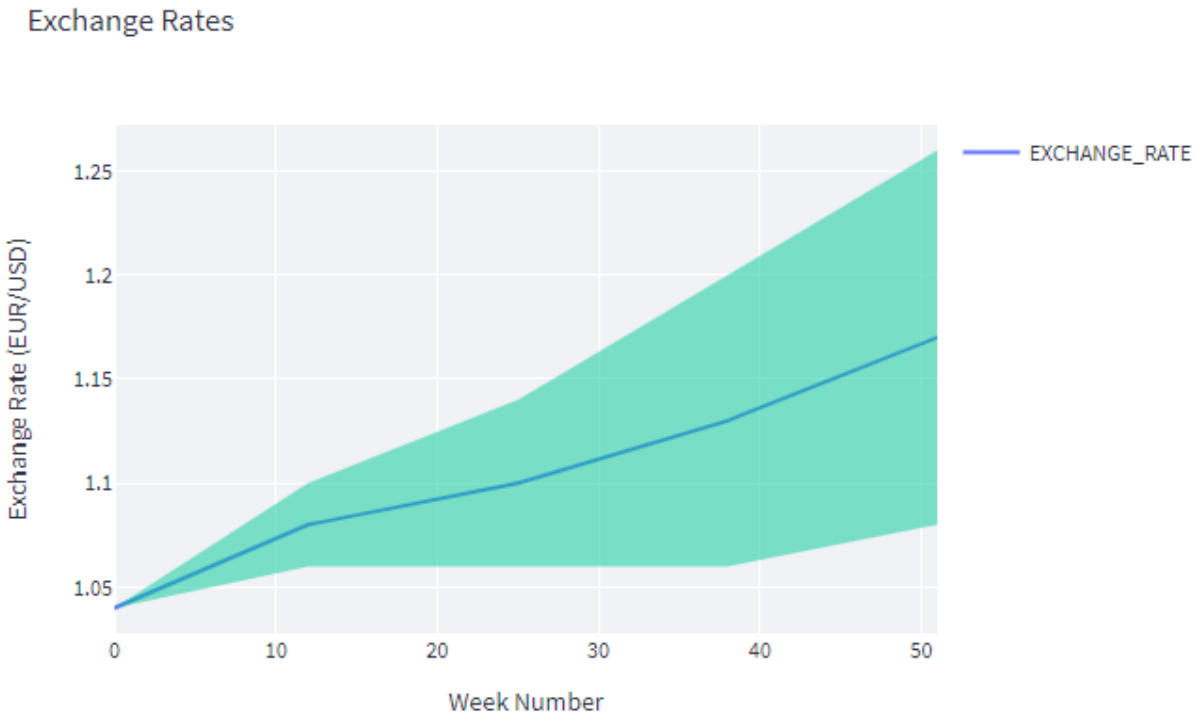

Figure 25: EUR/USD scenario

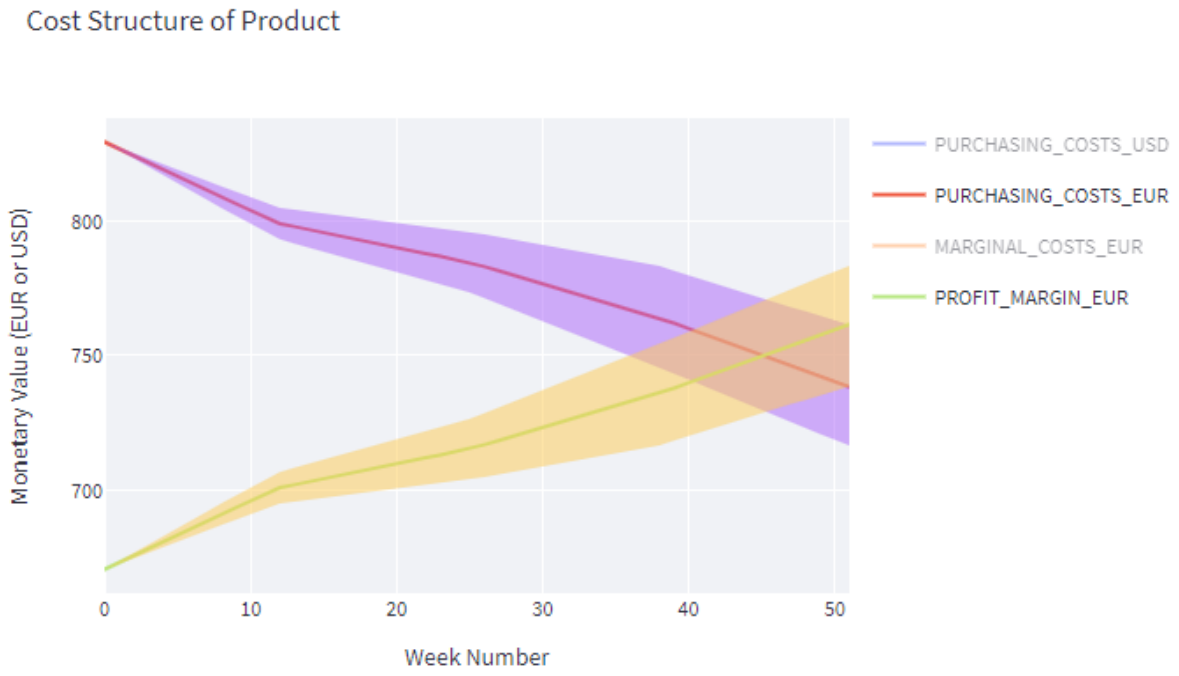

Figure 26: Cost structure of product

4.7 Practical relevance interactive dashboard

To prove the practical relevance of the interactive dashboard, two interviews were conducted with experts in the field of foreign exchange management. The dashboard will mainly support the visual aspect of decision-making which according to Black (2013) mainly helps to create shared understanding for joint action. This statement is also supported by a financial advisor, who mentioned the same.

"*Visually you will understand things much quicker and any tool that contributes to that will improve the decision-making process.*" (Financial Advisor 1)

Moreover, this tool is built to manage market uncertainty, hence the financial decision-maker can enter his own expectation with a lower and upper bound. This was also presented to the respondents, who confirmed that a tool like this helps to make clear what bandwidth you are in as a company and what risks you are covered for, one respondent mentioned the following.

"*A tool like this will always help to explain internally the bandwidth you are in and the risks you are hedged against to deal with uncertainties in the market.*" (Financial Advisor 1)

In addition, this tool is suitable for including other employees (with little financial knowledge) in the company in the process of hedging currency risk and its importance, this is also confirmed by one of the respondents.

"This tool is perfect for taking your company's employees into the process of hedging currency risk and especially for showing them the risks of an unfavourable price fluctuation." (Financial advisor 2)

4.8 Sector differences

This chapter examines the extent to which the dashboard can be used in a generalised manner. The study of Dornbush (1987) already indicated that there are differences by sector and the degree of sensitivity to a fluctuation of the EUR/USD exchange rate. This question was put to two foreign currency management experts in interviews, who came up with the following results.

The degree of sensitivity to a EUR/USD rate fluctuation is partly determined by the sector in which you operate. According to the respondents, trading companies with many international suppliers and partners are very sensitive to rate fluctuations. This is in line with the previously mentioned findings of Dornbush (1987), Doukas et al. (2001) and Sekkat (1985) (section 2.1.1.2).

"A trading company will have much more frequent exposure because they trade all over the world. If you have a manufacturing company, you usually only have two or three suppliers abroad, these are usually relationships that you have had for a long time and therefore you can manage the currency risk much better". (Financial Advisor 1)

The number of suppliers therefore plays an important role in how sensitive a company is to price fluctuations. According to the respondents, a rule of thumb is; the fewer foreign suppliers, the better the currency risk can be managed. According to one respondent, in addition to the use of hedging instruments this is a good way to manage the EUR/USD exposure.

"It is normal to make price agreements with suppliers. For example, a brazilian supplier would prefer to be paid in dollars or euros instead of the local currency because the dollar and euro are more stable in value." (Financial Advisor 1)

Another characteristic that determines dependence on the EUR/USD exchange rate is the percentage profit margin of a product. Companies with low profit margins such as trading companies, supermarkets etc. will be more sensitive to an unfavourable exchange rate change than companies with relatively high profit margins, according to one respondent.

"With companies where you work with small profit margins (< 15%) the currency policy is very important, when you have margins of 40 to 50% this policy is much less important." (Financial advisor 2)

Diversification of markets also plays an important role in how dependent a company is on the EUR/USD exchange rate. According to a respondent, it is good to sell your product in different currency markets in order to be not dependent on one currency rate. According to the respondent, this falls under risk spreading and thus creates a so-called natural hedge.

"That is the best thing you can have, you sell something in Canada, Eastern Europe in Asia for example. Spread it as much as possible to also spread your currency risk over different markets." (Financial advisor 2)

It is interesting to see what impact these sectoral differences have on the hedging strategy employed. Both respondents indicated that a logical consequence of high sensitivity to a change in the EUR/USD exchange rate is that a company takes less risk. For example, companies with low profit margins on their products will adopt a strong policy of hedging the currency risk, in order to at least secure their profit margin.

The degree of perceived uncertainty also plays a role here. One of the respondents even indicated that in very uncertain times, such as during the Brexit or now the war in Ukraine, policies are adjusted in order to run even less risk with the EUR/USD exposure.

"What we see in very uncertain times such as during the Brexit or now the war in Ukraine is that we lower the threshold even more in order to be even less at risk." (Financial advisor 2)

4.9 Validation of the models

A purpose of the disconfirmatory interviews was to validate the system dynamics model and the interactive dashboard. Both were presented to the respondents. The most important findings from the interviews are discussed below.

4.9.1 Qualitative system dynamics model

To validate the qualitative system dynamics model, the different feedback loops were presented to the respondents for confirmation. The findings are summarised in appendix 6.
Both respondents indicated that the interest rate component is not incorporated in the model but does play a major role in the foreign exchange market.

> "The interest rate differences between Europe and America determine, to put it simply, the EUR/USD rate". (Financial Advisor 1)

Apart from the comments about the absence of the interest rate component in the model, the respondents had little to say about the model and (partly) agreed with the relationships and feedback loops shown.

4.9.2 Interactive dashboard

In order to validate the interactive dashboard, particular attention was paid to the behaviour of the model. The respondents were presented with two scenarios:

- Rate increase (EUR/USD)
- Rate decrease (EUR/USD)

Both respondents confirmed the corresponding behaviour of the graph with regard to the profit margin. In addition, the hedging strategies were also presented to the respondents. The effect of these strategies was also confirmed by the respondents.

As discussed in section 3.3, an extreme condition test was used to validate the interactive dashboard. This is to see if the model functions in "extreme" conditions and produces realistic results. In appendix 7, the results of this extreme condition test can be found. As can be seen, the model still produces realistic behaviour under extreme conditions, indicating that the model is robust even under extreme conditions.

5. Conclusion & discussion

In this chapter, a conclusion about the study will be given based on the two formulated main research questions. This will be followed by a discussion of the theoretical and practical implications of this research. To conclude this chapter and the whole study, the limitations of this research and possibilities for further research will be presented.

5.1 Conclusion

In this mixed methods research, a qualitative system dynamics and a quantitative interactive dashboard was built to analyse the impact of an EUR/USD exchange rate fluctuation on the profit margin of products and whether this differs by sector. In the results chapter above, the results of this research are presented and some sub-questions are already answered. In this chapter, the two formulated main questions will be answered:

- *What is the financial effect of a change in the EUR/USD exchange rate on the profit margin of a product?*
- *To what extent does sensitivity to the EUR/USD rate differ between sector?*

Answering research question 1

Empirical support was founded for the first hypothesis (*"A change to a lower EUR/USD exchange rate leads to a lower profit margin per product over time"),* it can be concluded that a change in the EUR/USD exchange rate does influence the profit margin of a product over time. An increase in the EUR/USD exchange rate leads to a higher profit margin over time. This can be explained by the fact that the euro becomes more valuable in relation to the dollar. A decrease in the EUR/USD exchange rate will automatically lead to a lower profit margin over time. Besides that results shown that a relatively small rise in the EUR/USD exchange rate has a greater relative effect on a product's profit margin than a relatively large rise in the EUR/USD exchange rate.

Answering research question 2

The degree of sensitivity of the EUR/USD exchange rate is partly determined by the sector in which a company operates. As respondents, among others, indicated, trading companies are more sensitive to exchange rate fluctuations. This is because they often have many international activities with many different suppliers causing a relatively large currency risk. In addition, a high degree of sensitivity to the EUR/USD rate is also determined by the percentage profit

margin of a product; the higher the percentage profit margin, the less financial impact an unfavourable price fluctuation of the EUR/USD rate will have. This is due to the fact that with a relatively higher profit margin you can absorb this setback relatively easily. Another characteristic that determines sensitivity to the EUR/USD rate is the degree of diversification. If a company has the opportunity to operate in different (currency) buying and selling markets, the currency risk can be reduced by means of a so-called natural hedge.

In addition to the two main questions in this study, the focus was on the decision-making process regarding EUR/USD management. The constant uncertainty in the EUR/USD market is what makes this process so difficult. This study looked at how to deal with this uncertainty and how you as a company can formulate a robust strategy that is prepared for different scenarios. Therefore, one of the sub-questions was also: *Which strategy is the most robust with respect to the different scenarios identified?* After a review via the interactive dashboard of the three most commonly used hedging instruments in the Netherlands (Spots, Forwards and Options), the most robust strategy for the identified scenarios is the following: 40% spots, 60% options. In this way a company with purchasing costs in dollars profit optimally from a EUR/USD rate increase and covers itself against potential losses from a EUR/USD rate decrease. Because the decision-makers or company's own expectations of the movement of the EUR/USD exchange rate play a major role, the built dashboard is interactive in nature. Decision-makers can fill in an annual expectation of the exchange rate in order to find a robust hedging strategy at t=0. Respondents also said that a tool such as this helps in the decision-making process and dealing with the uncertainty, especially in understanding the impact of a EUR/USD fluctuation. Furthermore, the dashboard is suitable for involving employees outside the finance department of a company in the EUR/USD strategy decision-making process. It can namely be used as a “boundary object”, this visual representation can be used to create a shared understanding for joint action and thus provides the opportunity to involve employees from several departments in this decision process.

5.2 Discussion

5.2.1 Theoretical implications

This study contributes to the existing literature on foreign currency management, decision-making under uncertainty combined with system dynamics. This study has similarities but also distinctions with what has been shown in previous research.

The research provides information on how a company can deal with uncertainty as described by Marchau et al. (2019) and Walker et al. (2003). In this research, this is done using scenario planning according to the theory of Courtney (2001) and Schoenmaker (1995) in order to ultimately create a decision framework within which financial decision-makers can create a hedging strategy that is as robust as possible. To achieve this, a qualitative system dynamics model was built in which different relationships between variables were found. These relationships were then quantified, resulting in an interactive dashboard (decision framework). This decision framework confirms what had already been proven by Dominguez & Tesar (2006), namely that a fluctuation in the exchange rate has a major financial impact on companies with a large EUR/USD exposure.

This decision framework is not only about proving the effect but also about finding a robust hedging strategy. The studies of Morey & Simpson (2001) and Lioui & Poncet (2002) also deal with finding a proper hedging strategy. However, these studies are more a review of various strategies from past cases. A distinction with the current literature is that in this study a decision instrument is created in which financial decision-makers can find a robust strategy that takes into account the degree of uncertainty within the foreign exchange markets.

One similarity found in this study compared to the existing literature is the theory of diversification. As mentioned earlier, Levy & Sarnat (1970) and Markowitz (1952) claim that diversification of an international portfolio reduces corporate risk. This is confirmed by a respondent who claims that by diversifying currency markets, a company is less sensitive to currency fluctuations and therefore faces less corporate risk.
Another similarity found in this study has to do with the degree of sensitivity to a EUR/USD exchange rate fluctuation. Similar to Doukas et al. (2001) and El-Masry and Abdelsalam (2007), the respondents also argue that the degree of sensitivity of the EUR/USD exchange rate is strongly related to the number of international activities. The rule of thumb here is therefore

the more international activities you have as a company the more sensitive you are to the EUR/USD exchange rate.

5.2.2 Practical implications

Some elements of this study have practical relevance for financial decision-makers. The main practical relevance is the interactive dashboard that has been created, where a financial decision-maker can see the impact of a price fluctuation on her financial figures. Also, the decision-maker can test different hedging strategies based on self-imposed scenarios and make an informed decision at t=0. In this way, the decision-maker can pursue a strategy that is as robust as possible, which protects a company from potential losses and enables it to profit as much as possible from a rise of the EUR/USD exchange rate.

In addition, the dashboard can also be used as a boundary object. According to Black (2013), a boundary object can be used to create a shared understanding for joint action. This visual representation can involve people who usually have less knowledge about the process, and thus create more support for decisions on a certain hedging strategy. The practical relevance of using the interactive dashboard as a boundary object is also confirmed by respondents.

The tool will be used little or not at all for forming a new strategy, mainly because the respondents indicated that financial decision-makers have little room for manoeuvre in determining their own hedging strategy and often have to act in accordance with corporate policy.

5.6 Limitations and future research

The main limitation of this study is that the interactive dashboard was not tested by means of a real case. This would have been a great contribution to proving the practical relevance of the dashboard. Holding several sessions with financial decision-makers involved in managing EUR/USD exposure would have been a valuable addition. However, due to time constraints, this was not feasible.

Another limitation of this research is that the system dynamics model is based on own understanding and on the available relevant literature. Due to limited time and practical reasons, it was decided to leave group model building out of this research. According to Vennix (1996), group model building is used to understand different perspectives of stakeholders and

to obtain a comprehensive overview of the dynamic behaviour of a given situation. Understanding the dynamics and structure of the system via group model building even more could have helped in producing an better qualitative system dynamics model and thus better interactive dashboard.

The presented interactive dashboard can potentially be used in firms with a large EUR/USD exposure. The design of the dashboard is relatively simple and easy to understand for financial decision-makers. A limitation, however, is that it is less suitable for formulating a hedging strategy because the interviewees indicated that there is usually little room for financial decision-makers to formulate their own strategy. The hedging strategy is often determined on the basis of corporate policies. But the respondents indicated that this tool is very suitable for visually indicating the impact of a fluctuation in the EUR/USD rate. It can also be used to include employees from other departments within a company in the decision-making process. Based on this study, it is therefore recommended to use the tool for this purpose.

There is limited information available on how to develop a EUR/USD hedging strategy for the coming year as a financial decision-maker, also taking into account market uncertainty. Earlier studies by Morey & Simpson (2001) and Lioui & Poncet (2002), among others, mainly provide an overview of various hedging strategies. For a future research project, it would be useful to further examine how uncertainty can be taken into account in order to make a well-considered decision about a EUR/USD hedging strategy at t=0.

This study only looked at external hedging instruments. Another addition for future research is to look at other hedging instruments to hedge currency risk. As indicated by a respondent, it is also possible to create a natural hedge through diversification, for example. It would be interesting to examine in which way this contributes to reducing currency risk.

One aspect that has been deliberately left out of this study is risk-attitude behaviour. Kahneman et al. (1982) claims that cognitive biases can lead to serious and systematic errors in the decision-making process. It is interesting to investigate how these cognitive biases relate to the decision-making process regarding foreign currency management.

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7. Appendix

7.1 Appendix 1: Fictional case study

Company is an organisation based in the Netherlands. The company supplies wooden canopies to consumers here in the Netherlands. The organisation is very growing and receives about 1000 orders per month, which amounts to a total of 12000 orders per year. The wooden shelters are a seasonal product and Company X sees a high order flow especially in the months of February, March and April. Because Company X considers quality to be of paramount importance, the products are still produced in the Netherlands. Only the purchasing takes place abroad, namely in Asia. The suppliers in Asia want to be paid in Dollars because all the other costs of the suppliers are also in Dollars, because the power in this case lies with the supplier they can make these demands. Company X has all its costs and revenues in euros. Only the purchase of raw materials is in Dollars. This is where the currency risk of company X comes in; at some point it will have to start paying its suppliers in dollars. A currency fluctuation can have many financial consequences for the relative purchase price. Because company X works with fixed price lists, it cannot pass on this relative purchasing price difference to the customer. Because Company X offers exclusive products, the purchase price is $850. With a total number of orders of 12000, Company X has a so-called dollar requirement of over $10,000,000. The price of the product is €2000, this price is fixed for a period of one financial year and cannot be changed in the meantime. In table x the total number of orders for company X is visualised for each month corresponding with the dollar need. To illustrate how the system dynamics simulation model can help identify this risk and the financial impact of a price fluctuation on, among other things, the profit margin, this data will be used as input for the SD simulation model.

7.2 Appendix 2: Python script scenarios

In [10]:
```
# Aantal weken
n = 52
```

In [11]:
```
# Tabel met de verschillende start en eind punten van de scenarios
df_scenarios = pd.DataFrame(
    data={
        'START': [1.08] * 4,
        'END': [1.59, 0.83, 1.19, 0.97]
    }
)
```

In [12]:
```
df_scenarios
```

Out[12]:

	START	END
0	1.08	1.59
1	1.08	0.83
2	1.08	1.19
3	1.08	0.97

In [14]:
```
for index, scenario in df_scenarios.iterrows():
    # Start en eind exchange waarde van scenario
    start = scenario['START']
    end = scenario['END']

    # Maken van lineare lijn tussen start en eind punt
    x = np.linspace(start, end, n)

    # Genereren van random offset per tijdstip
    random_offset = np.random.normal(loc=1.0, scale=0.05, size=n)

    # Ervoor zorgen dat begin en eindpunt ongewijzigd blijven
    random_offset[0] = 1.0
    random_offset[-1] = 1.0

    # DataFrame aanmaken
    df = (
            pd.DataFrame(
            data = {
                'EXCHANGE_RATE_BASE': x,
                'EXCHANGE_RATE_RANDOM_OFFSET': x * random_offset
            }
        )
        .assign(
            EXCHANGE_RATE=lambda x: x['EXCHANGE_RATE_RANDOM_OFFSET'].rolling(5, center=True, min_periods=1).mean()

    # Defineren van bestandsnaam
    filename = f'exchange_rate_scenario_{index+1}.csv'

    # Printen van info
    print('Scenario: ', index+1)
    print('Start rate:', start)
    print('End rate:', end)
    print('File:', filename)

    # Grafiek maken
    df.plot().show()


    # Exporteren naar CSV
    (
        df
        [['EXCHANGE_RATE']]
        .assign(EXCHANGE_RATE=lambda x: x['EXCHANGE_RATE'].round(4).astype(str).str.replace('.', ','))
        .to_csv(filename, sep=';')
    )
```

Figure 27: Python script scenarios

7.3 Appendix 3: Average profit margin hedging strategies

The calculations were made on the basis of the EUR/USD dashboard, whereby the profit margin of the various hedging strategies was measured on the basis of the four formulated scenarios.

Table 13: averages of hedging strategies

Strategies	Spots	Forwards	Options	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Strategy 1	100%	0%	0%	957.78	459.16	769.25	628.40
Strategy 2	0%	100%	0%	860.1	592.68	720.90	669.08
Strategy 3	0%	0%	100%	945. 03	582.48	756.50	658.88
Strategy 4	40%	60%	0%	902.96	543.76	767.35	649.96
Strategy 5	40%	0%	60%	950.13	537.64	761.60	643.841
Strategy 6	40%	30%	30%	929.70	540.69	751.52	646.90

7.4 Appendix 4: EUR/USD scenario with bandwith

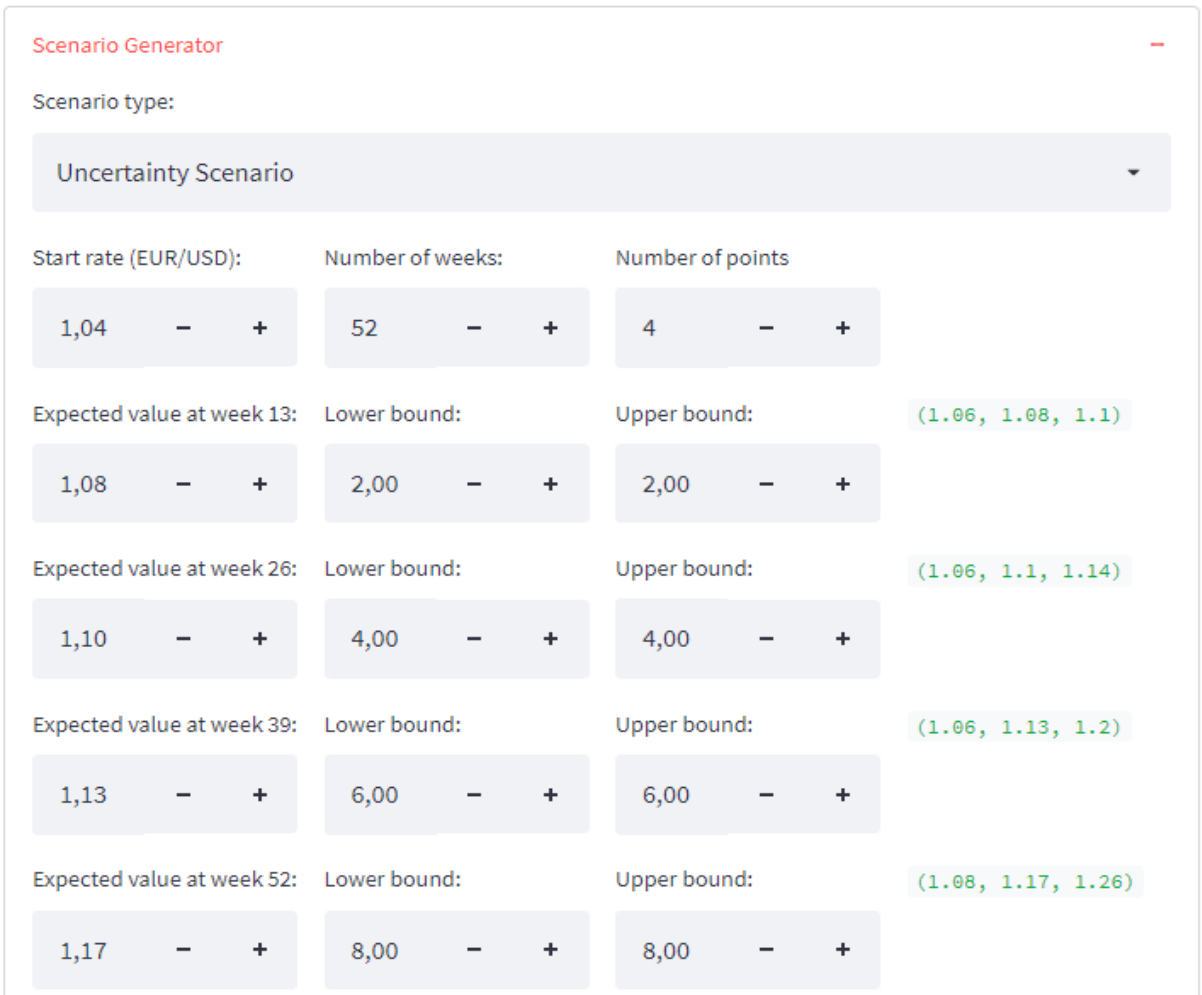

Figure 28: Bandwidth scenario generator

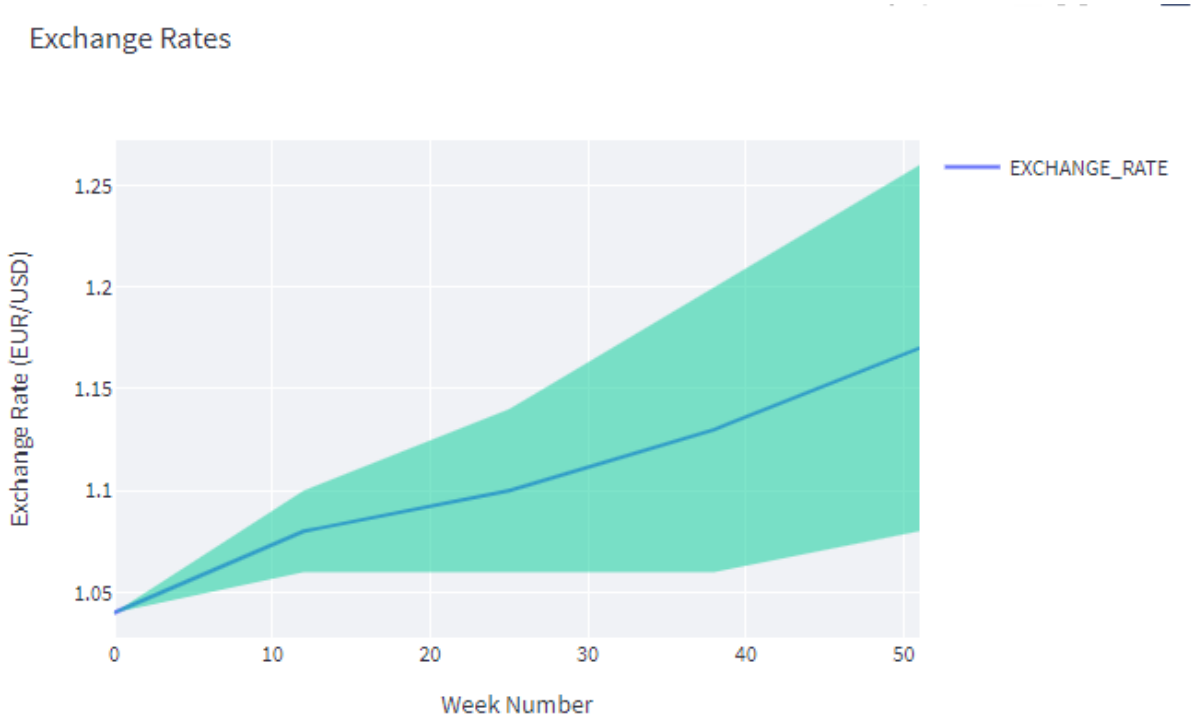

Figure 29: Bandwidth scenario

7.5 Appendix 5: Interview guide

The interviews are conducted with financial advisors in the field of currency management. These are semi-structured disconfirmatory interviews that will last approximately 45 minutes.

Goal of interviews

The purpose of the interviews is to discuss the relationships of the qualitative system dynamics model and to check whether this is a realistic representation of reality. In addition, the focus will be on the interactive dashboard that has been created. The behaviour of the results will be discussed with the respondents. The aim is to validate the dashboard and demonstrate its practical relevance.

Structure of the interview

The interview consists of five different parts:

- Foreign currency exposure
- Decision-making process
- Hedging strategies
- Qualitative system dynamics model
- Interactive dashboard
- Differences by sector

The semi-structured nature of the interviews allows room to deviate from the interview guide and elaborate on the respondent's answers. In order to give some guidance to the interview, a number of questions have been formulated for each section, which are asked at each interview. These are formulated below.

Introduction

The participants are asked to introduce themselves. In addition, the participants are asked to briefly state their job function and their expertise in the field of currency management. Then the purpose of the interview is explained to the participants and the different topics are discussed.

Foreign currency exposure

- What are the financial consequences of a change in the EUR/USD exchange rate for international operating firms?
- To what extent are companies covering this risk?

Decision-making process

- What does the decision-making process look like for decision-makers on a hedging strategy of one year?
- To what extent does scenario planning play a role in this process?
- Do you see any opportunities for improvement of this dashboard?

Qualitative system dynamics model

The qualitative SD model forms the basis of the interactive dashboard and shows the different relationships between the variables present. I would be happy to go through this model with you to validate it. * show the seven different feedback loops to the participants

- Do you find the different feedback loops logical and realistic?
- Are there any relationships between variables here that you miss?

Interactive dashboard

- Is the behaviour of a given scenario on the profit margin of a product realistic?
- Are the costs of the different hedging instruments realistic?
    - What are the costs in euro per dollar that you usually have to deal with
- Do agreements on payment terms with the supplier affect a company's currency risk?
    - Is a relatively short payment term favourable or a relatively long one?
- To what extent is this interactive dashboard practically relevant?
- Would this dashboard help financial decision-makers in their decision-making process?
- Could this dashboard help financial decision-makers deal with the uncertainty of their hedging strategy?

Differences by sector

- To what extent does the sensitivity to a EUR/USD fluctuation differ between sectors?
- What characteristics of companies make them highly sensitive?

7.6 Appendix 6: Summary table validation qualitative system dynamics model

Table 14: validation overview system dynamics model

Name	Overview of feedback loops	Respondent 1	Respondent 2
B1	Currency risk → Potential losses → Hedged exposure per product	Confirms the feedback loop. Comment: "This is indeed a simplistic representation of the problem"	Confirms the feedback loop.
B2	Orders → Purchasing costs → Marginal costs product → Profit margin product → Profit → Investments → Business growth	Confirms the feedback loop.	Confirms the feedback loop. Comment: True if the assumption is that more business growth directly leads to more orders
B3	Orders → Hedged exposure → EUR/USD exposure → Currency risk → Potential losses → Profit → Investments → Business growth	Confirms the feedback loop. Comment: This is indeed the basic structure of the management of EUR/USD exposure.	Confirms the feedback loop.
B4	Orders→ Dollar need → EUR/USD exposure → Currency risk → Potential losses → Profit → Investments → Business growth	Confirms the feedback loop.	Confirms the feedback loop.
R1	EUR/USD exposure → Currency risk → Potential losses → Hedged exposure per product → Hedged exposure	Confirms the feedback loop.	Confirms the feedback loop. Comment: Indeed, the more currency risk you have the more you are exposed to potential losses.
R2	Currency risk → Potential losses → Profit → Investments → Diversification	Partly agrees with the feedback loop Comment: Investments do not necessarily have to lead to diversification	Confirms the feedback loop.
R3	Orders → Purchasing costs → Hedged exposure per product → Hedged exposure → EUR/USD exposure → Currency risk → Potential losses → Profit → Investments → Business growth	Partly agrees with the feedback loop.	Partly agrees with the feedback loop. Comment: this loop seems a little bit far-fetched.

7.7 Appendix 7: Extreme condition test

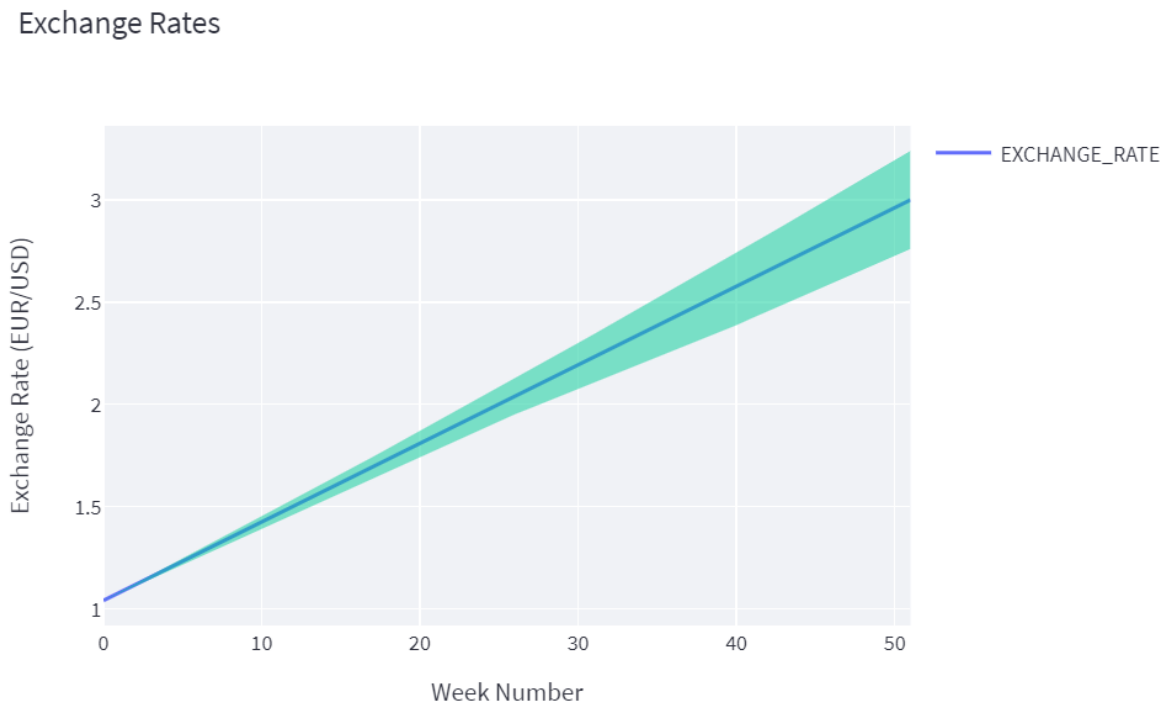

Figure 30: Extreme condition test EUR/USD scenario

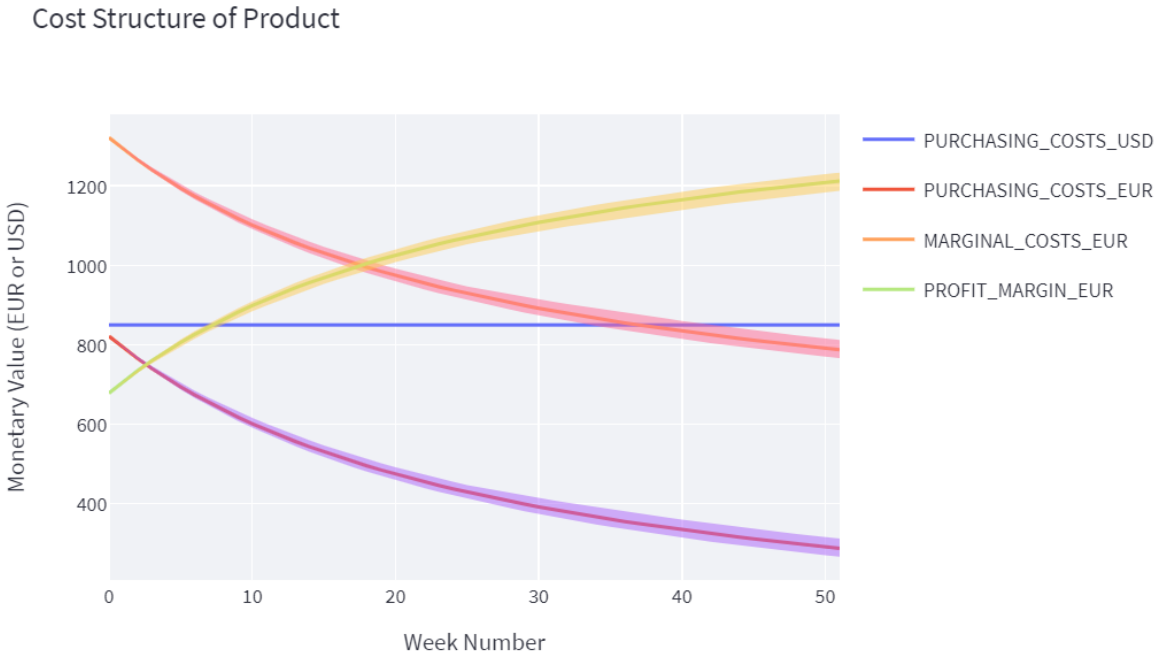

Figure 31: Extreme condition test cost structure

7.8 Appendix 8: Python code interactive dashboard

```
import numpy as np
import pandas as pd
import plotly.graph_objects as go
import plotly.express as px
import streamlit as st


pd.options.plotting.backend = 'plotly'


st.title('EUR/USD Case Study Strategy Dashboard')


@st.cache(max_entries=1)
def generate_scenario(start_rate, end_rate, number_of_weeks, scale=0.05):
    # Maken van lineare lijn tussen start en eind punt
    x = np.linspace(start_rate, end_rate, number_of_weeks)

    # Genereren van random offset per tijdstip
    random_offset = np.random.normal(loc=1.0, scale=scale, size=number_of_weeks)

    # Ervoor zorgen dat begin en eindpunt ongewijzigd blijven
    random_offset[0] = 1.0
    random_offset[-1] = 1.0

    # DataFrame aanmaken
    df = (
        pd.DataFrame()
        .assign(
            EXCHANGE_RATE_LINEAR=x,
            RANDOM_OFFSET=random_offset,
            EXCHANGE_RATE=lambda df: (
                df['EXCHANGE_RATE_LINEAR'] * (
                    df['RANDOM_OFFSET']
                    .rolling(
                        window=5,
                        center=True,
                        min_periods=4
                    )
                    .mean()
                    .fillna(1.0)
                )
            )
        )
        [['EXCHANGE_RATE']]
        .round(4)
    )

    return df


def compute_fixed_term_rate(
    df: pd.DataFrame,
```

```
    n: int,
    exchange_rate_col: str
):
    return (
        df
        .iloc[::n, :]
        .loc[lambda x, n=n: x.index.repeat(n)]
        .reset_index()
        .iloc[:len(df)]
        [exchange_rate_col]
        .round(4)
    )



def compute_scenario(
    df_scenario: pd.DataFrame,
    purchasing_costs_usd: float,
    orders: float,
    other_costs_eur: float,
    consumer_price_eur: float,
    pct_spot: float,
    pct_forward: float,
    pct_options: float,
    costs_spot: float,
    costs_forward: float,
    costs_options: float,
    term_forward: float,
    term_options: float
):
    df_result = (
        df_scenario
        .assign(
            PURCHASING_COSTS_USD=purchasing_costs_usd,
            ORDERS=orders,
            OTHER_COSTS_EUR=other_costs_eur,
            CONSUMER_PRICE_EUR=consumer_price_eur,
            PCT_SPOT=pct_spot,
            PCT_FORWARD=pct_forward,
            PCT_OPTIONS=pct_options,
            COSTS_SPOT=costs_spot,
            COSTS_FORWARD=costs_forward,
            COSTS_OPTIONS=costs_options
        )
    )

    exchange_rate_cols =
df_result.columns[df_result.columns.str.startswith('EXCHANGE_RATE')]
    for exchange_rate_col in exchange_rate_cols:
        suffix = exchange_rate_col.split('EXCHANGE_RATE')[1]
        df_result = (
            df_result
            .assign(
                **{
                    f'EXCHANGE_RATE_SPOT{suffix}': lambda df: df[exchange_rate_col],
```

```
                f'EXCHANGE_RATE_FORWARD{suffix}': lambda df: df.pipe(
                    compute_fixed_term_rate,
                    n=term_forward,
                    exchange_rate_col=exchange_rate_col
                ),
                f'EXCHANGE_RATE_OPTIONS_FIXED{suffix}': lambda df: df.pipe(
                    compute_fixed_term_rate,
                    n=term_options,
                    exchange_rate_col=exchange_rate_col
                ),
                f'EXCHANGE_RATE_OPTIONS{suffix}': lambda df: (
                    df
                    [['EXCHANGE_RATE', 'EXCHANGE_RATE_OPTIONS_FIXED']]
                    .max(axis='columns')
                ),
                f'EFFECTIVE_EXCHANGE_RATE{suffix}': lambda df: (
                    # Spot
                    ((df['PCT_SPOT'] / 100.0) * df[f'EXCHANGE_RATE_SPOT{suffix}']) +
                    # Forward
                    ((df['PCT_FORWARD'] / 100.0) *
df[f'EXCHANGE_RATE_FORWARD{suffix}']) +
                    # Options
                    ((df['PCT_OPTIONS'] / 100.0) * df[f'EXCHANGE_RATE_OPTIONS{suffix}'])
                ).round(4),
                f'TRANSACTION_COSTS': lambda df: (
                    # Spot
                    ((df['PCT_SPOT'] / 100.0) * df['COSTS_SPOT']) +
                    # Forward
                    ((df['PCT_FORWARD'] / 100.0) * df['COSTS_FORWARD']) +
                    # Options
                    ((df['PCT_OPTIONS'] / 100.0) * df['COSTS_OPTIONS'])
                ),
                f'PURCHASING_COSTS_EUR{suffix}': lambda df: (
                    df['PURCHASING_COSTS_USD'] /
df[f'EFFECTIVE_EXCHANGE_RATE{suffix}'] +
                    df['PURCHASING_COSTS_USD'] * df['TRANSACTION_COSTS']
                ),
                f'MARGINAL_COSTS_EUR{suffix}': lambda df:
df[f'PURCHASING_COSTS_EUR{suffix}'] + df['OTHER_COSTS_EUR'],
                f'PROFIT_MARGIN_EUR{suffix}': lambda df: df['CONSUMER_PRICE_EUR'] -
df[f'MARGINAL_COSTS_EUR{suffix}']

            }
        )
    )

    return df_result


def plot_df(
    df: pd.DataFrame,
    cols: list = [],
    title: str = '',
    xaxis_title: str = '',
    yaxis_title: str = ''
```

```
) -> go.Figure:
    fig = go.Figure()
    for col in cols:
        fig.add_trace(
            go.Scatter(
                name=col,
                x=df.index,
                y=df[col],
                mode='lines',
                legendgroup=col
            )
        )

        if f'{col}_UPPER_BOUND' in df:
            fig.add_trace(
                go.Scatter(
                    name=f'{col}_UPPER_BOUND',
                    x=df.index,
                    y=df[f'{col}_UPPER_BOUND'],
                    mode='lines',
                    line=dict(width=0),
                    showlegend=False,
                    legendgroup=col
                )
            )

        if f'{col}_LOWER_BOUND' in df:
            fig.add_trace(
                go.Scatter(
                    name=f'{col}_LOWER_BOUND',
                    x=df.index,
                    y=df[f'{col}_LOWER_BOUND'],
                    line=dict(width=0),
                    mode='lines',
                    fill='tonexty',
                    showlegend=False,
                    legendgroup=col
                )
            )

    fig.update_layout(
        title=title,
        xaxis_title=xaxis_title,
        yaxis_title=yaxis_title
    )

    return fig


with st.expander('Scenario Generator', expanded=True):
    # Default start value
    default_start_value = 1.04

    scenario_type = st.selectbox(
        label='Scenario type:',
```

```
    options=[
        'Random Scenario Generator',
        'Uncertainty Scenario'
    ]
)

# Random scenario
if scenario_type == 'Random Scenario Generator':
    col1, col2, col3, col4 = st.columns(4)

    start_rate = col1.number_input(
        label='Start rate (EUR/USD):',
        value=default_start_value
    )
    end_rate = col2.number_input(
        label='End rate (EUR/USD):',
        value=1.59
    )
    number_of_weeks = col3.number_input(
        label='Number of weeks:',
        value=52
    )
    scale = col4.number_input(
        label='Scale:',
        value=0.05
    )

    df_scenario = generate_scenario(
        start_rate=start_rate,
        end_rate=end_rate,
        number_of_weeks=number_of_weeks,
        scale=scale
    )

    # Plot
    fig = plot_df(
        df=df_scenario,
        cols=['EXCHANGE_RATE'],
        title='Exchange Rates',
        xaxis_title='Week Number',
        yaxis_title='Exchange Rate (EUR/USD)'
    )
    st.plotly_chart(fig, use_container_width=True)

elif scenario_type == 'Uncertainty Scenario':
    col1, col2, col3, col4 = st.columns(4)

    start_rate = col1.number_input(
        label='Start rate (EUR/USD):',
        value=default_start_value
    )
    number_of_weeks = col2.number_input(
        label='Number of weeks:',
        value=52
    )
```

```
number_of_points = col3.number_input(
    label='Number of points',
    value=4
)

week_numbers = [1]
exchange_rates = [default_start_value]
exchange_rates_lower_bound = [default_start_value]
exchange_rates_upper_bound = [default_start_value]
for i in range(number_of_points):
    week_number = int(number_of_weeks / number_of_points) * (i + 1)
    col1, col2, col3, col4 = st.columns(4)
    value = col1.number_input(
        key=f'value_week_{week_number}',
        label=f'Expected value at week {week_number}:',
        value=default_start_value
    )
    lower_bound_pct = col2.number_input(
        key=f'lower_bound_{week_number}',
        label='Lower bound:',
        value=2.0 * (i + 1),
        step=0.5,
    )
    upper_bound_pct = col3.number_input(
        key=f'upper_bound_{week_number}',
        label='Upper bound:',
        value=2.0 * (i + 1),
        step=0.5,
    )

    lower_bound = round(value * (1. - lower_bound_pct / 100.), 2)
    upper_bound = round(value * (1. + upper_bound_pct / 100.), 2)
    col4.write((lower_bound, value, upper_bound))

    week_numbers.append(week_number)
    exchange_rates.append(value)
    exchange_rates_lower_bound.append(lower_bound)
    exchange_rates_upper_bound.append(upper_bound)

df = (
    pd.DataFrame(
        data={
            'WEEK': week_numbers,
            'EXCHANGE_RATE': exchange_rates,
            'EXCHANGE_RATE_LOWER_BOUND': exchange_rates_lower_bound,
            'EXCHANGE_RATE_UPPER_BOUND': exchange_rates_upper_bound
        }
    )
    .set_index('WEEK')
)

df_scenario = (
    df
    .reindex(range(1, number_of_weeks+1))
    .interpolate(axis='index')
```

```
            .reset_index(drop=True)
        )

        # Plot
        fig = plot_df(
            df=df_scenario,
            cols=['EXCHANGE_RATE'],
            title='Exchange Rates',
            xaxis_title='Week Number',
            yaxis_title='Exchange Rate (EUR/USD)'
        )
        st.plotly_chart(fig, use_container_width=True)


with st.expander('Case study'):
    col1, col2, col3, col4 = st.columns(4)

    purchasing_costs_usd = col1.number_input(
        label='Puchasing Costs (USD):',
        value=850
    )

    orders = col2.number_input(
        label='Orders:',
        value=350
    )

    other_costs_eur = col3.number_input(
        label='Other costs (EUR):',
        value=500
    )

    consumer_price_eur = col4.number_input(
        label='Consumer price (EUR):',
        value=2000
    )


with st.expander('Hedging Strategies'):
    col1, col2, col3 = st.columns(3)
    pct_spot = col1.slider(
        label='Spot Strategy:',
        value=100
    )

    pct_forward = col2.slider(
        label='Forward Strategy:',
        value=0
    )

    pct_options = col3.slider(
        label='Options Strategy:',
        value=100-pct_spot-pct_forward
    )
```

```
    costs_spot = col1.number_input(
        label='Transaction Costs Spot (EUR):',
        value=0.005,
        step=0.001,
        format='%.3f',
        help='Transaction costs in EUR per 1 USD'
    )

    costs_forward = col2.number_input(
        label='Transaction Costs Forward (EUR):',
        value=0.008,
        step=0.001,
        format='%.3f',
        help='Transaction costs in EUR per 1 USD'
    )

    costs_options = col3.number_input(
        label='Transaction Costs Options (EUR):',
        value=0.02,
        step=0.001,
        format='%.3f',
        help='Transaction costs in EUR per 1 USD'
    )

    term_forward = col2.number_input(
        label='Transaction Term Forward:',
        value=4,
        help='Transaction term in number of weeks.'
    )

    term_options = col3.number_input(
        label='Transaction Term Option:',
        value=4,
        help='Transaction term in number of weeks.'
    )


df = compute_scenario(
    df_scenario=df_scenario,
    purchasing_costs_usd=purchasing_costs_usd,
    orders=orders,
    other_costs_eur=other_costs_eur,
    consumer_price_eur=consumer_price_eur,
    pct_spot=pct_spot,
    pct_forward=pct_forward,
    pct_options=pct_options,
    costs_spot=costs_spot,
    costs_forward=costs_forward,
    costs_options=costs_options,
    term_forward=term_forward,
    term_options=term_options
)


### Plot: Exchange Rate
```

```
cols = [
    'EXCHANGE_RATE',
    'EXCHANGE_RATE_SPOT',
    'EXCHANGE_RATE_FORWARD',
    'EXCHANGE_RATE_OPTIONS_FIXED',
    'EXCHANGE_RATE_OPTIONS',
    'EFFECTIVE_EXCHANGE_RATE'
]

fig = plot_df(
    df=df,
    cols=cols,
    title='Exchange Rates',
    xaxis_title='Week Number',
    yaxis_title='Exchange Rate (EUR/USD)'
)

st.plotly_chart(fig, use_container_width=True)



### Plot: Profit Margins
cols = [
    'PURCHASING_COSTS_USD',
    'PURCHASING_COSTS_EUR',
    'MARGINAL_COSTS_EUR',
    'PROFIT_MARGIN_EUR'
]

fig = plot_df(
    df=df,
    cols=cols,
    title='Cost Structure of Product',
    xaxis_title='Week Number',
    yaxis_title='Monetary Value (EUR or USD)'
)

st.plotly_chart(fig, use_container_width=True)


@st.cache
def convert_df(data):
    return (
        data
        .round(5)
        .assign(**{col: data[col].astype(str).str.replace('.', ',') for col in data.columns})
        .to_csv(sep=';')
        .encode('utf-8')
    )

csv = convert_df(df)

st.download_button(
     label="Download data als CSV",
     data=csv,
```

```
    file_name='data.csv',
    mime='text/csv',
)
```