Louvain School of Management
and Prague University of Economics and Business

Hedging of systematic risks in an internationally diversified portfolio

Author:
Fabian Bunge

Master's thesis with the view of getting the degrees:
Master in Finance and Accounting +
Master 120 credits in Management, European Business

Supervisor:
Karel Bruna

Academic Year *2022-2023*

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
Louvain School of Management
Place des Doyens, 1 bte L2.01.01, 1348 Louvain-la-Neuve, Belgique | **www.uclouvain.be/lsm**

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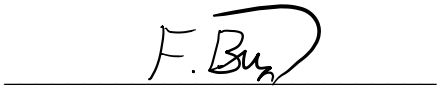
In Prague on 09.07.2023 

Acknowledgement

I would like to thank doc. Ing. Karel Brůna, Ph.D and all other persons, for their advice and support during my work on this thesis.

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Abstract

The international financial markets have been characterised by high volatility and uncertainty this millennium due to crises such as the dotcom bubble, the financial crisis in 2007, and the euro crisis, and ultimately the consequences of the Covid-19 pandemic and the war in Ukraine. Investors try to hedge against adverse portfolio movements by diversification and through derivatives. This study thus investigates to what extent international diversification reduces unsystematic risk and whether the use of derivatives such as forwards and futures can reduce systematic risks in the form of market risk, exchange rate risk, and interest rate risk. The results of the research suggest that naive international diversification is able to reduce the unsystematic risk. Market risk and exchange rate risk could be significantly reduced by hedging them separately using forwards and futures, while hedging interest rate risk worked only marginally. The simultaneous hedging of all risks for the entire portfolio was able to remarkably reduce volatility and generate profits at the same time. The outcomes of the backtesting may vary depending on the portfolio, the period under review and the instruments used, but nevertheless, this thesis provides valuable insights for investors and portfolio managers to navigate through volatile markets and highlights the importance of diversification and the use of derivatives.

JEL Classification: F31, G11, G15, G32

Keywords: Risk, Risk Management, Hedging, Derivatives, Portfolio Theory, Exchange Rates, Interest Rates

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List of abbreviations

AUD	Australian Dollar
BC	Before Christ
CAPM	Capital Asset Pricing Model
CME	Chicago Mercantile Exchange
EUR	Euro
EURIBOR	Euro Interbank Offered Rate
FRA	Forward Rate Agreement
GBP	British Pound
HKD	Hong Kong Dollar
ICAPM	International Capital Asset Pricing Model
JPY	Japanese Yen
LIBOR	London Interbank Offered Rate
n.d.	No date
OTC	Over-the-counter
Pf.Val.	Portfolio Value
SONIA	Sterling Overnight Index Average
St.Dev.	Standard Deviation
UK	United Kingdom
US	United States of America
USD	US Dollar
VaR	Value at Risk

1 Introduction

In the globalized and interconnected world of financial markets, investors face a multitude of risks that can significantly impact their portfolios. Furthermore, financial markets are increasingly volatile due to the trend of instability in the economic environment, which leads to an increased financial risk for investors (Dowd, 2007). In the literature, a distinction is made between systematic and unsystematic risk regarding the risk of securities. Systematic risk extends over the entire market and cannot be diversified. Unsystematic risk, on the other hand, is specific to a company or industry and can be reduced through diversification (Boyle, 2021). The concept of diversification has received widespread attention with the introduction of Markowitz's (1952) portfolio theory. He showed that diversification can reduce the risk of a portfolio and at the same time optimise the risk/return ratio.

Diversification does not only reduce unsystematic risk, but it also leads to international diversification of securities. This in turn causes exposure to systematic risks, such as exchange rate risk when investing in different currencies. Since the collapse of the Bretton Woods system and the introduction of floating exchange rates, the volatility of foreign investments has increased (Dowd, 2007). In addition to exchange rate risk, market risk and interest rate risk are considered to be the key systematic risks. However, since this systematic risk cannot be tackled through diversification, other means of managing the risk have to be found.

From a historical perspective, the prediction and management of risk dates back to the fifth century BC (Althaus, 2005). McNeil et al. (2015) also notes that the option as a form of derivative was used as early as 1800 BC to hedge crop yields. Since then, managing risk has evolved rapidly and has become a fundamental part of businesses and investors. According to Baker and Filbeck (2014), effective risk management consists primarily of measuring, monitoring and managing risk and return drivers among different asset classes. For the last step, i.e., the management of risk, various derivatives like forwards, futures, options or swaps are used to hedge the risk. Derivatives are defined as financial instruments whose values are derived from market prices of an underlying instrument. The concept of hedging has emerged as a powerful tool for managing risk and reducing exposure to adverse market movements. Hedging involves taking strategic positions to offset potential losses in one

investment with gains in another, thereby mitigating the impact of unfavourable market conditions.

The significance of this thesis lies in its potential to assist investors, fund managers, and financial institutions in making informed decisions about managing risk in their portfolios. By providing a comprehensive analysis of hedging techniques, this thesis aims to contribute to the existing literature and offer practical recommendations for risk management.

This thesis aims to delve into the complexities of hedging systematic risk in an internationally diversified portfolio and explore the various derivatives available for investors to navigate through volatile market environments. By analysing existing literature and empirical studies, it seeks to provide a comprehensive understanding of the benefits, challenges, and limitations of hedging. Furthermore, various hedging techniques and instruments available to investors to mitigate systematic risks will be explored, by analysing historical data and conducting scenario-based simulations, which aim to quantify the impact of different hedging strategies on risk mitigation. This includes evaluating the effectiveness of hedging market risk, exchange rate risk and interest rate risk. Which is done by using a portfolio of 24 shares and 5 bonds which is hedged with the help of various forwards and futures. For this purpose, daily data is analysed over a period of one year from 01.03.2022 to 28.02.2023. The applied backtesting aims to answer the two following hypotheses:

H1: Diversification reduces the unsystematic risk of the portfolio

H2: Hedging with derivatives reduces the systematic risk

For this purpose, the theoretical framework is first established in Chapter 2. Chapter 2.1 defines the term risk and explains the different ways of measuring it. Chapter 2.2 then introduces portfolio theory and the impact of its findings on investors' investment decisions. The following chapter gives the theoretical background regarding the assumptions on risk preferences. Subsequently, Chapter 2.4 describes the unsystematic and systematic risks faced by an international investor and then Chapter 2.5 introduces hedging techniques to reduce the systematic risk. In Chapter 3 the data and the portfolio construction as well as the risk metrics used to test the hypotheses are presented. The results of the backtesting are then analysed in Chapter 4. The thesis closes with a conclusion of the results.

2 Theoretical Part

2.1 Introduction to risk

In order to approach the topic of hedging risks strategically, the qualitative aspects of risk should first be considered. The best way to do this is by looking at the definition of the word risk. After some research, however, it was apparent that there is no universal definition of risk in the literature. Some definitions are based on probabilities, expected values, negative events or hazards (Aven and Renn, 2012). One of the reasons for this is that the concept of risk is multidimensional and nuanced (Haimes, 2009). Furthermore, risk is a function of the triggering event, the environment, and the time frame and is therefore not entirely unifiable. Various definitions capture some elements of risk but no single set is able to provide a fully satisfactory definition for all possible contexts (McNeil et al., 2015). In the following, different approaches to defining risk are therefore considered.

Starting with the definition from the Oxford Learner's Dictionary (n.d.), risk can be described as "the possibility of something bad happening at some time in the future; a situation that could be dangerous or have a bad result". This definition emphasises the negative effects that risk can have. Wharton (1992) also notes that risk is increasingly associated with negative consequences and therefore only the downside of a risk is considered but not the possible upside of the risk. However, Aven and Renn (2009) state that a definition of risk should include both desirable and undesirable outcomes of a given Scenario. He explains that the restriction to only undesirable outcomes is limited by the fact that an outcome can be positive and negative for different stakeholders at the same time. In other definitions, risk is also referred to as the deviation from expected value that might result in the future and is therefore also associated with positive deviations (Etti et al., 2006).

According to Althaus (2005), risk exists in many different disciplines and can therefore be viewed from different perspectives. Each discipline is associated with its own understanding of risk. In mathematical literature, risk is described in relation to calculability, through which uncertainties can be expressed in terms of probabilities. In the scientific and medical sense, risk is understood as objective reality which means that it is empirically confirmable, in anthropology as a cultural phenomenon and in psychology as a behavioural phenomenon. In economics theory, however, risk is seen as a decisional phenomenon concerned with

securing wealth and avoiding loss. In the field of finance, risk is often considered in connection with expected value, although equalising risk and expected value is not suitable as a general definition of risk (Aven and Renn, 2012). Since this view, which focuses only on expected value and expected returns, is limited, variance is often used as a risk measurement (Joyce and Vogel, 1970).

To gain a clear understanding of risk, it is important to distinguish it from the term uncertainty. Knight (1921) defines risk as measurable uncertainties, where the distribution of outcomes is calculable, and uncertainty is immeasurable. Kaplan (1981) also associates risk with a negative connotation. He describes risk as the sum of uncertainty and damage. By damage he means that an individual suffers a loss. According to this definition, risk must always concern a negative event. Uncertainty about future profits would consequently not be classified as a risk. Knight (1921) agrees that profit insecurities may be considered uncertainties, but not as risks, since the negative element of the definition is not fulfilled.

Similarly, according to Holton (2004), risk consists primarily of uncertainty and exposure. Uncertainty is when an individual is unsure of the validity of a proposition or unaware of it. Furthermore, exposure is the second factor that must be fulfilled for an individual to be subject to a risk. This is prevalent when the outcome of an event has an impact on an individual. If an individual is indifferent to a proposition or an outcome, he or she is not exposed to the risk. However, as soon as there are preferences about an event, the term exposure is used. An investor who acts profit-oriented is thus exposed with regard to their investment decisions. Risk is according to this definition therefore an exposure to an uncertain outcome or proposition. The problem with this definition, however, lies in the subjectivity of both factors. Furthermore, Kaplan (1981) notes that risk is always relative to the observer and its assessment is therefore subjective and depends on the individual's perception. In many cases, therefore, we can only speak of perceived risk. Moreover, there is a big difference in the assessment of risk based on the experience of the respective individual. While experts base their decisions on quantitative facts related to probabilities, lay people’s judgments are also influenced by qualitative aspects such as the controllability or familiarity of the risk (Sachse et al., 2012).

Since risk, as mentioned above, is not a unique concept and different actors have different perspectives and preferences, there are several metrics to quantify risk (Johansen, 2012).

Risk metrics are designed to measure and control risk exposure and therefore provide useful information for risk management. One of the most frequently used methods for quantifying risk or volatility is the standard deviation. The standard deviation is, in simple terms, the average distance of all measured values from the average. It is based on the theory that the returns of an asset fluctuate around the average and that they vary over a longer period (Kenton, 2021). If a stock has generated an average annual return of 5% over the last 20 years, this does not mean that an investor could rely on this 5% return in every year. Rather, this return has fluctuated over the period under consideration and may even have been negative in some years. The higher the standard deviation of a stock, the more its returns have fluctuated around the average.

More traditional methods to quantify risks are the gap analysis as well as the duration analysis. Both methods are simple to calculate but are limited to interest rate risk. The technological development of computers enabled them to be replaced by more complex methods (Dowd, 2007).

Particularly in the financial sector among banks and insurance companies, the Value at Risk (VaR) is the most widely used quantitative risk metric (Duffie, 1997). Psychologically, investors are more worried about potential losses than potential gains. This loss aversion was demonstrated by Kahnemann and Tversky (2013) through the introduction of their prospect theory (Kenton, 2021). VaR therefore addresses the need for maximum loss information and is a downside risk measurement. VaR has its origins in the American investment bank JP Morgan. The aim was to develop a system to measure risk across different trading positions throughout the whole institution and to aggregate this into a single risk metric (Dowd, 2007). Basically, the VaR is the loss in market value for a given time horizon and confidence level and is graphically nothing else than the integral of the loss density function up to a certain percentile (Prem, 2010). It can refer to the potential loss of a company, portfolio or a specific position over a certain time. From a statistical point of view, it is the critical p-value of a probability distribution of market value changes (Duffie, 1997). The fact that VaR can be directly and easily interpreted as a single metric, makes it a very clear and widely applicable method. Nevertheless, VaR also has some limitations as a risk measure. Dowd (2007) notes that VaR is subject to the risk of incorrect model assumptions.

Once these methods have been used to quantify risk, risk can also be classified according to its causes. In the literature, a distinction is often made between two types of risk, systematic and unsystematic risk.

Systematic risk cannot be diversified and exists due to changes in overall economic, political and social circumstances (Biswas, 2015). Unsystematic risk, on the other hand, is diversifiable within a portfolio. It is specific to a company or industry and is therefore often also known as non-systematic or specific risk (Boyle, 2021). This could be, for example, investing in a company involved in fraudulent activities or suffering reputational damage due to a product defect. According to Vaidja (2021), there are some fundamental differences between the two types of risk. By definition, systematic risk always affects a large number of securities in the portfolio, whereas unsystematic risk only affects individual positions. Consequently, systematic risk depends on a number of factors and affects the economy at a macro level. These factors are external and therefore cannot be controlled. This becomes particularly clear in the example of natural hazards or the recent pandemic. These count as systematic risks and cannot be influenced, let alone controlled or prevented.

Unsystematic risk, on the other hand, is based on internal factors of individual positions and is micro in nature. It can be controlled by sufficient diversification. A high degree of diversification can be achieved by spreading the portfolio widely across different industries, countries, and asset classes. The positive effect of diversification gained widespread attention with the emergence of the portfolio theory in the 1950s, which showed that better diversification and a greater number of securities reduce the risk of the portfolio (Biswas, 2015). Due to the importance of this concept, the following chapter will discuss it in more detail.

2.2 Portfolio theory

The concept of portfolio theory goes back to the American economist Harry Markowitz (1952). The basic idea is that an investor can reduce the overall risk of a portfolio through appropriate diversification and combination of different assets. Previously, it was assumed that each security or asset should be assessed individually (Adams, 2021). If a security was considered profitable enough and the risk acceptable, it was included in the portfolio.

Markowitz (1952) revolutionized the way of thinking about risk and reward of assets with his portfolio theory. Portfolio theory is commonly referred to as a set of models that describe how investors combine risk and return when constructing investment portfolios (Holton 2004). This allows investors to make investment decisions based on the means and variances of the portfolio's asset returns (Marling and Emanuelsson, 2012). Returns are relative to the initial assets and represent the ratio between the achieved income and the invested capital (Kitanov, 2016). The returns of a portfolio of assets over a certain time period can be mathematically expressed as follows:

$$\mathrm{P} = \frac{P_1 + D + I}{P_0} - 1 \qquad (1)$$

where:
P = Return of a Portfolio
P_1 = Market price of the Portfolio at time T = 1
P_0 = Market price of the Portfolio at time T = 0
D = Dividends
I = Interest payments

Markowitz (1952) showed that when considering an investment decision, not only the maximisation of returns should be taken into account. Although a consideration of the expected or anticipated returns improves the basis for decision-making, Markowitz refutes the thesis that this is sufficient as a maxim for decision-making. If only the expected return were taken into consideration in an investment decision, this would imply that diversification is not profitable and would therefore not be applied (Markowitz, 1952). Markowitz proves this analytically by showing that the maximum return of a portfolio would be achieved by weighting the asset with the highest expected return by 1. He thus states that if only the expected return is considered in decision-making, a non-diversified portfolio is preferred to a diversified one in every case. Instead, he states that the variance of the returns should also be taken into account and that a portfolio is optimally a combination of maximum return and minimum variance. This leads to a set of assumptions underlying this theory (West, 2006; Witt and Dobbins, 1979):

1. Investors base their investment decisions on only two parameters: The expected returns and risk.
2. The return and risk are approximated by the mean and the variance of the returns

3. The investor is risk averse: Higher expected returns as well as lower variances or standard deviations of the returns are desirable.
4. All investors have the same time horizon and are only interested in their terminal wealth at the end.
5. Financial assets are infinitely convertible.

In a portfolio with several assets, the expected return is the weighted arithmetic mean of the returns of the individual assets. If $E(R_x)$ is the expected return of an asset x and w_i is the weighting factor of this asset, the expected return of a diversified portfolio is expressed by the following equation (Markowitz, 1952):

$$E(R_x) = E(R_1)w_1 + E(R_2)w_2 + \ldots + E(R_n)w_n = \sum_{i=1}^{n} E(R_i)w_i \qquad (2)$$

Whereby it must apply that $w_1 + w_2 + \ldots + w_n = 1$. The risk of a portfolio is measured by its variance. However, this is slightly more complicated to calculate, as the covariances of each pair of assets in the portfolio must also be taken into account. The variance is therefore calculated as follows (Witt and Dobbins, 1979):

$$V(R) = \sum_{i=1}^{n} w_i^2 \sigma_i^2 + 2\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} w_i w_j \sigma_{ij} \qquad (3)$$

The covariance is the product of the standard deviations of the respective assets and their correlation, expressed by their correlation coefficients. Looking closer at Equation 3, it becomes evident that the variance and thus the risk of a portfolio depends not only on the variance of the individual assets, but also on their correlation with each other. The correlation is positively related to the variance and thus to the risk of a portfolio.

The correlation coefficient ranges between -1 and 1. A correlation coefficient of 0 means that both characteristics are not linearly dependent on each other. At a value of 1 there is a strong positive linear correlation and at -1 a strong negative linear correlation. The variance from Equation 3 is minimised by making the correlation coefficient of the asset returns negative. Looking at Equation 3 carefully, it can be seen that at a correlation of -1 the maximum effect is unfolded and the variance is minimised. In order to minimise the risk, it is therefore important to diversify the portfolio in such a way that the returns of the various combinations of assets are as negatively correlated as possible.

Rubenstein (2002) has noted that the individual risk of an asset is less important than the contribution this risk makes to the variance of the whole portfolio. The decision to acquire an asset depends therefore rather on the compatibility in terms of the portfolio variance than only on the expected return and variance of the asset itself. Modern portfolio theory therefore states that the risk of a portfolio generally decreases as the number of securities in the portfolio increases (Biswas, 2015). However, the marginal benefit of diversification decreases with increasing portfolio size, which means that above a certain portfolio size, additional security can only marginally reduce the risk of the portfolio. There is no consensus on the exact number of stocks that optimally reduce diversifiable risk, as this depends on the correlation between the securities. In most studies, the minimum number varies between 10 and 40 (Oyenubi, 2019).

Out of all available portfolios, an investor chooses the one which offers the highest utility. However, preferences are quite different and not easy to observe, let alone to generalise. In order to represent preferences consistently and mathematically, so-called utility functions were introduced. These graphically depict the utility level of a decision-maker and are explained in more detail in the following chapter.

2.3 Risk utility functions and assumptions

After observing in Chapter 2.2 that investors base their investment decisions according to the assumptions of portfolio theory on two factors, it remains to be examined what effects this has on the benefits of their investment. A basic assumption from Chapter 2.2 was that investors prefer higher returns and less risk. Therefore, they can be described as risk-averse. This can be illustrated using the following graph with fictional portfolio opportunities.

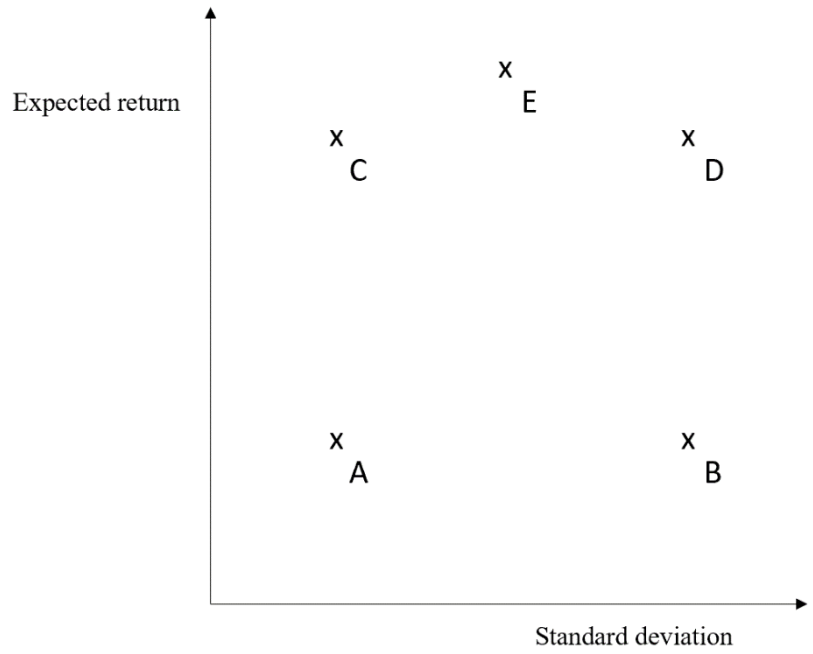

Figure 1 Risk Preferences
Source: Own illustration

According to this assumption, portfolio C is preferred to portfolio A, just as D is preferred to B since it has a higher expected return, while having the same variance. Following the same logic, portfolio A is also preferred to portfolio B and C to portfolio D. Both have a lower variance with the same expected return. Of the portfolios shown in Figure 1, A, B and D are therefore already eliminated due to our assumptions on preferences. If we look at portfolios C and E, for example, we see that no clear statement can be made about either of them without further information on the investor's preferences. Portfolio E has a higher expected return than C, but also a greater variance and thus a greater risk. This fundamental trade-off is faced by investors, as higher returns can usually only be achieved by increasing risk and, conversely, risk can only be reduced by lowering expected returns. In order to make a statement about the preference between portfolio C and E, we therefore need more information about the investor's preferences regarding return and risk.

This information can be found through the indifference curve of an individual. First, the example of the five portfolios A to E will be taken to a more complex and theoretical conclusion. Since an investor usually has an almost infinite number of portfolios to choose from, the example just given serves to illustrate the principle depicted in Figure 2.

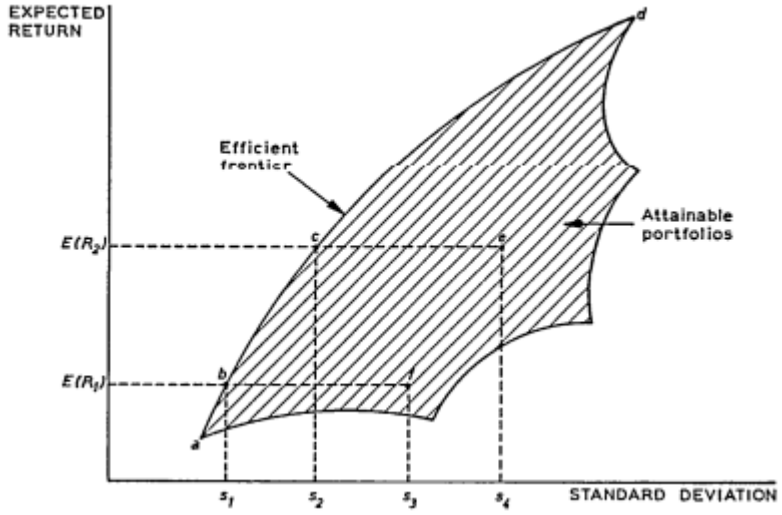

Figure 2 Efficient Portfolios
Source: Witt and Dobbins (1979) p. 8

Figure 2 shows the expected return of a portfolio and the associated standard deviation of the returns. The striped area represents all available portfolios of a decision-maker (Witt and Dobbins, 1979).

Following the analysis of Figure 2, it can be concluded that some portfolios within this area are dominant over others. For example, portfolio B dominates all portfolios that are located exactly to the right and exactly below it. These portfolios either have a higher standard deviation and thus a higher risk for the same return, or a lower expected return for the same standard deviation. The same applies to portfolio C. Consequently, all portfolios that are located as far to the upper left as possible in this area are dominant. This insight can now be used to determine the efficient frontier of all possible portfolios, which is plotted in Figure 2. Investors therefore prefer a portfolio on the efficient frontier to any other portfolio. The positive slope of the efficient frontier expresses the fundamental trade-off between risk and return, i.e., a higher expected return can only be achieved through increased risk. Whether an investor chooses portfolio A, B, C or D depends on their risk-return preference and thus on their degree of risk aversion (Witt and Dobbins, 1979). These preferences are represented by utility curves or indifference curves.

The term indifference curve goes back to Francis Ysidro Edgeworth and was introduced to the economic theory by Vilfredo Pareto in order to circumvent the problem of measuring utility (McLure and Montesano, 2019). Indifference curves show the utility level of a

decision maker. The basic idea is that there is a trade-off between two resources and that an additional unit of one resource can only be acquired by giving up another (Johnson, 1913). Companies or investors may attempt to reduce or avoid risk depending on whether they are risk-averse, risk-neutral, or risk-seeking. A risk-averse decision-maker prefers to minimize risk, even if this entails a lower return. Risk neutrality implies indifference to risk, making decisions only on the basis of the expected value of the outcome. On the other hand, a risk-seeking decision-maker prefers the alternative with the highest risk for the same expected value. An overview of the different risk settings is provided in Figure 3.

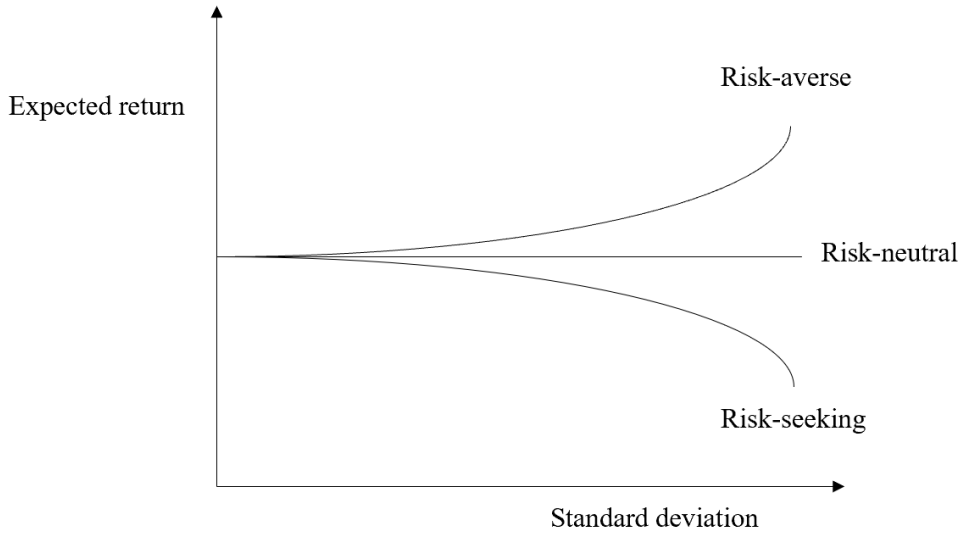

Figure 3 Risk Preferences
Source: Own illustration

Figure 3, it is noticeable that the indifference curves differ not only in terms of their shape (i.e., convex, linear or concave) but also in terms of their slope. A risk-averse decision-maker has a positively rising indifference curve, while the indifference curve of a risk-seeking decision-maker has a negative slope. The greater the absolute slope, the greater the risk aversion or the risk appetite. A risk-neutral decision-maker, on the other hand, makes their decision based only on the expected return. In other words, the investor is completely indifferent to risk, which is expressed by a slope of 0. Each point on the indifference curve with the same expected return has the same benefit despite different risk.

Since the decision-maker is assumed to be rational, the indifference curves are subject to certain assumptions of consumer preference theory. According to DeSarbo et al. (1991),

these assumptions are consumption space, completeness, reflexivity, transitivity, continuity, strong monotonicity and strict convexity. For the shape and properties of indifference curves in portfolio theory, the assumptions of consumption space and reflexivity are not important, which is why they will not be discussed any further. Completeness describes that the preferences must be complete and that the alternatives can be sorted from good to bad. An investor can therefore rank all portfolios according to their preferences without being indifferent between two portfolios. Transitivity is an assumption that guarantees consistency of preferences. To put it simply, if A > B and B > C, then A > C must hold (Block and Barnett, 2012). It follows that indifference curves cannot intersect, since in that case the same position would have different levels of utility. Furthermore, indifference curves are assumed to be continuous. This assumption guarantees a smooth preference order and ensures that the utility function has continuous differentiability. The continuity assumption presupposes arbitrary divisibility of the goods (DeSarbo et al., 1991). Strong monotonicity generally means that there is no saturation point and that a greater amount of a good is preferred to a lesser amount. In the case of return and risk, however, it must be noted that this applies to the return and only in reverse logic to the risk. Less variance or risk is better in this case. The last assumption about indifference curves is that they are strictly convex. This is derived from the decreasing marginal utility and the negative substitution effect, which leads to the fact that indifference curves are not linear, but convex to the origin (Gorman, 1957).

Under these assumptions, the indifference curves of an investor can be plotted in Figure 2. The result can be seen in Figure 4 as an example. The indifference curves run parallel to each other and do not intersect. As discussed above, they have a positive slope, since a risk-averse investor is being considered, and are convex to the origin. This means that an additional unit of risk must be compensated by more and more return. The higher the risk, the more critical an additional unit of risk is seen. The utility of the indifference curves increases from the lower right to the upper left, which means that an investor prefers to be on the highest possible indifference curve (Witt and Dobbins, 1979). This highest possible indifference curve is tangent to the efficient frontier at point C, which was discussed in Figure 1.

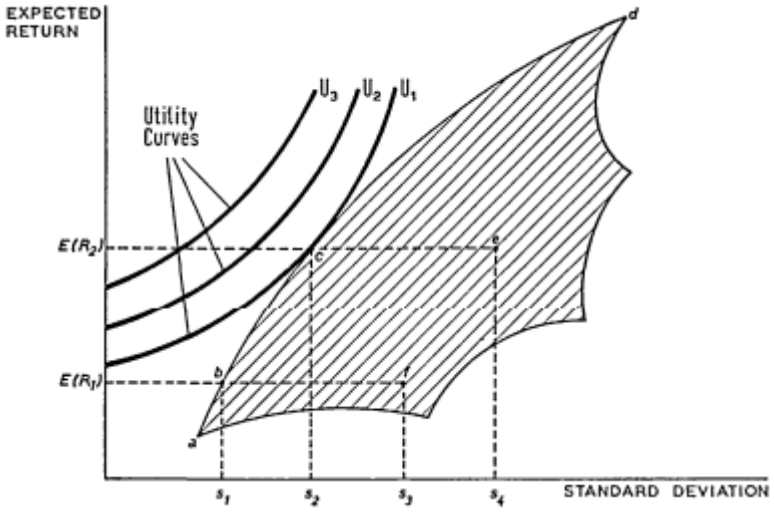

Figure 4 Utility Curves
Source: Witt and Dobbins (1979) p. 9

Having looked at how risk is fundamentally defined, what investors' preferences are in terms of returns and risk, and how they can optimise these through diversification, it becomes apparent how this leads to new kind of risk following these diversified investments. The following chapter deals with the risks that arise as a consequence for an international investor.

2.4 Risks international investors face

Before discussing the risks of an international investor, it is necessary to briefly define what is meant by this term. The basic definition of investment is the provision of resources for a specific purpose to generate profits (Salacuse, 2013). This definition is very broad and initially simply means that any investment of capital with the purpose of making a profit is considered an investment. It is therefore important to clarify that the investor referred to in this thesis is defined as a person who acquires financial assets on the capital market. Financial assets include for example stocks, funds, bonds or commodities. If this investor acquires globally distributed financial assets outside their home country, they can be considered an international investor.

In general, there is a certain amount of risk in almost every investment. It is therefore crucial to be sufficiently informed about the risks associated with the respective investment product to make the best decision given one's own risk preferences. The risk arising from an

investment in a portfolio is called investment risk. According to Olsen (1997, p. 62), investment risk is a combination of four attributes: „the potential for a large loss, the potential for a below-target return, the feeling of control, and the perceived level of knowledge“. Similarly, Sachse et al. (2012) note that when investors are questioned, they frequently mention loss of capital, returns below expectation and economic uncertainty, as well as their own deficits in knowledge about risk and lack of control. Identifying these risks is therefore in the best interest of every investor in order to protect themselves against these risks in the best possible way.

As already discussed in Chapter 2.1, risk can be subdivided into two types of risk, the unsystematic and the systematic risk. An investor is inherently exposed to both types of risk without any protection. The total risk is the sum of both of them.

2.4.1 Unsystematic risk

According to Mayo (2020), the sources of unsystematic risk for companies can be divided into two categories: business risk and financial risk. Business risk is the risk associated with the company itself. Different industries have different risks, both qualitatively and quantitatively. Operating a nuclear power plant naturally entails different risks than operating a bakery. Financial risk, on the other hand, refers to the way a company is financed. If a company is highly leveraged, the creditor may impose additional constraints on the company, which would typically increase the risk of debt-financed companies (Mayo, 2020). This initially poses a risk to the firm itself, but in the next step also to a potential investor of that firm. Investors, however, are not directly exposed to exactly the same risks as firms. Therefore, only the so-called investment risks are considered subsequently.

Investment risk consists of a number of other unsystematic risks. In the following, selected relevant unsystematic risks such as liquidity risk, credit risk, country risk and legal risk are briefly explained. Liquidity risk is usually defined as the risk of not being able to meet payment obligations (Goodhart, 2008). This definition initially applies to companies, but from an investor's perspective, liquidity risk is rather the risk of not being able to liquidate their securities or doing so with an appreciable loss (Olsen, 1997). The securities are then sold at less than their fair price. This can also affect investors with bonds if the spread

between the bid and ask price is too large and the bond can only be liquidated below its fair value before maturity (Chen, 2021).

Another risk is the credit risk. Credit risk is the risk of loss due to the failure of a counterparty to repay the amount owed (Stephanou and Mendoza, 2005). This can concern both the principal and, if applicable, interest payments. An investor is particularly affected by this risk if they hold bonds in their portfolio. In the case of government bonds or corporate bonds, there is the risk of insolvency of the issuer, i.e., the party that issued the bond. In order to be able to assess this reliably, the creditworthiness of a bond is determined by external rating agencies. The rating agency market is controlled by the three big players Moodys, Standard & Poor and Fitch. These have a market share of about 95% (White, 2010). The default probabilities are classified in a scale and abbreviated with rating codes. These rating codes differ only marginally between the agencies, whereby a triple A stands for bonds with the best credit rating and C or D on the other side of the scale for the highest probability of default. This allows an investor to quickly assess the default probability of a bond at a glance. Since credit risk is mainly unsystematic, it is in theory diversifiable, but difficult to eliminate entirely, as it also contains a systematic risk component (Santomero, 1997).

Unsystematic risks also include country risk. Kitanov (2016) describes this as the risk that investments are made in assets or companies based in political or economically unstable countries or that the country in which investments are made has poor relations with the investor's country. This could be the case especially in emerging or developing countries. Since an economic crisis or recession can also extend beyond a single country and affect the entire economy through spillover effects, there is also a certain degree of systematic risk involved in country risk.

Another unsystematic risk is that of legal risk. While legal risk used to be understood as the risk of being sued for violating laws or regulations, it is now seen more as a risk of change in law as government intervention has increased (McCormick, 2010). Investors who hold securities of companies that are affected by negative reactions on the capital market due to changes in the law are exposed to legal risk.

All of these aforementioned risks are diversifiable due to their nature as unsystematic risks and are already to a large extent managed and reduced through the diversification of the international investor.

2.4.2 Systematic risk

In addition to the unsystematic risk, investments are also subject to systematic risk. In Chapters 2.2 and 2.3 it was shown how the results of the portfolio theory can be used by risk-averse investors to minimise the risk of their portfolio. Even if this is applied correctly, diversification can only minimise the unsystematic risk but not eliminate it completely.

According to most definitions, systematic risk includes market risk, exchange rate risk, interest rate risk and inflation risk. The first three risks are considered in detail in the following subsections. As the inflation risk does not play a major role in the course of this work, it will only be rudimentarily dealt with here.

However, every investor is exposed to the risk of inflation. Inflation is defined as a persistent increase in the general price level (Giavazzi et al., 2010). Rising prices lead to lower purchasing power and thus to reduced real wealth. The real rate of return, which takes into account the loss in value of an investment due to inflation, is therefore decisive for investors. It is defined as the difference between the nominal rate of return and the inflation rate (Nelson, 1976). If the inflation rate exceeds the nominal rate of return, the real rate of return is negative. Inflation risk therefore potentially damages the real returns of investors (Visconti, 2012).

Inflation mainly affects fixed-income securities such as bonds (Fang et al., 2022). However, not much can be done about inflation risk. Diversifying the portfolio does not help, as it has no impact on the purchasing power of the returns. In fact, in some countries, governments have issued securities linked to inflation indexes (Bekaert and Wang, 2010).

In addition to the risk of devalued returns itself, the extent to which inflation affects nominal returns can also be considered. According to Adjasi et al. (2008), the consumer price index has a strong positive relationship with stock market volatility. This means that rising inflation leads to rising volatility.

Contrary to the Fisher hypothesis, stock returns are negatively related to inflation according to empirical findings (Boudoukh et al., 1994). Fama (1981) observes in his study that there is a negative relationship between real stock returns and inflation. Barnes et al. (1999), Bodie (1976) and Nelson (1976) also confirm this theory. Canova et al. (2000), however, confirm this hypothesis only for the US, while the relationship is according to their study insignificant

for Germany, Japan and the UK. Nevertheless, the literature is not unanimous about the relationship. Kim and In (2005), for instance, observe a positive correlation in the short and long term of one month and 128 months respectively, while a negative correlation is found in the medium term.

2.4.2.1 Market risk

Market risk is defined as "the risk of loss (or gain) arising from unexpected changes in market prices (e.g., such as security prices) or market rates" (Dowd, 2007 p. 1). Investors who invest in different assets via stocks, bonds or funds are faced with market risk due to the unpredictable change in their market prices.

These market prices of for example stocks are determined by their aggregate supply and demand. Supply and demand depend on various factors such as the overall economic outlook, expectations of corporate earnings or the rate of return of alternative assets (Bosworth et al., 1975). In a low interest rate environment, conventional savings are comparatively unattractive and the demand for stocks is increasing, which is leading to generally rising market prices. For an investor owning stocks, a fall in the market price leads to a lower portfolio value and thus lower wealth. This risk exists for every investor and fluctuations in the market price are therefore perceived as market risk.

A common way to measure market risk is the ß of a security. This expresses the volatility of a security in relation to the entire market. This is derived from the capital asset pricing model (CAPM) used for calculating expected returns and pricing securities (Kenton, 2022). The CAPM equation is generally as follows:

$$E(R_i) = R_f + ß_i(E(R_m) - R_f) \quad (4)$$

Where $E(R_i)$ is the expected return of an asset; R_f is the risk-free rate, i.e., the return of a risk-free asset such as a government bond; $ß_i$ is the market beta, i.e., the correlation with the market and $E(R_m)$ is the expected return of the market (Fama and French, 2004). If R_f is placed on the left-hand side of the equation, the significance of ß becomes clear. As a factor, it expresses the ratio of the expected returns over the risk-free rate between the respective security and the market portfolio. The ß can be calculated in two different ways, both of which underline its logic:

$$ß = Corr(R_i, R_m)\frac{\sigma_i}{\sigma_m} = \frac{Cov(R_i,R_m)}{\sigma^2_{Rm}} \quad (5)$$

where:

$R_i = Security\ return$

$R_m = Market\ return$

The ß can have different interpretations depending on its value. A ß of 1 means that a stock and its return moves exactly with the market. A ß greater than 1, on the other hand, implies greater volatility and more market risk, while a ß less than 1 implies lower volatility and lower market risk.

Since the existence of the CAPM, there have been repeated attempts to expand it and add further factors, taking into account different sources of systematic risk. For example, Banz (1981) found that the size of the market equity in addition to the market beta provides an explicative value of the returns. Furthermore, empirical studies by Stattmann (1980) have shown that the ratio of book value to market value also has different risk-return relationships. Subsequently, Fama and French (1992 and 1996) developed the three-factor model, which refines the original CAPM equation. This model corrects for the higher returns of small sized companies and companies with low book to market equity value. Pastor and Stambough (2003) added the factor of liquidity to it.

$$E(R_i) = \ R_f + \beta_i^{market} RMRF + \beta_i^{size} SMB + \beta_i^{value} HML + \beta_i^{liq} LIQ \quad (6)$$

All these additions were introduced to provide a more accurate pricing of systematic risk based on several factors. In addition to the initial market risk premium (RMRF), risk premiums were introduced for the size of the firm (SMB), the book to market value (HML) and the liquidity (LIQ) of the equity investment.

However, the original CAPM only prices the domestic market risk. It can therefore only be used to determine the risk of assets denominated in the domestic currency, as this is subject to the assumption that risk and returns are influenced by the domestic currency. The model cannot be used for foreign currencies without further modifications and therefore does not provide any explanation of exchange rate risk which will be discussed in the following chapter.

2.4.2.2 Exchange rate risk

In a globalised and interconnected world, it is very easy to invest across national borders and currencies. Usually, exchange rate risk is especially relevant for international companies with cash flows in different currencies. These are often exposed to three main types of exchange rate risk, which are transaction risk, translation risk and economic risk. For a non-institutional investor, translation risk, i.e., the risk that the balance sheets of foreign subsidiaries are denominated in foreign currencies, and economic risk, which includes the effect of exchange rate changes on revenues and operating expenses, are not relevant. Of relevance, however, is transaction risk, which refers to the risk of unexpected changes in exchange rates on future cash flows (Shapiro and Hanouna, 2019). Investors should take this into account as they expect the acquisition of an asset in a foreign currency to generate a cash flow in the same currency in the future, which must be converted back into their own domestic currency.

Having seen that unsystematic risks can be reduced through diversification, investors will use this to their advantage. As a result, they will not invest exclusively in their home country but will acquire foreign shares or bonds to diversify their portfolio as much as possible. Accordingly, an investor will, for example, acquire shares that are listed in another currency. Eun and Resnick (1988) showed that exchange rate risk remains non-diversifiable in a multicurrency portfolio. Exchange rate risk primarily affects owners of stocks, funds or bonds denominated in other currencies. Relevant for the investor's risk is not the country from which the stock, fund or bond comes, but the currency in which it is denominated. A bond denominated in euros in the US, for example, does not affect an investor whose domestic currency is the euro regarding exchange rate risk. Similarly, by the same logic, an investor is affected by the exchange rate risk of a bond issued in their home country in a foreign currency. Exchange rate risk can therefore arise from various constellations.

This exchange rate risk must be captured in the risk-return relationship of the security. Since, as explained in the previous chapter, the initial CAPM model does not include the exposure to foreign currencies in the pricing of securities, the international CAPM (ICAPM) has been created. This is intended to compensate investors for the exchange rate risk in addition to the time value of money and the premium for market risk (Chen, 2021).

$$E(R_i) = R_f + \beta_i^{market}\ (E(R_m) - R_f) + \beta_i^{FX} FCRP \quad (7)$$

The CAPM model was therefore extended to include another beta and the foreign currency risk premium. One assumption that distinguishes the ICAPM from the CAPM is that capital markets are seen as integrated rather than segmented. Capital can therefore move freely across borders, eliminating arbitrage opportunities (Schramn and Wang, 1999). The new ICAPM therefore makes it possible for an investor to take into account differences in the characteristics of global investments.

The performance of an investment in an asset of another currency is therefore a combination of the nominal performance of this asset and the performance of the domestic currency relative to the foreign currency (De Santis, 1998). Thus, a nominally rising stock may lead to a negative return for an investor due to changes in the exchange rate.

Adler and Dumas (1980) define exchange rate risk for investors as the risk of unexpected fluctuations in the purchasing power of a currency relative to an investor's own consumption mix index. The exposure for the investor therefore depends on the currency rates with their own domestic currency for a certain date in the future. These exchange rate changes can be both positive and negative for the investor. However, as investors are usually only concerned with downside risks, exchange rate risk is often understood as the adverse change in exchange rates. Exchange rate risk can in principle apply to all currencies, so a strong currency can be riskier than a weak currency (Adler and Dumas, 1980).

An exchange rate is first of all the exchange ratio between two currencies. There are different exchange rate regimes. Some countries operate with a flexible exchange rate and some with fixed exchange rates. The exchange rate can be seen as a crucial connection between the domestic economy of a country or a monetary union and the international economy (Williamson, 2009).

Flexible exchange rates arise in the foreign exchange market as supply and demand fluctuate due to macroeconomic factors such as a country's monetary policy, inflation, interest rates and balance of payments (Evans, 2014). The response to a change in economic conditions varies for different assets.

In the case of bonds, it should be noted that they are also affected by interest rate risk. When considering exchange rate risk, it is therefore also important to note that it is not fully independent of interest rate risk. According to Chow et al. (1997) and Engel (1986), there is a negative correlation between exchange rates and domestic interest rate changes. In their study, they showed that a depreciation of the dollar, i.e., a higher exchange rate, is associated with lower current and future interest rates. Since bond prices are inversely related to interest rates, this leads to rising bond prices. A foreign investor with, for example, the euro as their domestic currency, could sell the bond at a higher price before maturity, but would have to exchange the dollars they received for it back into their domestic currency, the euro, at a worse exchange rate. Consequently, exchange rate risk cannot be considered completely separate from interest rates, as exchange rates and interest rates are considered to be interconnected.

However, these links between exchange rates and interest rates are not clear-cut and vary depending on the investment direction and countries or currencies. In the past, the returns from US bonds and returns from a currency position in USD were negatively correlated. For Canada, Germany, Japan or the UK, on the other hand, the opposite was the case (Sturges, 2000). In a study examining the relationship between interest rates, exchange rates and stock prices between 1990 and 2008 in the US, Trifi (2011) found no significant relationship between interest rates and exchange rates.

In addition to floating exchange rates, there are also fixed exchange rates. Here the exchange rate of a currency is tied to a certain standard, usually another currency, which is achieved through the intervention of the respective central bank, who keeps the exchange rate within a certain range (Giavazzi et al., 2010). Safe and non-volatile currencies are used as pegging currencies. Examples include the Danish crown or various African currencies pegged to the euro, as well as many Latin American and Asian countries that have pegged their currencies to the USD (Schewe, 2015; Mosteanu, 2017). However, these tend to be smaller currencies, whereas the most important currencies worldwide are floating currencies and develop freely according to supply and demand. Since the demise of the Bretton Woods system and the abandonment of the fixed exchange rate system in the early 1970s, exchange rates have become increasingly volatile (Dowd, 2007). An investment of an investor in a currency that is pegged to their domestic currency therefore carries no, or only a very small risk. An

investor should therefore be aware of the relationship between the foreign currency and the domestic currency beforehand.

The following example illustrates the exposure of an investor to exchange rate risk, i.e., the uncertain change in exchange rates and how this might affect their cash flows from investments.

An investor whose domestic currency is the euro invests in stocks of a US company listed in USD. If this investor invests, for example, 10,000 EUR in stocks listed in USD, the Euros must first be converted into USD. Assuming that the exchange rate between the USD and EUR is 1.00, which means that there is parity between the two currencies and both can be exchanged at a 1 to 1 ratio. If the value of a stock is currently 10 USD, the investor can acquire 1,000 stocks at 10 USD each for the investment of 10,000 EUR. Approximately 1 year later, these stocks are to be sold again. The current stock price is 10.50 USD per stock, which means that the stock price has increased. The portfolio value at this point in time in USD is calculated by multiplying the number of stocks by the current value per stock:

$$1{,}000\ stocks * 10.50\ USD/stock = 10{,}500\ USD \tag{8}$$

The investor's assets in USD have thus increased by 500 USD and the investor achieves a return of 5%. Regardless of possible transaction costs and inflation, this is initially positive. However, the new assets must now be converted back into the domestic currency, the euro. During the investment period, however, the exchange rate has fluctuated and since the euro has appreciated, it is currently at 1.05 USD per EUR. The exchange into euro is done according to the following equation:

$$\frac{10{,}500\ USD}{1.05\ \frac{USD}{EUR}} = 10{,}000\ EUR \tag{9}$$

The final wealth of this investment thus corresponds again to the initial wealth of 10,000 EUR despite the increased stock price. This is because the investor's future wealth depends not only on the stock price, but also on the exchange rate of the currencies concerned. The 5% return of the stock price is wiped out by the 5% increase in the exchange rate. In this constellation, the rise in the exchange rate therefore has a negative impact on the investor's final assets in the domestic currency and should therefore be taken into account in the

decision-making process. However, this example also illustrates that additional gains from the risk of fluctuating exchange rates are possible. In the event that the exchange rate falls and is therefore less than 1, the investor will profit additionally. A changed exchange rate of 0.95 USD per EUR, calculated in the same way as in Equation 9, leads to a final asset of 11,052.63 EUR and thus to additional profit of 552.63 EUR compared to the case where the exchange rate does not change at all.

The same principle also applies to funds listed in other currencies or, in a somewhat more complex form, to bonds. Different assets are affected differently by exchange rate risk. Chow et al. (1997) and Bodnar and Wong (2003) find that exchange rate risk becomes statistically more significant over a longer investment period. Bonds are particularly sensitive to exchange rate fluctuations, as they generally have a lower level of absolute returns (Beers, 2022). Adverse exchange rate fluctuations are therefore more significant and can consume returns more quickly.

For example, the geometric average historical return of the S&P 500 over the last 20 years, i.e., the stock index comprising the largest 500 listed companies in the US, is 9.70%. By comparison, the average annual growth rate for US Treasury bonds or Baa corporate bonds is only 2.68% and 5.97%, respectively (Historical Returns on Stocks, Bonds and Bills: 1928-2022, 2023). Baa corporate bonds are moderately safe corporate bonds and are rated investment grade, whereas US treasury bonds are considered risk-free and therefore yield a lower return. In light of these figures, it is evident that the returns on the stock market are significantly higher than those on the bond market.

However, exchange rate changes not only have an effect on the total returns of an investor over the translation risk, but also on the performance of the asset itself. According to Chow et al. (1997), there is a negative correlation between the exchange rate and the performance of stocks and bonds, so a weaker dollar is associated with higher domestic bond and stock returns. There are two explanations for this, based on different directions of causality.

On the one hand, Dornbusch and Fischer (1980) develop a causality via their flow-oriented model that goes from exchange rates to stock prices. According to this, the current account determines the exchange rate via its effect on the asset market. This insight goes back to Mundell (1963) and Fleming (1962) and their model of capital mobility. Accordingly, the exchange rate of a currency changes the global competitiveness of domestic companies.

Prices for other countries become cheaper due to the devalued currency and lead to more exports by domestic companies, which in turn improves their economic situation. This improved economic situation leads to increased stock market prices for domestic companies. The exchange rate therefore has a causal effect on stock prices.

While bond returns react to both short-term and long-term exchange rate changes, stock returns only react significantly to long-term changes of more than 1 year (Chow et al., 1997). Adjasi et al. (2008) also confirm this relationship for stocks in the long term. In the short term, however, they find an opposite relationship, according to which a depreciation of the local currency reduces stock returns. Kanas (2000) finds that volatility spillovers from exchange rates to stock returns are insignificant for all six developed countries studied.

On the other hand, there is evidence that, contrary to the theory of Dornbusch and Fischer (1980), a reverse causality exists between exchange rates and stock prices. This is called the stock-oriented model (Chkili and Nguyen, 2014). Smith (1992) and Kanas (2000) found that stock returns affect exchange rates. The basic idea is that investors hold foreign and domestic assets, and when domestic stock returns increase, they purchase more domestic currency to buy further domestic stocks. The increased demand for the domestic currency subsequently leads to its appreciation (Jebran and Iqbal, 2016). Thus, there is a positive correlation.

The literature is therefore not completely consistent on the direction of the causal relationship, but tends to suggest that stock prices influence the exchange rate more significantly than exchange rates influence stock prices (Kanas, 2000; Yang and Doong, 2004). This can also be attributed to the fact that multinational companies can hedge well against exchange rate movements through various hedging instruments and that stock prices and returns are therefore not as strongly dependent on exchange rate changes (Grant and Marshall, 1997; Chkili and Nguyen, 2014).

However, predicting floating exchange rates remains a complicated task. The literature is very ambiguous as to which macroeconomic factors are causally related to changes in exchange rates. Many results are stating that economic models are partly useless to predict exchange rate movements and rather follow a random walk (Chen et al., 2010). This inability to predict implies uncertainty and thus increased risk for investors. Interest rates are considered as one of the numerous influencing factors for exchange rate changes, which represent a further separate risk for certain securities.

2.4.2.3 Interest rate risk

Another central systematic risk is interest rate risk. Interest rate risk is defined as losses from unexpected changes of interest rates (Kaufmann, 1984). Originally, interest rate risk referred to a general fluctuation in interest rates, but since investors are generally only concerned with downside risk, this definition applies.

Interest rate risk related to the price risk mainly concerns fixed income securities such as fixed rate bonds. Floating rate bonds have a rather low interest rate risk in comparison. Floating rate bonds have a variable interest rate that is adjusted each period and therefore there are usually only minor price fluctuations (Buhrs, 2012). These are often based on reference interest rates like for example the federal funds rate, European Interbank Offered Rate (EURIBOR) or the London Interbank Offered Rate (LIBOR) and contain an additional spread, which reflects the creditworthiness of the issuer (Kenny, 2021). However, floating rate bonds are also subject to a certain interest rate risk, as their ownership is associated with uncertainties about their future cash flows, but this interest rate risk is comparatively low.

Fixed coupon bonds promise the buyer over the maturity fixed coupons or payments that have been defined in advance at a certain interest rate. This interest rate is also called yield to maturity for bonds (Giavazzi et al., 2010). If this yield to maturity of bonds is below the interest rate available on the market in alternative investment forms, the attractiveness of this bond decreases.

Specifically, there are two risks involved here. The price risk and the reinvestment risk. Price risk is the danger that the price of the corresponding security, in this case the bond, will fall due to changing interest rates on the market. Bond prices are inversely related to interest rates (Chow et al., 1997). If the general interest rate on the market rises, the market value of a bond falls. The bond can only be sold at a loss on the market before maturity, since the interest payments of the bond are below those of the market. An investor is therefore tied to lower interest rates through the bond and suffers a loss of opportunity through unused attractive market returns.

Gonçalves (2021) defines the reinvestment risk of bonds as a deterioration of investment opportunities. An investor who owns a bond that guarantees constant interest payments usually wants to reinvest the current payments. If the interest rate on the market falls, the

payments can only be reinvested at a lower interest rate and the investor's return falls. This is the result of falling interest rates for bonds. The higher and the more frequent the bond payments, the greater the reinvestment risk. Zero coupon bonds, on the other hand, have no reinvestment risk, as no interest payments can be reinvested (Pereira et al., 2009). An investor who holds fixed rate bonds is therefore exposed to price risk through rising interest rates and to reinvestment risk through falling interest rates.

The extent to which a bond is affected by rising interest rates also depends on the coupon rate. If two bonds differ only in their coupon rate and otherwise have the same characteristics, the bond with the lower coupon rate is more strongly affected by rising interest rates and experiences a greater price drop (Streuli, 2008). Since the interest rate risk exposure increases as the coupon rate decreases, zero-coupon bonds are the most affected.

Moreover, different maturities have different effects on the interest rate risk of a bond. The maturity of a bond is the time at which the face value of the bond must be repaid to the investor. The longer the maturity of a bond, the more its price is affected by an interest rate change and the greater its interest rate risk (Witzany, 2020). This is because a longer commitment to an interest rate is less attractive for an investor. For this reason, this higher risk is usually compensated for by a higher coupon rate, given otherwise identical characteristics. Accordingly, bonds with a combination of long maturity and low coupon rates are exposed to the greatest interest rate risk.

Beyond the interest rate risk of bonds, stocks are also affected by interest rate changes. In their study, Alam and Uddin (2009) examined the relationship between interest rates and stock returns and found that there is a negative correlation between the two. The studies by Fama (1981) also support this theory. This means that when interest rates rise, stock prices tend to fall and vice versa. This negative correlation is primarily due to two reasons. On the one hand, this is due to the way in which investors value companies, and, on the other, to the existence of alternative investment opportunities (Schmitt, 2020). The valuation of a company is based on discounting its future cash flows by the cost of capital to obtain the present value of the company. Rising interest rates lead to a rising cost of capital and thus to increased discounting of future cash flows. This lowers the present value of a company and therefore might results in the fair value being below the current market price of the stock. A rational investor would therefore not buy the stock or would rather sell it. This general

market expectation leads to falling stock prices. The second reason is that with falling interest rates, investors are more attracted to invest in assets that offer a higher return.

Predicting variables such as interest rates or exchange rates as well as stock prices is difficult even for experts. Due to various ambiguous correlations and causal directions and interdependencies of the different risks, a unified perspective is appropriate even if the positions should be considered individually for better risk minimisation (Duffie, 1997). Adequate risk management is therefore essential.

There are several possible actions or strategies how to deal with these risks. An investor can therefore engage in preventive risk management (risk avoidance), accept the risk and make no attempt to reduce it (risk retention), try to systematically reduce the risk through, for example, diversification (loss prevention) or transfer the risk to another market participant (risk transfer) (Baker and Filbeck, 2014).

Of these risk management strategies, only the last two are suitable for reducing the risk of a portfolio. While unsystematic risk can be reduced or avoided through diversification, the aforementioned systematic risks can only be managed through transferring the risk. Risk transfer can be achieved by hedging a position. Hedging can be carried out with various financial products; the best-known ones include forwards, futures, options, swaps, and further derivative products or the purchase of insurance. Which hedging techniques are used for which product and risk in order to hedge a portfolio is subject of the following chapter.

2.5 Hedging techniques to mitigate these risks

Hedging is a risk management strategy that reduces potential losses and protects against unknown fluctuations in investment prices by taking offsetting positions (Tiwari, 2019). This involves hedging a transaction or asset against adverse changes in market prices, interest rates or exchange rates. By acquiring a derivative in the opposite position, these adverse changes are offset and provide financial security for the future.

For international companies, hedging and risk management are indispensable and, for various reasons, an integral part of their organisational structure. Reasons for hedging of companies from the point of view of their shareholders are, for example, tax advantages,

financial distress costs in the event of bankruptcy, or the reduction of underinvestment, as internal funds are available for the optimal distribution in investment opportunities (Ramlall, 2010). Financial derivatives also reduce the risk of mispricing the firm's stock price (Lin et al., 2010). From a managerial perspective, hedging is also practiced because managers are often risk-averse and can signal their managerial skill by hedging risks that are outside of their control (Ramlall, 2010).

These reasons suggest the use of hedging techniques and derivatives from a theoretical point of view. Accordingly, the investigation of whether risk management and hedging for companies provides a lower level of risk and increases the company value is the subject of numerous studies. For example, various studies find that the use of foreign exchange rate and interest rate derivatives reduces the corresponding sensitivity measures and thus the risk (Smithson and Simkins, 2005; Brewer et al., 1996; Choi and Elyasiani, 1997; Guay, 1999).

Furthermore, there is the question of whether this reduced risk leads to an increased value of the company. Various studies have been conducted on exchange rate risk and interest rate risk for different firms in different industries. The literature largely agrees that there is a positive correlation between hedging with derivatives and the company value (Afza and Alam, 2016; 2004; Bartram et al., 2004). However, these studies cannot fully clarify the direction of causality, as it is also conceivable that successful firms tend to use derivatives for hedging (Smithson and Simkins, 2005).

All these studies point to the fact that hedging is beneficial for companies and that they can achieve lower risk and increased company value through the use of derivatives. But this finding first applies only to international companies. For the time being, this insight is only relevant for investors insofar as they can take this into account when selecting stocks. However, the subsequent question is whether these findings are also applicable to a private investor who invests in the capital market and is not affected by these risks to the same extent as an international company. In contrast to a company, an investor is only accountable for themselves and their own profits or losses. The extent of tolerated risk and potential hedging depends solely on their individual risk preferences and knowledge of hedging techniques. The most obvious reason is therefore to preserve the investor's financial stability and to gain planning security over future assets and cash flows. Investors are therefore able to reduce and control their exposure to risks through hedging them. However, also taxes can be of

relevance for investors. In many countries, disposing financial assets at a profit is accompanied by a capital gains tax. Depending on the country, this can apply to the entire profit or only to interest income or dividends. By offsetting gains and losses, investors may therefore have tax incentives to postpone the sale of positions and therefore the need to hedge.

The extent to which hedging is carried out, or the percentage of the portfolio assets that is hedged, depends on the risk preference. The question for investors is therefore what they will accept as the maximum loss and how much money they are prepared to spend in return. The possibilities range from very cautious hedging, which only hedges a small part of the portfolio and still allows larger losses, to perfect hedging, where the risk is eliminated entirely, for very risk-averse investors (Hull, 2021). In general, the aim of hedging is to reduce the risk to an acceptable degree, not to completely eliminate it. Therefore, often only a part of the portfolio or the risk is hedged. For this, given the preferences of the investor, a ratio must be found to which the risks are hedged. According to Black (1989), the optimal hedging ratio, i.e., the proportion of foreign investments that should be hedged, consists of three components. These are the expected return and the volatility of the world market portfolio as well as the average exchange rate volatility. From this, Black (1989) concludes that foreign equities should be hedged equally for all countries, but less than 100%. This is explained by "Siegel's paradox" and therefore suggests that a certain degree of risk has a positive effect on the future wealth of the investor.

In the context of market risk, in order to decide whether hedging is desirable and, if so, which technique to use, investors or firms must first evaluate the specific type of risk they face and then consider which hedging strategies are appropriate. Several derivatives are available for this purpose, the most widely used of them are briefly explained below. Derivatives are defined as financial instruments that are derived from and whose values depend on the market prices of a basic underlying instrument and are designed to transfer the risk between different counterparties. A derivative is a contractual agreement between at least two counterparties by means of which risks from an underlying (original) value are transferred to the contractual partner. Derivatives are characterised by the fact that their settlement takes place in the future (Witzany, 2020).

2.5.1.1 Forwards

A forward contract is often considered the simplest form of a derivative. This contract assures to buy or sell an underlying asset at a fixed price at a certain time in the future (Hull, 2021). Forward contracts are derivatives that are not concluded on exchange markets but on the over-the-counter market (OTC). They are often used for currencies or commodities, but can also be used for stocks, bonds or any other asset. The price (K) at which the transaction occurs in the future is called the forward price and the future date describes the maturity (T) of the contract. The assumption is that the forward price is equal to the expected future spot price.

In a forward contract, there are two counterparties that can take two different positions. The party that agrees to buy the underlying asset at a future date under the contract is in a long position. The selling party, on the other hand, is in a short position (Hull, 2021). An investor who wants to hedge their exchange rate risk can therefore enter into a forward contract. A currency forward contract could include, for example, that this investor buys one million EUR at an exchange rate of 1.10 USD/EUR from party B on 1 July 2024. They are therefore in a long position. Assuming the current spot rate is 1.08. In monetary terms, the investor commits to buy 1 million EUR for 1.10 million USD. If they wanted to conclude the transaction now, they would only have to pay 1.08 million USD to exchange it for 1 million EUR. The forward contract thus hedges against the depreciation of the dollar and enables the purchase of euros in the future at a fixed price determined now. Through this hedging, the investor gains planning security for their future cash flows and assets. Even if the security gained is initially positive, it can only be assessed on the settlement date whether this results in a profit or loss for the investor. For this purpose, the payoff function of the forward contract is considered.

The payoff of a forward contract is determined at the settlement date. The profit or loss results from the comparison of the spot rate on the settlement date (St) and the forward rate (K), because forward transactions do not include premiums or any other costs. The payoff of the party in the long position results from the difference St - K, while the K - St indicates the payoff of the short position. This is based on the logic that the buyer can sell the asset immediately at the spot price and the seller can acquire the underlying asset at the current spot price right before the transaction. Forwards are usually physically settled, but can also

be settled by the respective counterparty in cash by compensating for the difference between the spot and forward price (Witzany, 2020).

The following example will illustrate the way an exchange rate forward works. Assuming the exchange rate on 01.07.2024, i.e., on the settlement day, is 1.15 USD/EUR. This means that the exchange rate has risen and the USD has depreciated. Without the forward contract, the investor would have to pay 1.15 million USD on this day to receive 1 million EUR. Thanks to the forward contract, however, the 1 million EUR can be acquired for 1.10 million EUR. Since the investor is long in this contract and the spot rate (St) is higher than the forward rate (K), they make a profit by entering into the forward contract. The profit is calculated as follows:

$$(ST - K) * N = (1.15\ USD/EUR - 1.10\ USD/EUR) * 1{,}000{,}000\ EUR = 50{,}000\ USD \quad (10)$$

Like exchange rates or commodities, forwards can also be concluded for interest rates. The best-known derivative is the forward rate agreement (FRA), which enables the fixing of an interest rate for the future. Here, an interest rate is fixed for a deposit or loan for a period of time between the two future dates T1 and T2. For the final settlement, it should be noted that only the difference between the contractually fixed interest (RK) and the market interest rate at T1, which is an appropriate reference rate such as LIBOR or EURIBOR, is settled (Witzany, 2020). In addition to the forward, other derivatives exist to hedge against a risk. A derivative very similar to the forward is a future.

2.5.1.2 Futures

Futures contracts are very similar to forwards. Here as well, two parties agree to buy or sell an asset at a certain point in the future. In contrast to a forward contract, a futures contract is a standardised forward contract that is traded on an organised exchange market (Dowd, 2007). In a way, they are the financial equivalents of forwards in the organised exchange market. This organized exchange market, like for instance the CME Group in the US and Eurex in Europe, enables two mutually unknown parties to enter into a transaction. For futures, there is always a clearing house as an intermediary, which guarantees that the settlement takes place by collecting deposits and thus bears the credit risk. Futures are therefore less risky than forwards. For futures, as for forwards, a range of standardised

quantities of stock indices, bonds, currencies and commodities can be traded (Hull, 2021). With futures, however, these assets are traded in standardised contracts. The asset, quantities, prices or expiration dates are therefore not flexible or customisable, in contrast to forwards.

Stock index futures are a particularly effective way of hedging against movements in the overall stock market. These can be concluded for various indices such as for example the S&P 500, Euro Stoxx or the DAX. Stock index futures are exclusively settled in cash, as the physical settlement of an index consisting of multiple shares is almost impossible (Witzany, 2020).

Both forwards and futures have the advantage that they guarantee price stability and thus increase planning security. However, this hedging against falling prices also has the disadvantage that no profit participation in rising or falling prices is possible.

In addition to the forward rate agreement, hedging of interest rate risk is also possible via a futures derivative. These are interest rate futures, which are based on interest-bearing financial instruments such as Treasury bonds or Eurodollars. The contract can be physically delivered or settled in cash. The aim of hedging with interest rate futures is to find a futures contract with a duration of the underlying asset that is closest to the duration of the hedged asset (Hull, 2021).

2.5.1.3 Options and Swaps

Another widely used derivative for hedging are options and swaps. An option gives the investor the opportunity to buy or sell an asset at a certain price, called strike price (K), in the future. However, it is important to note that it is an option to execute the transaction and not an obligation, therefore the execution depends on the preferences of the option holder. This strategic advantage of the option holder means that in return the option holder has to pay a price for the option in advance. An option that gives the option owner the possibility to acquire the underlying asset is called a call option and the possibility to sell the asset is called a put option (Witzany, 2020). A distinction is made between two types of options, the European and the American. However, the name does not indicate the location where an option is traded, but rather distinguishes between the different ways in which the option can be exercised. While a European option can only be exercised on the expiration day, an

American option can be exercised at any day until the expiration day. European options are mostly traded on the OTC market, while American options are mostly traded on the exchange market.

There is a fundamental difference between forward contracts and options. A forward contract fixes the price at which the asset is bought or sold and thus neutralises the risk. An option, on the other hand, is characterised more by the fact that it offers a protection against adverse price movements, and therefore hedge against the adverse risk. At the same time, they enable a profit through favourable price movements allowing to exploit the positive risk (Hull, 2021). Due to this freedom of choice of options, they can be classified as conditional, as the holder of the option is free to decide on its execution. Forwards, on the other hand, are considered unconditional derivatives (Witzany, 2020).

Another derivative for hedging are so-called swaps. A swap is literally translated an exchange transaction. In these swaps, future cash flows are exchanged. The best-known swap is the so-called plain vanilla interest rate swap, in which two counterparties exchange a fixed and a floating interest rate.

In addition to interest rate swaps, currency swaps are also used to hedge exchange rate risk. Swaps are traded on the OTC market and exist in various forms. Swaps have the advantage over futures that they are also available for longer maturities. Furthermore, the forward and future rates depend on the maturity and therefore do not deliver constant interest payments over all periods as swaps do.

Since this work generally considers both positive and negative risk, as well as primarily the price risk for bonds, no further attention will be paid to options and swaps, as these are not used in the practical part of the work.

3 Methodology and data

After having seen in Chapter 2.1. and 2.2. that the unsystematic risk of an asset can be reduced by diversification, but the systematic risk can only be managed by suitable hedging, the idea of the practical part is to imitate hedging of market risk, exchange rate risk and interest rate risk using financial derivatives. In order to analyse this, a quantitative examination in the form of backtesting was carried out by compiling a fictitious portfolio of shares and bonds for the historical reference date of 01.03.2022. By using the quotations of the assets as well as various forward and futures prices, it should then be examined whether the diversification of the stock portfolio can reduce the unsystematic risk and whether the acquisition of derivatives are able to reduce the systematic risk.

3.1 Construction of the portfolios

The portfolios were constructed from the perspective of a fictitious US investor whose home currency is the USD. It is assumed that the investor has 15 million USD at their disposal on the reference date and wants to invest 10 million USD in a stock portfolio and 5 million USD in a bond portfolio.

For the stock portfolio, the risk-minimising findings of diversification were taken into account and therefore when selecting the portfolio's shares, attention was paid to ensure that they are spread geographically across the world as well as in various industries. No specific rules were applied to the geographical weighting of the portfolio, only that the largest share is in the domestic US market. Accordingly, 35% of the portfolio is in the US, 20% each in China and the Eurozone, 10% each in Japan and the UK, and only 5% in Australia. Within each market, the shares were distributed equally, which means that with a weighting of 20% of shares in the euro area, these 20% are distributed with 5% to each of the four shares. In addition to the geographical distribution of the shares, a distribution across different industries and sectors was crucial for diversification. It was ensured that at least one share came from each of the 11 Global Industry Classification Standard (GICS) sectors. According to the GICS, each company can be assigned to a specific economic sector (Hayes, 2022). This allows identification of the industries and sectors of the assets. Holding shares from all sectors means that one participates in the whole economy and is therefore well diversified in terms of industries.

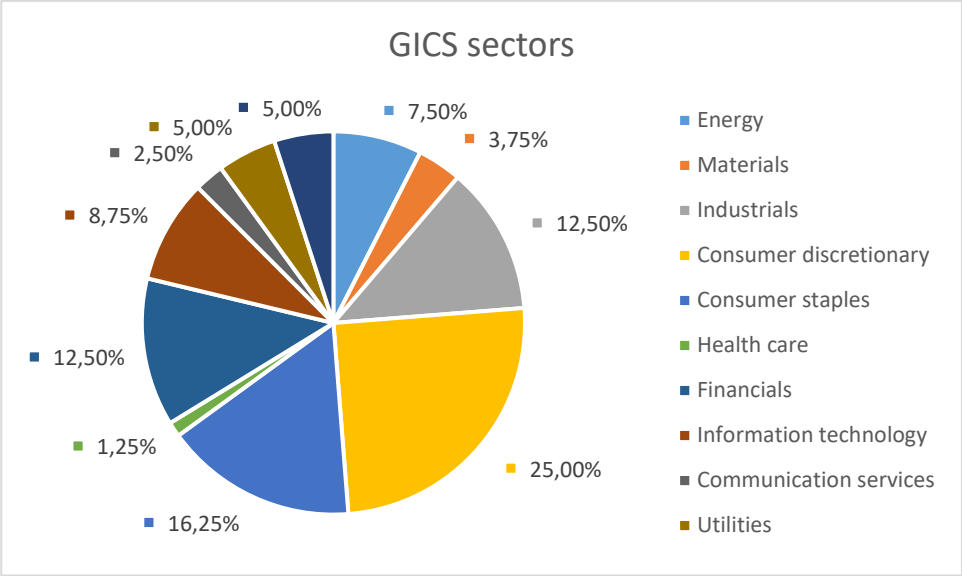

Figure 5 Diversification of the Stock Portfolio
Source: Own illustration

Due to better availability of data, the selection was limited to big sized companies with a market capitalisation of more than 10 billion USD. Apart from that, the stocks were not selected according to any particular pattern, but purely by random selection, provided that they fulfil the criteria described above. Thus, the portfolio contains a total of 24 stocks listed in six different currencies (Australian Dollar (AUD), Euro (EUR), British Pound (GBP), Hong Kong Dollar (HKD), Japanese Yen (JPY) and US Dollar (USD)) from four different continents, which can be seen in Appendix 2. According to the analysis of the literature in Chapter 2.2, this is sufficient to benefit from the positive diversification effects.

After deciding on the individual shares, their prices were extracted using Yahoo Finance. The "adjusted close" prices were used for all shares, as they are adjusted for splits and dividends or capital distributions and therefore this does not have to be taken into account separately in the calculations. The exchange rates of the five currencies against the USD were extracted from Investing.com. It is important to note that AUD, EUR, GBP and JPY have a floating exchange rate against the USD and the HKD is a special case of a pegged currency. This currency is pegged to the USD by the Hong Kong Monetary Authority, which controls supply and demand to keep it in a range of 7.80 ± 0.05 USD/HKD (Chen and Yung, 2022). From the perspective of an American investor, an investment in HKD therefore poses only minimal exchange rate risk.

After all these data had been collected, it was simulated in the next step that the investor bought shares on the 01.03.2022 according to the budget derived from the weights, bearing in mind that the investor would hold these shares for a period of 1 year. The process of determining the amount of shares to acquire is illustrated by the example of the RWE share. According to the weighting, this share should receive a part of 5% of the 10 million USD portfolio and thus contain shares worth around 500,000 USD. That budget is then divided by the stock price on 01.03.2022 to obtain the number of shares. Since the share prices are quoted in the respective currency, which in the case of RWE is the euro, this still has to be converted into USD on the reference date and therefore needs to be multiplied by the EUR/USD exchange rate. The result of this calculation must be rounded up or down to a whole number, as only whole shares can be acquired. The equation in this case therefore is as follows:

$$\frac{10{,}000{,}000\ USD * 5\%}{39.07\ EUR/stock} * \frac{1}{1.1126\ EUR/USD} = 11{,}502.37\ stocks \approx 11{,}502\ stocks \quad (11)$$

Accordingly, with the budget of 500,000 USD on the reference date, 11.502 RWE shares could be acquired for 499,983 EUR. Based on this, a portfolio with the following share numbers and portfolio values as of 01.03.2022 resulted, which is illustrated in Appendix 2.

To ensure homogeneity of the database, adjustments had to be made. The data had to be standardised according to availability, taking into account the different opening hours of the stock exchanges due to different public holidays. For this purpose, days on which several stock exchanges were closed were eliminated from the data set and, if this was only the case for one stock exchange, the share price of the previous day was taken for this day in each individual case. Since British shares are quoted in pence instead of pounds, it was important to convert their prices to British pounds.

In order to calculate the portfolio risk at the time of investment, the daily returns were first calculated for all share prices for the period from 01.01.2020 to 28.02.2022, and then the correlation and covariance between all shares were determined based on these. The corresponding correlation matrix can be found in Appendix 4. With the help of the covariance matrix from Appendix 5 in the appendix and the weighting factors from Appendix 2, the portfolio risk could then be determined according to Equation 3.

Accordingly, the portfolio variance is 0.000130 and the standard deviation of the portfolio is 0.011412. This means that the average deviation from the daily mean percentage return is 1.14 percentage points.

In addition to the stock portfolio, a fictitious bond portfolio was created. A total of 5 different bonds were selected according to the following criteria. Since, according to the analysis in Chapter 2.4.2.3, fixed rate bonds are particularly affected by interest rate risk, all selected bonds should be fixed rate ones. The risk-minimising findings of diversification should also be used for the bond portfolio. The bonds should therefore come partly from the investor's home market, i.e., the US, and partly from the same countries or denominated in the same currencies as the foreign equities. Furthermore, the portfolio should be diversified in terms of maturity and therefore long-term (>10 years) as well as short-term bonds (<10 years) should be selected. Moreover, the portfolio should contain both government bonds as well as corporate bonds in order to diversify in terms of the type of issuer. The bonds selected according to these criteria are shown in Appendix 3.

For these 5 bonds, notional units worth approximately one million USD were acquired on 01.03.2022 by taking the minimum increment into account. For the bonds in foreign currencies, the minimum increment first had to be converted into USD using the spot price in order to then calculate the number of units that can be acquired with 1 million USD per bond using the percentage price. For the further analysis, only the price risk of bonds was considered as the interest rate risk, which should be hedged. Coupon payments of the bonds and other cash flows were not taken into account.

In order to examine the hypothesis that diversification of the portfolio and the use of derivatives for hedging reduces the risk of an investor, various historical data were collected. This includes various share prices and bond prices, as well as data on S&P 500 futures, interest rate futures and various currency futures relevant to the portfolio, as well as the relevant currency forwards of the other currencies in relation to the USD. This data was largely obtained from the Bloomberg database as well as from internet sources such as Investing.com and Yahoo Finance.

For the entire analysis, it was assumed that the shares and bonds were acquired on 01.03.2022 and held for the entire investment period until 28.02.2023. Furthermore, the

derivatives were also held for the entire period and therefore no dynamic hedging strategies were followed.

3.2 Measuring volatility

Once the portfolios had been created, the only thing left to do was to define a method of measuring risk. To facilitate easier interpretation, the volatility was calculated in form of the standard deviation throughout this thesis. Due to the different absolute portfolio values that were considered, the standard deviation of the portfolio values cannot be directly compared in a meaningful way. To ensure comparability of the standard deviation, the standard deviation of the daily percentage returns was therefore used. This ensures that the different absolute levels of the portfolios do not play a role, as the returns are relative to the initial value.

Due to the different currencies, the respective share prices for the stock portfolio were converted to USD using the daily exchange rates. Together with the gains or losses of the derivatives quoted in USD, the current portfolio value in USD could be determined for each day, and thus also the daily percentage return for all scenarios.

For the bond portfolio, for the purpose of calculating the hedging of the interest rate risk, the bond values were not converted into USD. Since both the bond prices and the profits and losses of the interest rate futures are denominated in the respective foreign currency, the portfolio values were calculated in the foreign currency. This allowed to exclude the influence of exchange rate fluctuations on the portfolio returns and thus to consider the price changes due to interest rates isolated. For hedging the exchange rate risk of the bond portfolio, however, the portfolio values had to be converted back into USD, as the gains and losses of the currency derivatives are quoted in USD, thus ensuring a uniform analysis.

In addition to the standard deviation, the portfolio minima and maxima as well as the calculated range of the portfolio were also considered. The portfolio minima enable a simple analysis of the downside risk of the investor and the range is an easy-to-interpret indicator of the fluctuations within the investment period.

4 Empirical results and Discussion

4.1 Unhedged stock portfolio

For the investment period, the portfolio value was then calculated in USD for each day. Since the share prices are quoted in a different currency except for the US shares, these share prices had to be converted into USD using the daily spot prices.

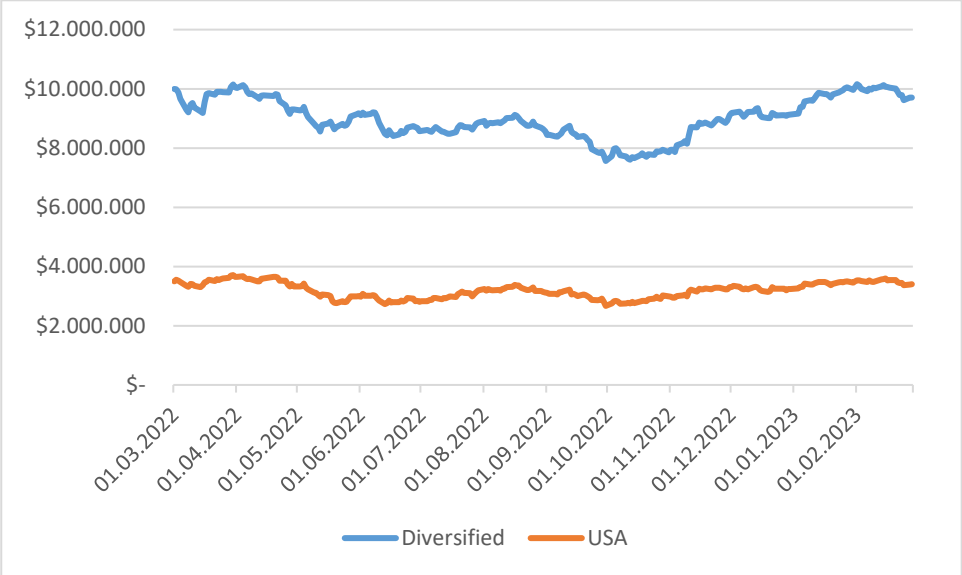

Figure 6 Portfolio Value of the Unhedged Stock Portfolios
Source: Own illustration

Figure 6 shows the portfolio performance of the unhedged stock portfolio, on the one hand for the portfolio of only the four US equities and on the other hand for the entire diversified portfolio including the US equities. To support the hypothesis that diversification has a positive effect on risk minimisation, the daily volatility was calculated for both portfolio values over the investment period. This amounts to 1.7394% for the American portfolio and 1.2033% for the diversified portfolio. The diversified portfolio value line may look more volatile at first glance, but since the standard deviation is calculated based on the daily percentage changes and therefore in relative terms, the graph may initially give a misleading impression in terms of volatility. The diversification of the portfolio thus reduced the standard deviation of the returns by 0.5361 percentage points or by 30.82%. Therefore, it confirms the concept of Markowitz (1952) and is in line with the findings of Biswas (2015) and Oyenubi (2019).

As can be seen, the diversified portfolio is worth 10 million USD at the start. Over the course of the year, however, the portfolio value is almost without exception below the initial value, with a minimum value of 7,563,158 USD in October and a maximum value of 10,157,174 million USD. The portfolio value therefore fluctuated within a range of 2,594,015 USD during the period under review. This initial situation will now be compared in the following chapters with the hedging of different risks through various derivatives.

4.2 Hedging systematic market risk of the stock portfolio

Stock index futures are suitable for hedging the systematic market risk in form of systematic market price fluctuations of a stock portfolio. Futures contracts and stock index futures in particular have already been explained in more detail in Chapter 2. For this purpose, a suitable stock index must first be selected for which futures are then acquired. Of course, it is possible to select a stock index that one believes represents the portfolio as well as possible. This could be the MSCI World, as it contains stocks from all over the world and thus has a similar diversification as the existing portfolio.

In order to obtain an optimal representation of the portfolio by the stock index futures, the market beta of the stocks was considered. The most commonly used stock index to calculate the market beta is the S&P 500 (Smith, 2022). This means that the S&P 500 index is taken as the reference in the calculation and corresponds to a beta of 1. Based on this, the betas of the stocks in Appendix 2 Stock Portfolio refer to the S&P 500 as a benchmark. Consequently, the S&P 500 is the optimal stock index for hedging with stock index futures.

To determine the optimal number of futures contracts based on the beta of the portfolio, the beta of the portfolio must first be calculated. This is calculated as the weighted average of the betas of the shares in the portfolio. For this purpose, the betas of the shares were multiplied by the portfolio value as of 01.03.2022 and then divided by the total portfolio value. Accordingly, the weighted beta of the portfolio is 0.9665, which is close to the S&P 500 index. The portfolio is therefore slightly less volatile than the market or the S&P 500.

This portfolio beta can now be used in the next step to buy the optimal number of futures contracts. The equation for the optimal quantity N is calculated as follows (Witzany, 2020):

$$N = \frac{\beta \cdot V_0}{F_0 \cdot M} \tag{12}$$

The optimal quantity of the futures therefore depends positively on the portfolio beta and the initial portfolio value V0 and negatively on the initial futures index value F0 and the index multiplier M. The only unknowns in this equation are the futures index value as of 01.03.2022 and the index multiplier. To solve this, a suitable futures contract for the S&P 500 must first be selected. Since an investment period from March 2022 to March 2023 is considered, the March 2023 future is suitable, which is traded on the CME and has 13.03.2023 as the value settlement date. This is settled in cash. The index multiplier is 50 USD and the index value of this future on 01.03.2022 is 4,303.75 USD.

$$N = \frac{0.9665 \cdot 10{,}000{,}000\ USD}{4{,}303.75\ USD \cdot 50\ USD} = 44.9131 = 45\ contracts \tag{13}$$

Since the investor wants to hedge against an adverse market movement of the portfolio and assumes that the portfolio will move with the S&P 500, they must profit from falling market prices of the S&P 500 in order to be hedged. Since only a whole number of contracts can be traded, a short position of 45 futures contracts must be taken. Futures contracts are cleared through a clearing house, which means that gains and losses are realised on a daily basis. The profits and losses are therefore calculated on a daily basis according to the following equation (Hull, 2021):

$$N * (F_{t-1} - F_t) * M = P/L \tag{14}$$

As can be seen from the Equation 14, a profit is made if the futures price falls compared to the previous day, since it is a short contract. The difference between these two futures prices is then multiplied by the multiplier M and the number of contracts. One short futures contract was purchased on 01.03.2022 for 4,303.75 USD. The nearest future is at 4,381.75 USD. The profit or loss for the 02.03.2022 is therefore as follows:

$$45 * (4{,}303.75 - 4{,}381.75) * 50 = -175{,}000\ USD \tag{15}$$

Since the standard deviation of the daily portfolio returns is considered in the analysis of the risk, the daily profits or losses must be added up for each day in order to be able to determine

the portfolio value for each day. This is shown graphically for the entire investment period in Figure 7:

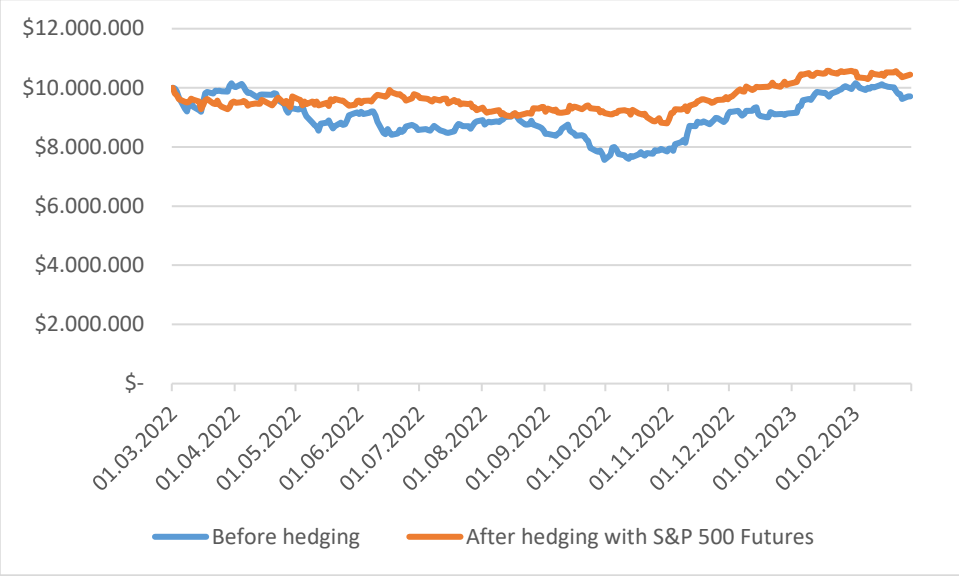

Figure 7 Portfolio Values before and after Hedging Market Risk
Source: Own illustration

The blue line represents the unhedged portfolio value as a reference and the orange line the portfolio value including the gains and losses from hedging using the S&P 500 future. In order to check whether the hedging has reduced the volatility of the returns, the standard deviation of the daily returns have been calculated for both portfolios. The visual impression given by Figure 7, that the futures are smoothing the portfolio values, is also reflected in concrete figures. The standard deviation of the daily returns of the hedged portfolio is 0.9329% and has thus fallen by 22.47% from the initial value of 1.2033%. Furthermore, when looking at the minima and maxima of both portfolios, one can see that the range of the portfolio values has decreased significantly due to hedging.

Table 1 Comparison of Hedging Market Risk with Unhedged Situation
Source: Own illustration

	St.Dev.	Min	Max	Range
Unhedged	1.2033%	7,563,158 $	10,157,173 $	2,594,015 $
Hedging with S&P 500 Futures	0.9329%	8,798,935 $	10,573,760 $	1,774,824 $
Difference	-22.47%	+16.34%	+4.10%	- 31.58%

The hedging was therefore successful in terms of minimising the risk and smoothing the portfolio values. Thus, the hedging fulfilled the primary objective and even if the profitability is rather marginal in this analysis, it is worth taking a look at it. In this respect, it can be stated that the investor has made a profit of approximately 738,562 USD through the future and that the portfolio value at the end of the period is 7.61% higher than it would be in the unhedged situation.

In retrospect, it could also be interesting to examine whether the number of optimal futures contracts calculated according to the beta as systematic market risk is in fact optimal in hindsight. For this purpose, the Excel solver was used to calculate the number of futures contracts that minimises the standard deviation of the daily returns of the portfolio. The result is that already 28 futures contracts would have reduced the standard deviation to a value of 0.7565% and thus by 37.13%. Nevertheless, a lower number of futures would have also lowered the profit. In this scenario, the profit would only be 459,550 USD, which is 279,013 USD less than in the initial optimal number of contracts. In hindsight, it is of course always easy to calculate the optimal number given the market movements, but nevertheless the reduction of the standard deviation of 22.47% by the futures used is effective enough.

4.3 Hedging exchange rate risk of the stock portfolio

After hedging the market risk in the previous chapter, this chapter deals with hedging the exchange rate risk. In the course of diversification, the investor's portfolio contains shares from 6 different currencies. The more uncorrelated the currencies, the more effective the diversification of assets into the various currencies. To ensure a valid comparison of the correlation coefficients, all currency pairs were brought into direct quotations with the USD. Table 2 shows that the currencies in the portfolio that are quoted relative to the USD have a positive correlation over the investment period. Since the correlation is not perfect, diversification has a positive effect, which could, however, be optimised in case of weaker or negative correlations between the currency pairs.

Table 2 Exchange rates correlations
Source: Own illustration

	EUR/USD	*GBP/USD*	*HKD/USD*	*JPY/USD*	*AUD/USD*
EUR/USD	1				
GBP/USD	0.937710	1			
HKD/USD	0.600246	0.547753	1		
JPY/USD	0.920915	0.959618	0.543250	1	
AUD/USD	0.765324	0.850888	0.207253	0.806369	1

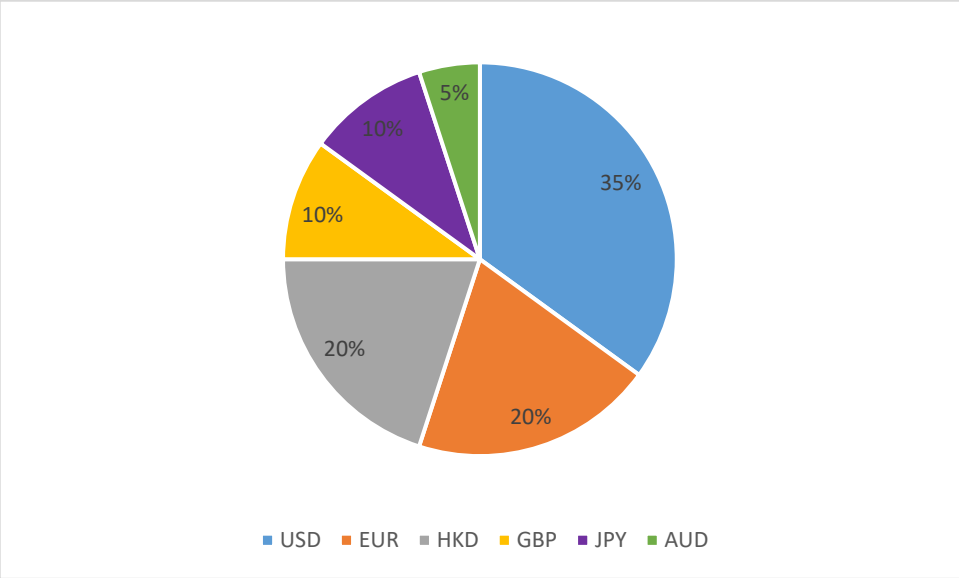

Figure 8 Stock Portfolio Diversification by Currencies
Source: Own illustration

The weighting of these currencies in the portfolio can be seen in the pie chart in Figure 8. On the historical reference date of 01.03.2022, the corresponding amount of USD must be converted into the respective currency in order to acquire the shares. At the end of the investment period on the 28.02.2023, the portfolio value of the foreign currency must be converted after the disposal back into the home currency, the USD. For the euro, the Australian dollar and the British pound, the exchange rates with the USD are in direct quotation, which means that the exchange rate indicates how many USD must be exchanged for one unit of the foreign currency. In the end, the portfolio value in the foreign currency has to be multiplied by the exchange rate to convert it into the home currency. Therefore, a rising exchange rate over the investment period is advantageous for these currencies, as the investor then receives more USD at the end of the final exchange. It is therefore essential to hedge against falling exchange rates for these currencies.

The Japanese yen and the Hong Kong dollar, on the other hand, are indirectly quoted. The exchange rate indicates how many units of the foreign currency are received for one unit of the USD. In this case, however, the portfolio value in the foreign currency must be divided by the current exchange rate. Rising exchange rates result in a loss at the end of the period. The investor with equity in these currencies should therefore hedge against rising exchange rates. To hedge the exchange rate risk, hedging through both forwards and futures was simulated.

4.3.1 Hedging exchange rate risk with currency forwards

For this purpose, the forward quotations of a 12-month forward from 01.03.2022 were used to simulate a currency forward. A forward contract was then concluded in the amount of the portfolio value of the respective currency. For example, the EUR/USD exchange rate on 01.03.2022 was 1.11 EUR/USD and the 12-month outright forward rate on the same day was 1.13 EUR/USD. This means that the investor secures the possibility of exchanging one EUR for 1.13 USD in 1 year. The value of the forward contract changes with the value of the spot price of the currency. Since in the case of the EUR/USD, as described above, a high exchange rate is profitable for the investor, the value of the forward contract increases when the exchange rate falls, as the investor has secured a better exchange rate. However, if the exchange rate rises above the forward rate, the investor has locked in a lower exchange rate and thus suffers losses. The opposite is true for indirectly quoted currencies. The value of the forward per unit over the term of the contract is therefore the difference between the forward price and the current spot price for the directly quoted currencies.

$$V_t = (F_0 - S_t) * PfV_0 \tag{16}$$

Since both the forward price and the spot price are quoted in USD per EUR, the result per EUR can then be multiplied by the EUR amount of the portfolio value for which the forward was concluded to obtain the total value of the forward.

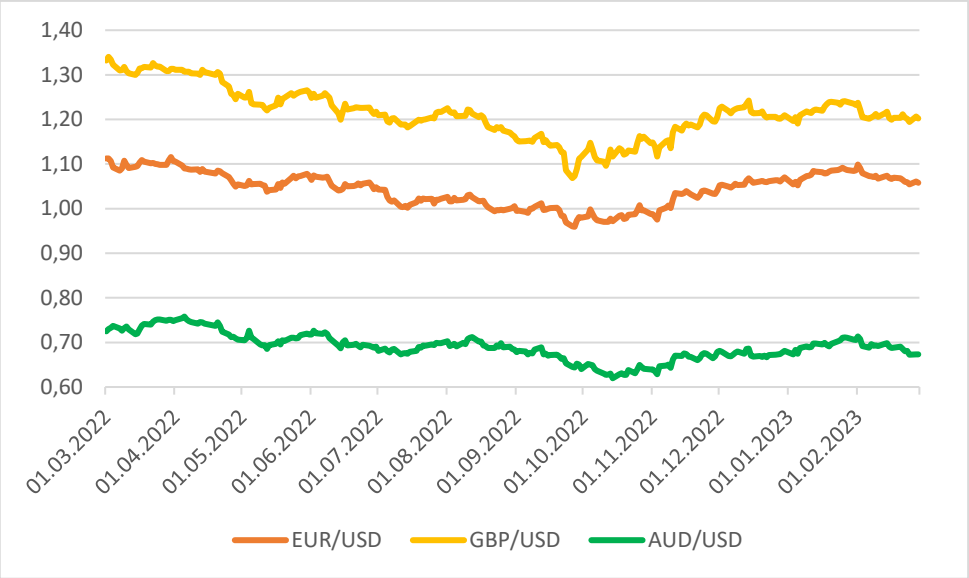

Figure 9 Exchange Rates Direct Quotations
Source: Own illustration

Figure 9 shows the exchange rates of the direct quotation currencies. It becomes evident that all three currencies have depreciated against the USD during the investment period, which means that their exchange rates have fallen. Since the forward was concluded precisely for this case, Figure 10 shows how this is reflected in the profit in USD per unit of the foreign currency. Figure 9 and Figure 10 therefore show an inverse pattern.

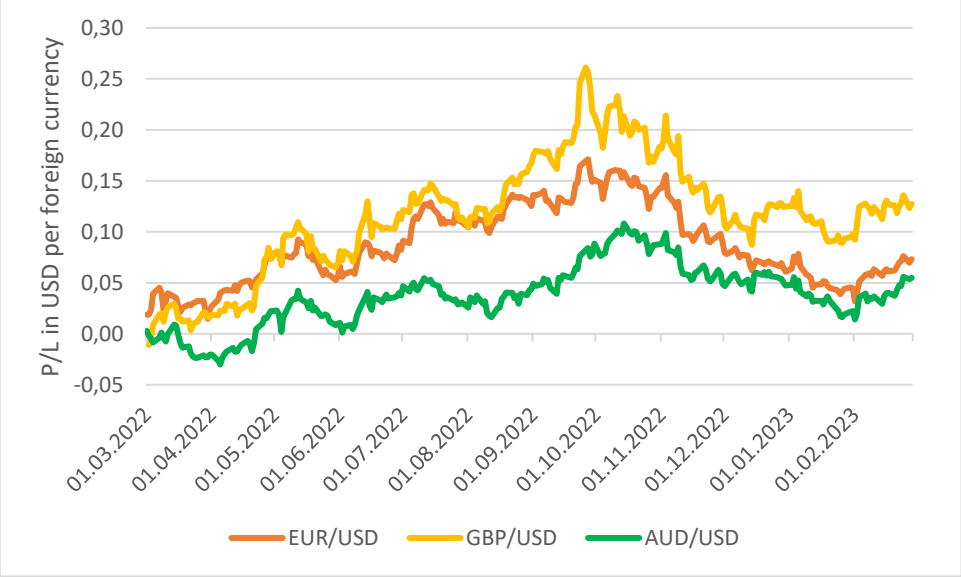

Figure 10 Profit and Loss of Currency Forwards
Source: Own illustration

Given the course of Figure 9 and Figure 10, one can see how the forward manages to reduce the exchange rate risk. The opposing movements ensure that the currency in which the investment was made does not matter in relative terms. The next question, however, is whether this is also the case for the portfolio values quoted in the three foreign currencies. For this purpose, the portfolio values were again calculated and compared with and without hedging through the currency forwards. Figure 11 shows this example for the EUR-denominated shares.

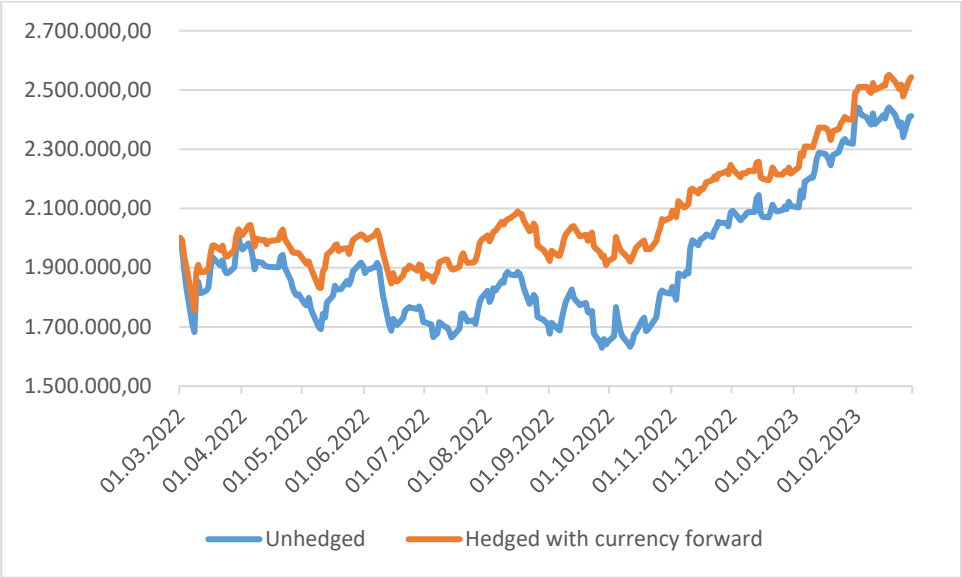

Figure 11 Euro Stocks Portfolio Value in USD
Source: Own illustration

Figure 11 shows that the portfolio values with and without hedging diverge more strongly in the summer/autumn of 2022. While the euro had depreciated strongly against the USD during this period and was at parity in the meantime, the investor benefited considerably from the protection of the forward. The line of the hedged portfolio therefore appears smoother. This is also reflected in the standard deviation of the daily returns of the portfolio value. While the standard deviation of the unhedged portfolio of EUR equities is 1.6785%, hedging reduces it by 26.50% to 1.2337%. The same can be said for the other two direct-quoted currencies such as the British pound and the Australian dollar. Here the standard deviation falls by 30.48% and 25.73% respectively. With regard to the minima and maxima of the portfolio values, it is also evident that hedging with currency forwards reduces the range and significantly increases the portfolio minima, i.e., lowers the downside risk.

Table 3 Portfolio Values Hedging Exchange Rate Risk with Forwards
Source: Own illustration

	Pf. Val. 01.03.2022	Pf. Val. 28.02.2023	Min	Max	Range
EUR unhedged	1,999,883 $	2,412,049 $	1,629,290 $	2,441,305 $	812,015 $
EUR currency forward		2,543,568 $	1,756,101 $	2,551,253 $	795,153 $
GBP unhedged	1,000,005 $	1,002,982 $	807,755 $	1,041,911 $	234,156 $
GBP currency forward		1,098,704 $	931,199 $	1,126,297 $	195,098 $
AUD unhedged	500,063 $	518,654 $	408,310 $	560,925 $	152,615 $
AUD currency forward		556,441 $	469,138 $	580,019 $	110,880 $

In terms of profitability, it can also be seen that the investor was more profitable by hedging with currency forwards compared to the unhedged situation. The portfolio value at the end of the investment period is 5.45% higher for the euro, 9.54% higher for the British pound and 7.29% higher for the Australian dollar compared to the unhedged portfolio.

For the indirectly quoted currencies such as the Hong Kong dollar and the Japanese yen, Equation 16 must be adjusted due to the inverse exchange rate. The value of the forward is calculated as follows:

$$V_t = \frac{PfV_0}{F_0} - \frac{PfV_0}{S_t} \tag{17}$$

Due to the inverse quotation and the fact that the investor benefits from lower exchange rates, the value of the forward at any given time is calculated as the difference obtained by applying the forward rate and the current spot rate. Therefore, the higher the current spot price of the exchange rate, the lower the value of the forward. Figure 12 shows the movement of the two exchange rates against the USD over the period under consideration.

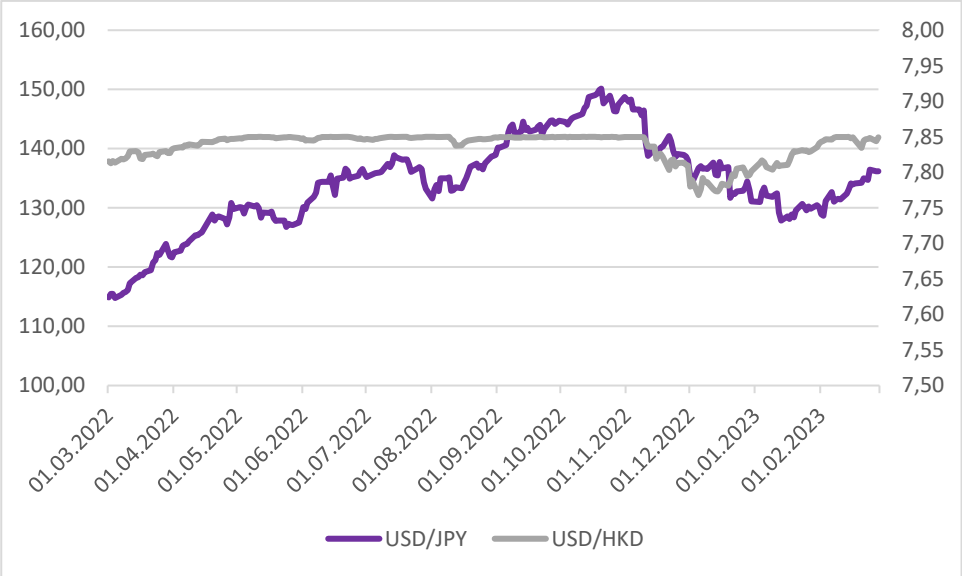

Figure 12 Exchange Rates Directly Quoted Currencies
Source: Own illustration

Since both currencies have very different absolute levels, they were plotted in a graph with two vertical axes. As described above, the Hong Kong dollar remains stable over time within the fixed range of 7.80 ± 0.05 USD/HKD, as it is pegged to the USD. Since an investment in indirectly quoted currencies is negative when the exchange rate rises, the forward hedges against this change in the exchange rates. This is especially the case with the floating currency of the Japanese yen, which rises from an initial 115 USD/JPY to almost 150 USD/JPY. As this unfavourable increase in the exchange rate was hedged by the forward, this forward was profitable over the period. This can be seen from the difference between the two lines in Figure 13.

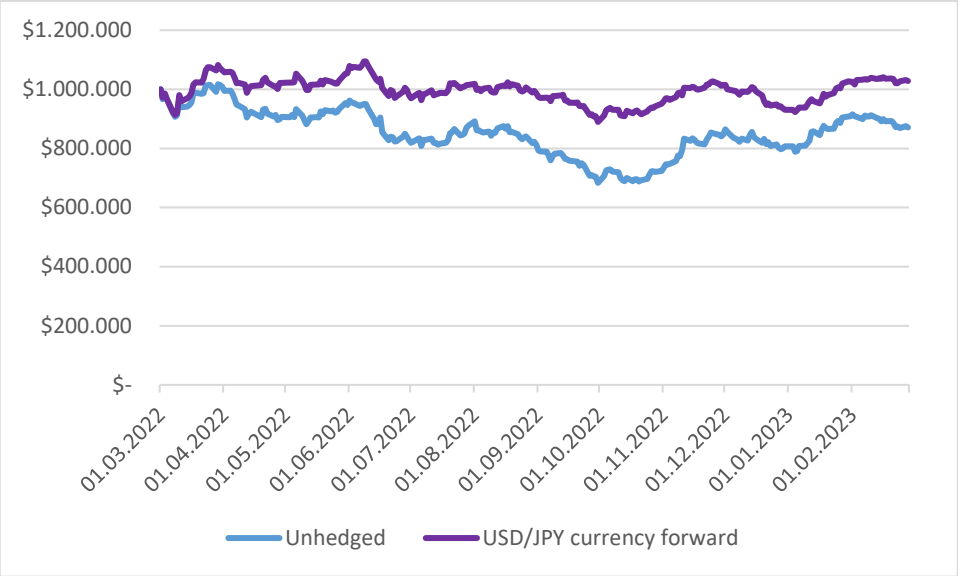

Figure 13 JPY Stock Portfolio Value in USD
Source: Own illustration

The fact that the forward has minimised the risk can again be seen graphically here. The portfolio value of the hedged portfolio of Japanese equities is clearly straighter along the 1 million USD line. The unhedged portfolio, on the other hand, has a clear downward dip in the autumn and generally fluctuates more strongly. This is also reflected in the standard deviations of the daily returns of the portfolio value. While the standard deviation of the unhedged portfolio is 1.5823%, the currency forward was able to reduce the standard deviation by 20.98% to 1.2503%.

The Hong Kong dollar, on the other hand, shows a different picture. We have already seen in Figure 12 (see above) that its exchange rate is stable due to pegging to the USD. Due to the exchange rate of 7.7932 USD/HKD fixed with the forward and the possible range of 7.80 ± 0.05 USD/HKD, the maximum loss of the forward from Equation 17 is as follows:

$$V_{\text{max. loss}} = \frac{15{,}630{,}969\ HKD}{7.7932\ USD/HKD} - \frac{15{,}630{,}969\ HKD}{7.75\ USD/HKD} = -11{,}179.49\ \text{USD} \quad (18)$$

The maximum profit by using 7.85 USD/HKD instead of 7.75 USD/HKD is 14,513.49 USD. With an initial portfolio value of 2 million USD, the maximum gain of the forward is therefore less than 1% of the portfolio value. Accordingly, the currency forward of the Hong Kong dollar has only a minor influence on the fluctuations of the portfolio value. Consequently, the graphs of the portfolio values of the unhedged portfolio and the portfolio hedged by the currency forward are almost congruent, as can be seen in

Figure 14.

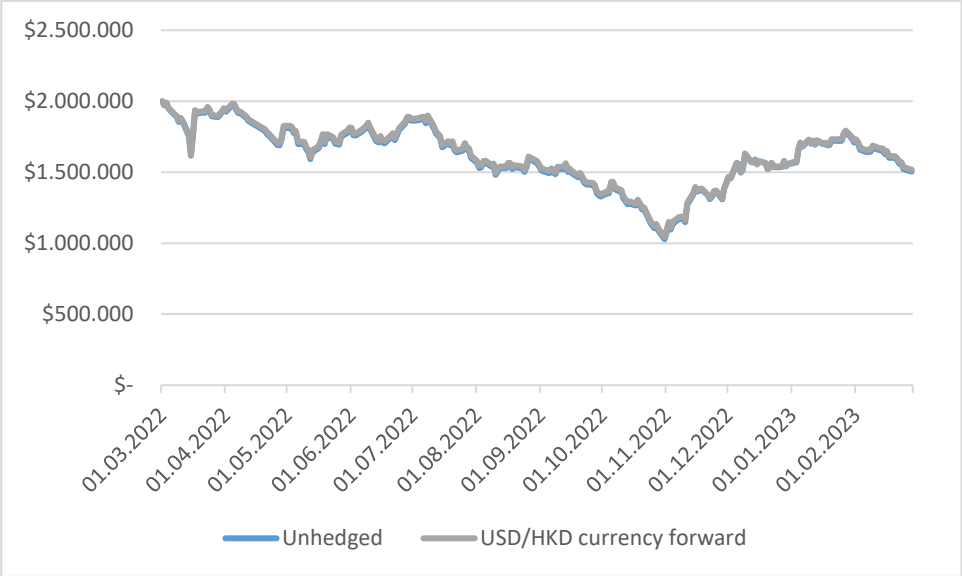

Figure 14 HKD Stocks Portfolio Value in USD
Source: Own illustration

This can also be seen in the standard deviation of the daily returns. Although the exchange rate has been stable, the Hong Kong shares have been quite volatile and have reached a minimum of almost half of the initial value of 2 million USD. As a result, the standard deviation of the daily returns of the shares in HKD is also the highest at 2.4415%. The use of the forward was able to reduce this, but only marginally to 2.4109%, i.e., by only 1.25%.

4.3.2 Hedging exchange rate risk with currency futures

The same principle was then used to simulate the hedging of exchange rate risks through the use of currency futures. Forwards and futures do not differ a lot, as examined in Chapter 2.5. However, futures are offered in standardised sizes and can therefore not be purchased exactly for the respective portfolio size.

The EUR/USD futures, for example, are offered in 125,000 EUR denominations. To determine the number of futures contracts, the portfolio value in euros as of 01.03.2022 must be divided by the contract size and then mathematically rounded up or down to a full number. As with the S&P 500, a futures contract for March 2023 is also suitable here. The settlement day is 13.03.2023 in each case.

As with the forward, investors in directly quoted currencies such as the euro, British pound and Australian dollar benefit from rising exchange rates and want to hedge against falling exchange rates. For this reason, short futures contracts must be concluded for these currencies and long futures for the Japanese yen and the Hong Kong dollar. The cumulative profit and loss function of a futures at any time during its life is therefore calculated as follows:

$$P/L_{short} = N * (F_0 - F_t) * M \quad (19)$$

$$P/L_{long} = N * (F_t - F_0) * M \quad (20)$$

In this case, the letter M stands for the point value. The point value is specified in the contract details as the dollar equivalent of the contract size. This means, for example, that a change in the EUR/USD futures price by one point means a profit or loss of 125,000 USD. Since the futures are very similar to the forwards in Chapter 4.3.1, the profit and loss functions of the two derivatives are very similar as well. For this reason, the individual currency futures are not examined in as much detail as in the previous Chapter, as the effect remains the same. The currency futures were able to reduce the standard deviation of the portfolio's returns to a similar extent.

Table 4 Standard Deviations Hedging Exchange Rate Risk with Forwards and Futures
Source: Own illustration

Currency	Derivative	Unhedged	Hedged	%-change
EUR	Forward	1.6785%	1.2337%	26.50%
	Future	1.6785%	1.2790%	23.80%
GBP	Forward	1.4503%	1.0082%	30.48%
	Future	1.4503%	1.0165%	29.91%
AUD	Forward	1.6301%	1.2107%	25.73%
	Future	1.6301%	1.2244%	24.89%
JPY	Forward	1.5823%	1.2503%	20.98%
	Future	1.5823%	1.2510%	20.94%
HKD	Forward	2.4415%	2.4109%	1.25%
	Future	2.4415%	2.4309%	0.43%

Table 4 therefore summarises the results of hedging in terms of the standard deviation of the portfolio's returns and compares the effectiveness of forwards and futures. Looking at the last column, it is clear that forwards and futures have reduced risk by a very similar percentage. It is also apparent that in all cases the currency forward has performed minimally better than the future in reducing risk in terms of the standard deviation of returns. But the differences between the two derivatives are marginal.

Table 5 Portfolio Values Hedging Exchange Rate Risk with Forwards and Futures
Source: Own illustration

	Pf. Val. 01.03.2022	Pf. Val. 28.02.2023	Min	Max	Range
EUR unhedged	1,999,883 $	2,412,049 $	1,629,290 $	2,441,305 $	812,015 $
EUR forward		2,543,568 $	1,756,101 $	2,551,253 $	795,153 $
EUR future		2,505,674 $	1,720,966 $	2,514,105 $	793,139 $
GBP unhedged	1,000,005 $	1,002,982 $	807,755 $	1,041,911 $	234,156 $
GBP forward		1,098,704 $	931,199 $	1,126,297 $	195,098 $
GBP future		1,097,107 $	932,453 $	1,126,736 $	194,283 $
AUD unhedged	500,063 $	518,654 $	408,310 $	560,925 $	152,615 $
AUD forward		556,441 $	469,138 $	580,019 $	110,880 $
AUD future		554,424 $	466,534 $	576,097 $	109,562 $
JPY unhedged	1,000,029 $	871,395 $	683,549 $	1,017,295 $	333,746 $
JPY forward		1,027,815 $	889,636 $	1,094,609 $	204,972 $
JPY future		1,023,213 $	885,149 $	1,091,808 $	206,659 $
HKD unhedged	1,999,996 $	1,503,606 $	1,027,552 $	1,999,996 $	972,444 $
HKD forward		1,518,094 $	1,042,040 $	1,999,996 $	957,956 $
HKD future		1,516,398 $	1,040,812 $	1,999,840 $	959,028 $

A similar picture emerges when comparing the portfolio values and their minima and maxima as well as the range. Both the forwards and the futures were able to increase the portfolio minima and reduce the range. A positive conclusion can also be drawn with regard to the profitability of hedging. All forwards and futures generated profits and a positive return, while the forwards worked out slightly better in terms of profitability.

Table 6 Profitability of hedging exchange rate risk
Source: Own illustration

	P/L	%-return
EUR forward	131.518 $	6,58%
EUR future	93.625 $	4,68%
GBP forward	95.722 $	9,57%
GBP future	94.125 $	9,41%
AUD forward	37.787 $	7,56%
AUD future	35.770 $	7,15%
JPY forward	156.419 $	15,64%
JPY future	151.819 $	15,18%
HKD forward	14.488 $	0,72%
HKD future	12.792 $	0,64%

After the various currencies of the portfolio were considered separately, the next step was to consider hedging through currency forwards and futures for the entire portfolio. For this purpose, the profit and loss figures of the forwards and futures were aggregated, and the portfolio values were compared with the unhedged situation.

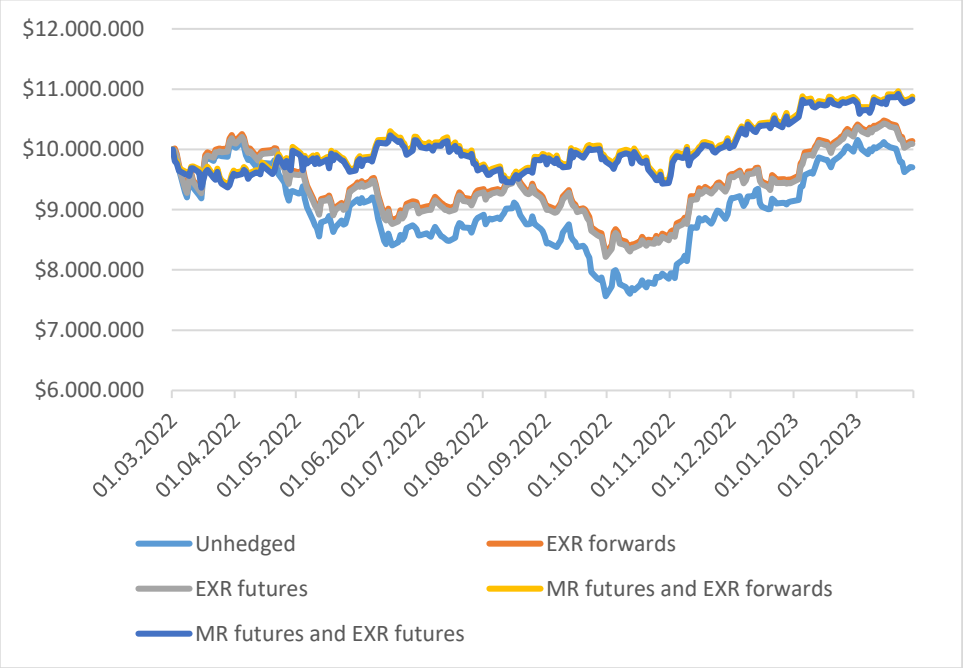

Figure 15 Hedging all Exchange Rate Risks simultaneously
Source: Own illustration

Figure 15 shows that the difference between hedging with forwards and futures is negligible, as both lines are almost congruent. However, it can be seen that hedging the exchange rate

risk with both forwards and futures leads to smoothed portfolio values. If the exchange rate hedging is subsequently combined with the hedging of the market risk, this additionally smoothes the portfolio. The standard deviation can also be reduced by hedging all currencies simultaneously. A combination of hedging the exchange rate risk and the market risk results in the greatest possible reduction in the standard deviation and thus the risk. Simultaneous hedging of market and exchange rate risk therefore reduces the standard deviation more than if only one of the two is hedged.

Table 7 Standard Deviations Hedging all Exchange Rate Risks and Market Risk
Source: Own illustration

	Derivative	Unhedged	Hedged	%-change
Hedging all EXR	Forward	1.2033%	0.9939%	-17.40%
	Future	1.2033%	1.0049%	-16.49%
Hedging all EXR + MR	Forward	1.2033%	0.9247%	-23.16%
	Future	1.2033%	0.9218%	-23.40%

4.4 Hedging exchange rate risk of the bond portfolio

As there are three bonds in the portfolio that are not denominated in USD, these are also subject to exchange rate risk. In order to hedge against this risk, a similar approach was taken as for the stock portfolio in Chapter 4.3 and fictitious forwards and futures for the three currencies (EUR, GBP and JPY) were acquired. The number of futures and forwards only had to be adjusted to the portfolio values of the foreign currencies.

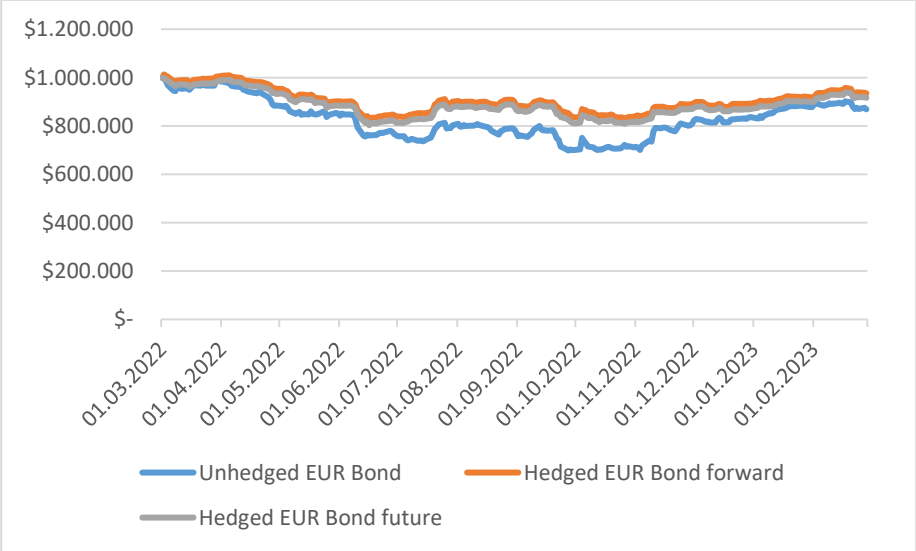

Figure 16 Hedging Exchange Rate Risk of the EUR Bond
Source: Own illustration

Figure 16 illustrates the values of the EUR-nominated corporate bond with and without hedging. A similar picture emerges for the Japanese and British government bonds. Since, as already seen in Chapter 4.3.1 and 4.3.2, the forwards and futures have made profits based on the exchange rate development of the period under consideration, the line is above the unhedged situation. The fact that the forwards and futures smooth the portfolio returns can also be proven in numbers. The standard deviation of the daily returns could be reduced by between 34 and 93% through the exchange rate forwards and futures. The results are shown in Table 8.

Table 8 Standard Deviations Hedging Exchange Rate Risks of Bonds with Forwards and Futures
Source: Own illustration

	Derivative	Unhedged	Hedged	%-change
EUR	Forward	1.1868%	0.7010%	-40.93%
	Future	1.1868%	0.7433%	-37.37%
GBP	Forward	2.9310%	1.9465%	-33.59%
	Future	2.9310%	1.9447%	-33.65%
JPY	Forward	0.8115%	0.0542%	-93.33%
	Future	0.8115%	0.1578%	-80.55%

It is striking that the hedging of the Japanese bond in particular has worked extraordinarily well and has been able to reduce the standard deviation tremendously. This is also underlined by the values in Table 9. Hedging through currency forwards and futures was able to reduce the range of portfolio values for all currencies, but especially significant for the Japanese bond. As can be seen by comparing the portfolio endvalues, both derivatives were able to generate profits, with the forwards being more profitable in each case.

Table 9 Portfolio Values Hedging Exchange Rate Risks of Bonds with Forwards and Futures
Source: Own illustration

		Pf. Val. 01.03.2022	Pf. Val. 28.02.2023	Min	Max	Range
EUR	Unhedged	999,846 $	869,109 $	698,275 $	999,846 $	301,570 $
	Forward	999,846 $	934,862 $	828,614 $	1,013,056 $	184,443 $
	Future	999,846 $	915,922 $	802,694 $	999,846 $	197,151 $
GBP	Unhedged	1,000,000 $	484,125 $	357,045 $	1,000,000 $	642,955 $
	Forward	1,000,000 $	579,847 $	548,455 $	1,000,000 $	451,545 $
	Future	1,000,000 $	578,250 $	547,822 $	1,000,000 $	452,178 $
JPY	Unhedged	999,792 $	842,413 $	764,740 $	1,000,920 $	236,180 $
	Forward	999,792 $	998,796 $	998,001 $	1,001,607 $	3,606 $
	Future	999,792 $	994,232 $	989,843 $	1,001,285 $	11,442 $

In addition to the exchange rate risk to which the bonds are subject due to their different currencies, they are also subject to interest rate risk, which is considered in the following chapter.

4.5 Hedging interest rate risk of the bond portfolio

As explained in Chapter 2.4.2.3, fixed rate bonds are subject to the risk of changing interest rates on the market. Bond prices have an inverse relationship to interest rates. Rising interest rates cause bonds with a fixed rate to become relatively less attractive and bond prices to fall as a result. This leads to a lower portfolio value against which investors try to protect themselves.

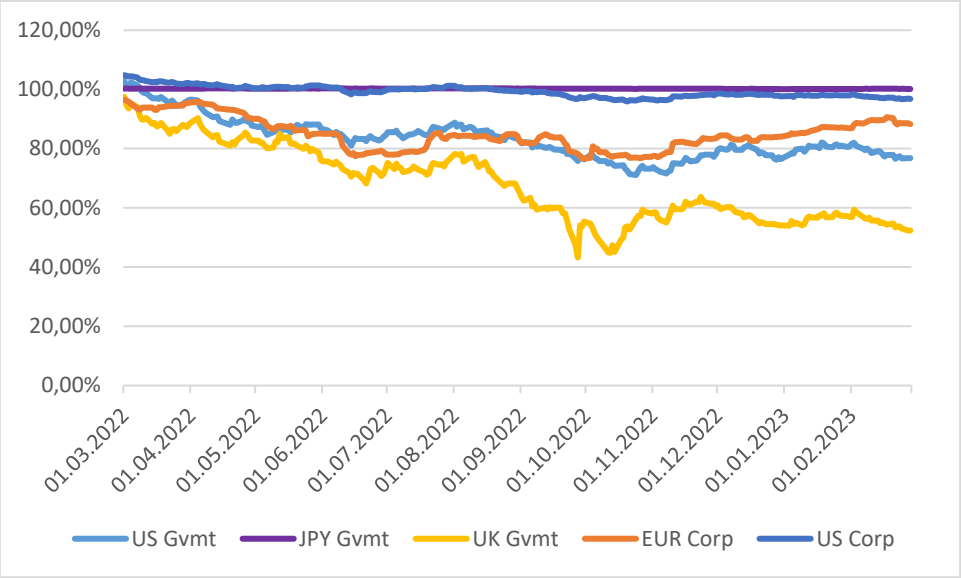

Figure 17 Bond-Prices in % over Investment Period
Source: Own illustration

Figure 17 shows the bond prices of the five bonds in percent over the investment period. The Japanese government bond and the US corporate bond have remained relatively stable, while the prices of the UK government bond, for example, have collapsed significantly. In the theoretical part we have already seen that bonds with a low coupon rate and a long maturity tend to be more affected by interest rate risk. In order to be able to compare this effectively, this presupposes of course that the bonds only differ in their maturity or coupon rate and are identical in all other criteria as for example creditworthiness. Since this is not the case here, this thesis cannot be examined properly. However, tendencies can be identified, the UK Government Bond has the longest maturity of almost 30 years and the second lowest coupon rate. Accordingly, it is not surprising that this bond is particularly affected by the price risk of interest rate changes.

There are various possibilities to hedge the interest rate risk of bonds. In the following, the hedging of interest rate risk will be analysed using different futures. To hedge the interest rate risk of bonds from the US, the acquisition of Eurodollar futures was simulated. The Eurodollar futures quotes are based on the three-month USD LIBOR interest rate and are quoted inversely (Hull, 2021). This means that they are expressed as 100 minus the three-month USD LIBOR rate. The three-month USD LIBOR rate is the reference rate which is determined by the average interest rate certain banks in London borrow USD from each other for three months. A contract is for one million USD with a value of 2,500 USD per

point movement of the futures quote. As there are bonds in the portfolio amounting to two million USD, two futures were purchased.

Since the prices are quoted inversely, the Eurodollar rate falls when the three-month USD LIBOR rate rises and vice versa. An investor who wants to hedge against rising interest rates must therefore buy Eurodollar short contracts, as this allows them to profit from rising interest rates. For the EUR-denominated bond, three-month EURIBOR futures were used instead of Eurodollar futures. This is the interest rate at which European banks lend money to each other. The UK government bond is hedged using three-month SONIA (Sterling Overnight Index Average) futures. SONIA is the average interest rate at which banks lend sterling overnight (Bank of England, 2023). The Japanese government bond will be hedged using three-month EUROYEN futures, which are based on a similar principle as Eurodollar futures on the interest rates on deposits held outside Japan in Japanese yen.

The EURIBOR and SONIA futures are for one million euros and British pounds respectively, and the EUROYEN futures for 100 million yen. Given the exchange rates to the USD, this does not correspond exactly to the principal amount of the bonds held, but it comes quite close. For this reason, one contract of each of these futures was acquired.

All these futures are based on the interest rates for three-month deposits and are due in March 2023, so they are covering the entire holding period. It was therefore decided to hedge the interest rate risk of the bonds with the short-term futures described above due to the similarity of the futures and the availability of the data. In addition, short-term interest rates are influenced more by monetary policy, while long-term interest rates are influenced more by market participants' expectations of future macroeconomic developments (Deutsche Bundesbank, 2006).

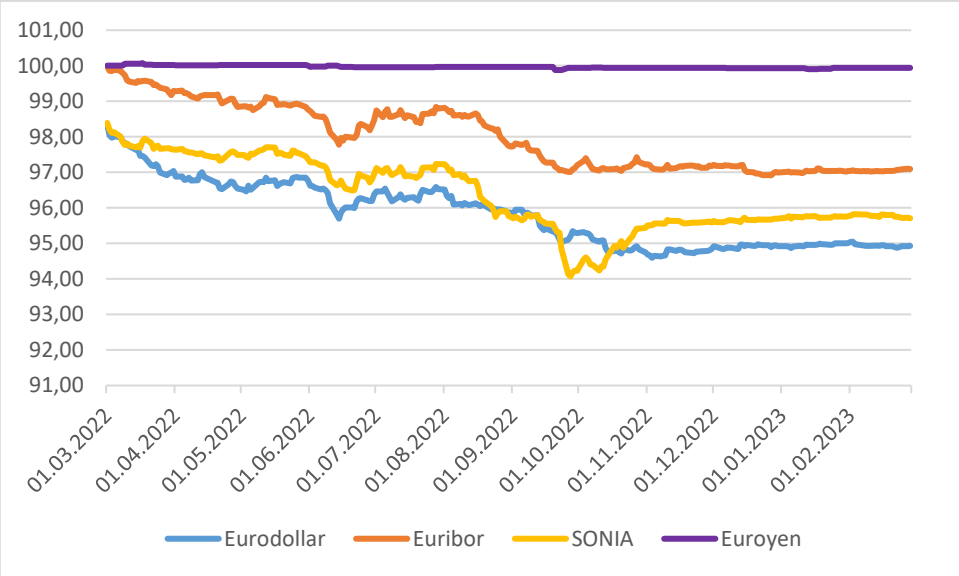

Figure 18 Interest Rate Futures Quotations in percent
Source: Own illustration

Figure 18 shows the futures quotations over the investment period. The EUROYEN futures prices have only fallen minimally over the period and have remained largely stable. For the remaining futures, it can be seen that the rise in short-term interest rates has caused prices to fall due to the inverse quotation of the futures prices. Due to the short futures contracts, this price movement has led to profits. The Eurodollar rate fell by about 3.4 points in the period under consideration. The profit or loss is accordingly calculated as in Equation 19. A comparison of the unhedged bond portfolio and the Eurodollar contract is shown in Figure 19.

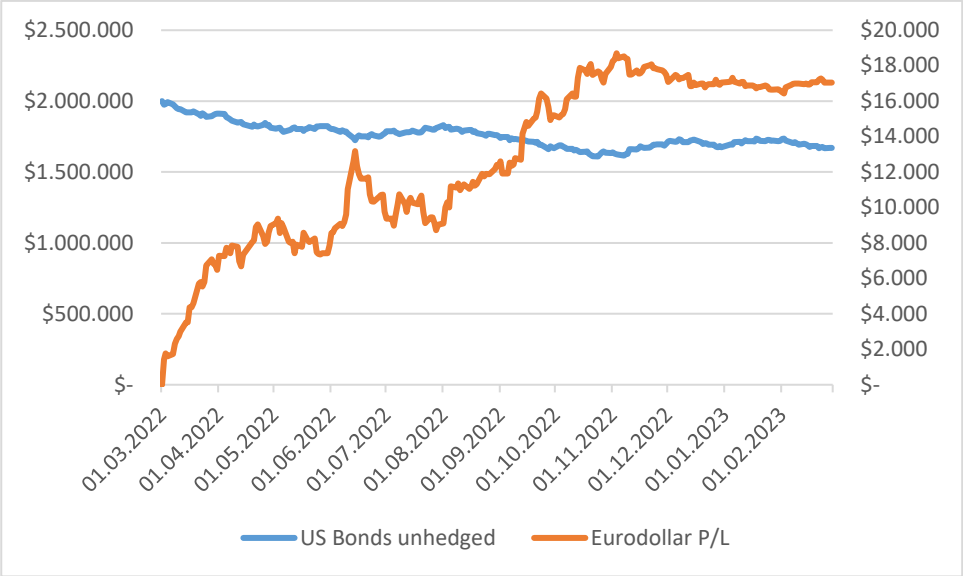

Figure 19 Hedging Interest Rate Risk of the US Bonds
Source: Own illustration

While the value of the unhedged bond portfolio decreases over the period, the profit of the Eurodollar futures increases at the same time. However, it is important to note the different absolute levels and thereby the two scales. The maximum gain of the Eurodollar futures is 18,700 USD, which is only about 1% of the value of the US bonds. As a result, the futures contract was only marginally able to reduce the standard deviation of the daily bond returns. A similar picture emerges for the other bonds and related futures, which is shown in Table 10. For the Japanese government bond, on the other hand, the future even slightly increased the standard deviation and thus the risk.

Table 10 Standard Deviations Hedging Interest Rate Risk
Source: Own illustration

	Unhedged	Hedged	%-change
US	0.5814%	0.5642%	-2.9662%
EUR	0.8093%	0.7999%	-1.1651%
GBP	2.6514%	2.5653%	-3.2487%
JPY	0.0119%	0.0122%	+2.1524%

In order to assess whether the number of futures contracts was the only reason why the standard deviation could not be reduced, the optimal number of futures contracts that would have minimised the standard deviation was subsequently calculated using the Excel solver. In fact, a larger number of futures would have minimised the risk for all bonds. For the US and UK bonds, increasing the number of futures contracts to 36 and 47, respectively, would

have been optimal and would have been able to reduce the standard deviation by 28.72% and 49.15%, respectively. For the euro area corporate bond and the Japanese bond, the inefficiency of the futures was not primarily due to their number of contracts. Rather, not even an optimal number of contracts determined by the solver in retrospect would have been able to reduce the standard deviation significantly, or not at all for the Japanese bond (see Appendix 6).

After the stock portfolio and the bond portfolio as well as the risks have been considered separately in the previous chapters, the entire portfolio will now be simultaneously hedged against market risk, exchange rate risk and interest rate risk.

4.6 Hedging all systematic risks of the whole portfolio

In order to examine the aggregated portfolio, the profit and loss values of the S&P500 futures, the currency forwards and futures, and the interest rate futures were summed up and added to the unhedged portfolio values. Since the exchange rate risk can be hedged with either currency forwards or futures, a distinction is made between the two alternatives in Figure 20 and Table 11.

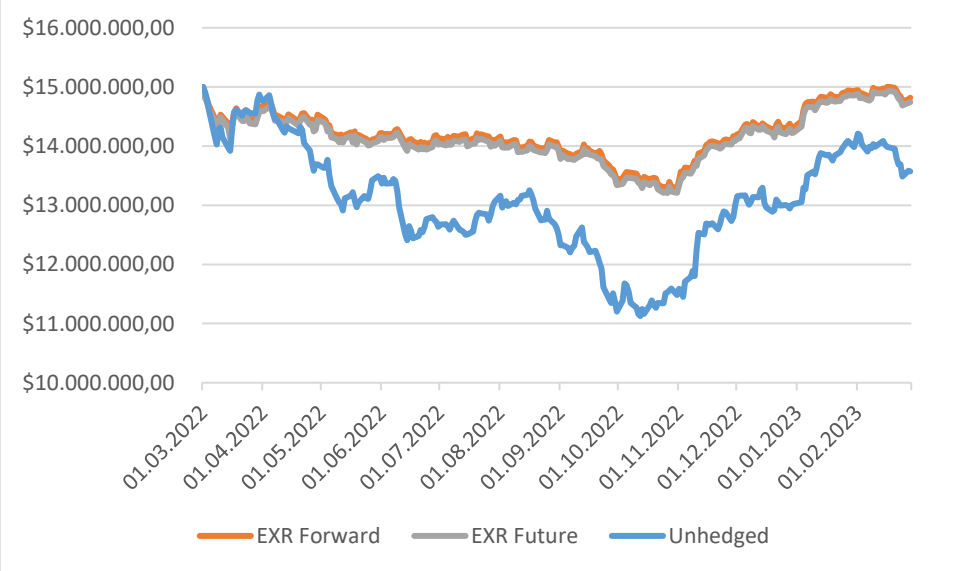

Figure 20 Hedging all Risks simultaneously for the entire Portfolio
Source: Own illustration

Table 11 Portfolio Values and St.Dev. Hedging all Risks simultaneously for the entire Portfolio
Source: Own illustration

	Pf. Val. 01.03.22	Pf. Val. 28.02.23	Min	Max	Range	St.Dev.
Unhedged	14,999,645 $	13,570,479 $	11,127,044 $	14,999,645 $	3,872,601 $	0.9634%
Forward		14,816,648 $	13,289,322 $	15,000,693 $	1,711,372 $	0.4900%
Future		14,743,741 $	13,206,620 $	14,999,489 $	1,792,869 $	0.4912%

Looking at both Figure 20 and Table 11, it can be seen that the simultaneous hedging of the entire portfolio worked very effectively. In both cases, the volatility of the portfolio returns was almost reduced by 50%. The portfolio minima increased by approximately 2 million USD as a result of the simultaneous hedging, which is also expressed in a range that is cut by more than half. A positive conclusion can also be drawn with regard to profitability, even if the portfolio value at the end of the investment period is slightly below the starting value. Using the currency forwards results in a profit of 1,246,169 USD and using the futures in a profit of 1,173,262 USD compared to the unhedged situation. The simultaneous hedging of all risks was thus both risk-minimising and profitable for the securities examined in the investment period.

A large part of the profitability of the hedging can be explained by the rise in interest rates in 2022. In response to the increase in inflation, the central banks around the world have raised key interest rates to stabilise the price level. Since hedging the interest rate risk of the bonds was done to protect against increasing interest rates, the offsetting futures generated profits. Furthermore, different interest rate levels have an impact on exchange rates. If interest rates rise in a country, capital is attracted and increases the demand for the domestic currency, which causes the currency to appreciate. Since the Federal Reserve Bank has already raised interest rates comparatively early and significantly, this has increased the demand for the US dollar, which has led to its appreciation. Because investments in assets denominated in foreign currencies were hedged against the depreciation of these currencies, the corresponding currency forwards and futures generated profits and thus compensated for the exchange rate losses. Nevertheless, all available information was priced into the market prices of the financial markets at the time of the investment on 01.03.2022. Profitability

therefore depends on future macroeconomic developments, which are almost impossible to predict. For this reason, profitability was only secondary in this analysis, as the primary objective was to examine risk reduction.

5 Conclusion

This research gave an overview of the risks international investors are exposed to and identified strategies to manage or reduce them. It aimed to answer the questions whether diversification reduces portfolio risk and whether hedging with derivatives can reduce unsystematic risk such as market risk, exchange rate risk and interest rate risk.

First of all, a global diversification of the stock portfolio has proven to be an effective strategy for risk reduction in the applied backtesting. The diversified stock portfolio has a significantly lower volatility in the examined period. Secondly, the use of derivatives for hedging was, with few exceptions, able to lower the volatility and thus the risk of an investor. The hedging of market risk as well as the hedging of exchange rate risk of the stock and bond portfolios was significantly effective and reduced the volatility of the respective portfolio values. Simultaneous hedging of market and exchange rate risk had an additional risk-reducing effect for the stock portfolio. The hedging of interest rate risk, on the other hand, only worked to a minimal extent with the derivatives used, which in retrospect can partly be attributed to the contract size. Simultaneous hedging of all systematic risks for the entire portfolio was also able to almost reduce volatility by half and generate profits of over one million US dollars, thus underlining the effectiveness of hedging.

Nevertheless, this study is also subject to some limitations. One of the biggest limitations concerns the construction of the portfolios. The stock portfolio was limited to big sized companies with a market capitalization of bigger than 10 billion USD and, due to the amount of data to be analysed, to 24 stocks. The bond portfolio was limited to 5 bonds for the same reason. Although the analysis shows a general trend, it cannot be concluded that hedging would have worked just as effectively with different securities. Furthermore, the data had to be adjusted manually due to the different stock exchange opening hours and public holidays, which had a slight impact on the analysis. To simplify the analysis, various possible transaction costs, effects of taxes and the time value of money were omitted to ensure the generalisability of the results.

Future analysis or research could therefore focus on hedging small or mid capped companies, assets in currencies other than those under review, and a shorter or longer time horizon. An analysis of other hedging strategies, such as dynamic hedging, could also provide valuable insights into the effectiveness of derivatives in minimising risk.

Overall, the findings of this thesis provide valuable insights for investors and portfolio managers seeking to navigate through volatile and uncertain market conditions. The research has highlighted the importance of derivatives in hedging systematic risks and reducing portfolio volatility. By employing these instruments, the study has demonstrated that the portfolio's exposure to market fluctuations can be effectively controlled, resulting in a smoother return profile and a more stable investment performance. The study affirms the benefits of diversification as a risk reduction strategy, emphasizing the need to allocate investments across different asset classes and geographical regions.

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7 Appendix

Appendix 1 Standard Deviation of Currencies during Investment Period

	EUR /USD	GBP/USD	USD/JPY	AUD/USD	USD/HKD
St.Dev.	0.0062984	0.007989	0.0079415	0.0087903	0.0005379

Appendix 2 Stock Portfolio

	Stocks	Industry	Weight	Pf. Val. on 01.03.2022	St. Dev.	Beta
USA	Apple	Tech	8,75%	$ 875.078,40	0,0222	1,2800
35%	Walmart	Retail	8,75%	$ 874.959,66	0,0168	0,5250
USD	Boeing	Aircraft	8,75%	$ 874.950,99	0,0288	1,4400
	Nike	Clothing	8,75%	$ 875.031,96	0,0264	1,0900
Japan	Toyota motor	Cars	2,50%	$ 250.004,16	0,0165	0,5610
10%	Sony	Tech	2,50%	$ 249.971,49	0,0193	0,9330
JPY	Shin etsu chemical	Chemicals	2,50%	$ 250.047,87	0,0190	1,2500
	Komatsu	Manufactoring	2,50%	$ 250.005,38	0,0177	1,2500
UK	Unilever	Food	2,50%	$ 250.004,60	0,0130	0,1220
10%	Barclays	Bank	2,50%	$ 249.999,84	0,0203	1,3300
GBP	Vodafone	Telecommunication	2,50%	$ 250.000,54	0,0155	0,5520
	BP	Energy	2,50%	$ 250.000,41	0,0212	0,6370
Australia	Fortescue Metals Group	Mining	1,25%	$ 125.004,34	0,0274	0,9430
5%	TABCORP	Gambling	1,25%	$ 124.999,92	0,0180	0,8280
AUD	Cochlear	Medical devices	1,25%	$ 125.058,10	0,0171	0,4340
	Qantas	Airlines	1,25%	$ 125.000,95	0,0206	1,0100
China	AIA	Insurance	5,00%	$ 499.996,00	0,0250	0,9000
20%	Alibaba	E-Commerce	5,00%	$ 500.001,10	0,0451	0,6300
HKD	China Oilfield Services	Oil and Gas	5,00%	$ 500.000,14	0,0167	0,5650
	Longfor Group	Real estate	5,00%	$ 499.998,75	0,0552	0,9920
Euro Zone	LVMH	Luxury goods	5,00%	$ 499.918,33	0,0201	1,0200
20%	RWE	Energy	5,00%	$ 499.983,68	0,0199	0,7150
EUR	ABInBev	Beverages	5,00%	$ 499.986,06	0,0154	1,1000
	UniCredit	Bank	5,00%	$ 499.994,94	0,0293	1,7000
SUM			100,00%	$ 9.999.997,60	0,0242	0,9665

Appendix 3 Bond Portfolio

	Bond	Gov/Corp	Issuer	Curr/Area	Weight	Coupon ra	Frequency	Issue Date	Maturity	Denomination	Denomination	Price in %	# Bond shares	Pf Value
US Treasur	US Treasur	Gov	USA	USD	20,00%	2,375%	semiannu	28.02.202	15.02.2042	$ 100,00	$ 100,00	102,84%	9.723,00	$ 999.949,78
Japan Trea	Japan Trea	Gov	Japan	JPY	20,00%	0,100%	semiannu	04.09.201	20.03.2024	¥ 50.000,00	$ 435,20	100,28%	2.291,00	$ 999.792,48
UK GILT	UK GILT	Gov	UK	UK	20,00%	1,250%	semiannu	27.04.202	31.07.2051	£ 0,01	$ 0,01	97,51%	76.987.190,00	$1.000.000,00
Douglas	Douglas	Corp	Douglas	EUR	20,00%	6,000%	semiannu	26.03.202	08.04.2026	€ 1.000,00	$ 1.112,60	96,53%	931,00	$ 999.845,84
CVS Health	CVS Health	Corp	CVS	USD	20,00%	3,875%	semiannu	13.07.201	20.07.2025	$ 1.000,00	$ 1.000,00	104,83%	954,00	$1.000.059,12
SUM					100,00%									4.999.647,22

Appendix 4 Correlation Matrix Stock Portfolio

Apple	Walmart	Boeing	Nike	Toyota Mc	Sony	Shin-Etsu (	Komatsu L	Unilever P	Barclays P	Vodafone ı	BP PLC	Fortescue	TABCORP	Cochlear L	Qantas	AIA	Alibaba Gr	Hong Kon	Longfor Pr	LVMH Mo	RWE	Anheuser I	UniCredit
1																							
0,4677	1																						
0,4100	0,1554	1																					
0,5103	0,2747	0,5008	1																				
0,0964	0,0390	0,2576	0,2192	1																			
0,1857	0,1314	0,1941	0,2234	0,5019	1																		
0,1139	0,0051	0,2616	0,2391	0,5618	0,5258	1																	
0,0651	-0,0373	0,2931	0,1890	0,5555	0,3711	0,5615	1																
0,1795	0,2348	0,0736	0,2022	0,1661	0,0357	0,1426	0,0686	1															
0,2274	0,0448	0,5670	0,3842	0,2974	0,1956	0,2673	0,2904	0,1476	1														
0,2368	0,1684	0,3849	0,3334	0,2852	0,1842	0,1751	0,2101	0,4110	0,5194	1													
0,2055	0,0580	0,5233	0,3468	0,2638	0,1858	0,2612	0,3048	0,1933	0,6624	0,5074	1												
0,1224	0,1556	0,1431	0,1470	0,2165	0,2157	0,1692	0,1053	0,1462	0,2358	0,2394	0,2155	1											
0,0870	0,0811	0,0512	0,1624	0,0305	0,0807	0,0567	0,0580	0,0079	0,0512	0,0328	0,0179	-0,0048	1										
-0,0106	-0,1049	0,0258	0,0425	0,0377	0,0741	0,1188	0,0510	-0,0166	0,0372	0,0290	0,0670	-0,0001	0,0529	1									
0,0993	0,0106	0,2107	0,1877	0,1650	0,1508	0,1637	0,2970	0,0763	0,1784	0,1500	0,1403	0,0136	0,1644	0,1147	1								
-0,0361	-0,0672	0,0792	0,0847	0,1178	0,1051	0,1946	0,1627	0,0442	0,0636	0,0462	0,1052	0,0723	0,0147	0,1349	0,2033	1							
0,0637	0,0605	0,1402	0,1575	0,2293	0,2582	0,1907	0,1118	0,0737	0,1770	0,1150	0,1870	0,1791	0,0533	0,0546	0,0557	0,1321	1						
0,1330	0,0561	0,0908	0,2115	0,2254	0,0951	0,2013	0,1367	0,2100	0,1846	0,1348	0,1550	0,1807	0,1008	0,0214	0,0853	0,1906	0,0774	1					
0,0591	-0,0144	0,1133	0,1768	0,1355	0,1365	0,2250	0,1728	0,1031	0,2004	0,0579	0,1900	0,1665	0,0243	0,0107	0,0395	0,1600	0,2780	0,2189	1				
0,3585	0,1677	0,4619	0,4652	0,2962	0,2110	0,2703	0,2618	0,2652	0,5692	0,4374	0,5040	0,1564	0,0198	0,0514	0,1565	0,0864	0,2248	0,1451	0,2865	1			
0,0523	0,0218	0,0365	-0,0059	-0,0014	0,0092	-0,0124	-0,0401	-0,0045	0,0570	0,0558	0,0278	-0,0056	-0,0447	-0,0015	-0,0538	0,0419	0,0535	-0,0660	0,0346	0,0549	1		
0,2280	0,1158	0,4466	0,3118	0,2309	0,1404	0,2095	0,1794	0,2747	0,6504	0,4844	0,5514	0,1991	-0,0060	0,0635	0,1081	0,0821	0,2103	0,1598	0,2107	0,5756	0,0796	1	
0,0147	-0,0232	0,0669	0,0207	0,0406	0,0282	0,0536	0,0934	-0,0716	0,0477	0,0254	0,0763	-0,0187	0,0387	-0,0569	0,0958	0,0888	0,0221	0,0547	0,0822	-0,0222	-0,0408	0,0183	1

Appendix 5 Covariance Matrix Stock Portfolio

	Apple	Walmart	Boeing	Nike	Motor Corp	Sony	-Etsu Chen	omatsu Ltd	nilever PL	larclays PL	ufone Grou	BP PLC	ue Metals	TABCORP	ochlear Ltd	Qantas	AIA	Group Hol	and China	Properties	ennessy Lo	RWE	Busch Inb	UniCredit
Apple	0,000533	0,000168	0,000385	0,000255	0,000037	0,000087	0,000052	0,000030	0,000063	0,000154	0,000110	0,000136	0,000080	0,000082	-0,000006	0,000068	-0,000019	0,000041	0,000037	0,000031	0,000163	-0,000004	0,000141	0,000010
Walmart	0,000168	0,000243	0,000098	0,000093	0,000010	0,000042	0,000002	-0,000012	0,000056	0,000021	0,000053	0,000026	0,000069	0,000051	-0,000039	0,000005	-0,000024	0,000026	0,000011	-0,000005	0,000051	0,000012	0,000048	-0,000010
Boeing	0,000385	0,000098	0,001650	0,000440	0,000175	0,000160	0,000212	0,000239	0,000046	0,000676	0,000314	0,000610	0,000165	0,000084	0,000025	0,000254	0,000073	0,000158	0,000045	0,000105	0,000369	-0,000084	0,000485	0,000077
Nike	0,000255	0,000093	0,000440	0,000467	0,000079	0,000098	0,000103	0,000082	0,000067	0,000244	0,000145	0,000215	0,000090	0,000143	0,000022	0,000120	0,000041	0,000094	0,000056	0,000087	0,000198	-0,000031	0,000180	0,000013
Toyota Mc	0,000037	0,000010	0,000175	0,000079	0,000279	0,000170	0,000187	0,000186	0,000042	0,000146	0,000096	0,000126	0,000103	0,000021	0,000015	0,000082	0,000044	0,000106	0,000046	0,000052	0,000097	0,000008	0,000103	0,000019
Sony	0,000087	0,000042	0,000160	0,000098	0,000170	0,000411	0,000212	0,000151	0,000011	0,000116	0,000075	0,000108	0,000124	0,000066	0,000036	0,000091	0,000048	0,000145	0,000023	0,000063	0,000084	-0,000002	0,000076	0,000016
Shin-Etsu (	0,000052	0,000002	0,000212	0,000103	0,000187	0,000212	0,000396	0,000224	0,000043	0,000156	0,000070	0,000149	0,000096	0,000046	0,000056	0,000097	0,000087	0,000105	0,000049	0,000102	0,000106	-0,000002	0,000112	0,000030
Komatsu L	0,000030	-0,000012	0,000239	0,000082	0,000186	0,000151	0,000224	0,000402	0,000021	0,000171	0,000084	0,000175	0,000060	0,000047	0,000024	0,000176	0,000074	0,000062	0,000033	0,000079	0,000103	0,000017	0,000096	0,000053
Unilever P	0,000063	0,000056	0,000046	0,000067	0,000042	0,000011	0,000043	0,000021	0,000233	0,000066	0,000126	0,000085	0,000063	0,000005	-0,000006	0,000035	0,000015	0,000031	0,000039	0,000036	0,000080	-0,000014	0,000112	-0,000031
Barclays Pl	0,000154	0,000021	0,000676	0,000244	0,000146	0,000116	0,000156	0,000171	0,000066	0,000862	0,000306	0,000558	0,000196	0,000061	0,000026	0,000155	0,000042	0,000144	0,000066	0,000134	0,000328	-0,000033	0,000511	0,000040
Vodafone	0,000110	0,000053	0,000314	0,000145	0,000096	0,000075	0,000070	0,000084	0,000126	0,000306	0,000402	0,000292	0,000136	0,000027	0,000014	0,000089	0,000021	0,000064	0,000033	0,000027	0,000173	-0,000038	0,000260	0,000014
BP PLC	0,000136	0,000026	0,000610	0,000215	0,000126	0,000108	0,000149	0,000175	0,000085	0,000558	0,000292	0,000823	0,000175	0,000021	0,000046	0,000119	0,000068	0,000149	0,000054	0,000125	0,000284	-0,000043	0,000423	0,000062
Fortescue	0,000080	0,000069	0,000165	0,000090	0,000103	0,000124	0,000096	0,000060	0,000063	0,000196	0,000136	0,000175	0,000806	-0,000006	0,000000	0,000011	0,000046	0,000141	0,000062	0,000108	0,000087	-0,000014	0,000151	-0,000015
TABCORP	0,000082	0,000051	0,000084	0,000143	0,000021	0,000066	0,000046	0,000047	0,000005	0,000061	0,000027	0,000021	-0,000006	0,001648	0,000051	0,000198	0,000013	0,000060	0,000050	0,000023	0,000016	0,000066	-0,000007	0,000044
Cochlear L	-0,000006	-0,000039	0,000025	0,000022	0,000015	0,000036	0,000056	0,000024	-0,000006	0,000026	0,000014	0,000046	0,000000	0,000051	0,000568	0,000081	0,000072	0,000036	0,000006	0,000006	0,000024	0,000024	0,000041	-0,000038
Qantas	0,000068	0,000005	0,000254	0,000120	0,000082	0,000091	0,000097	0,000176	0,000035	0,000155	0,000089	0,000119	0,000011	0,000198	0,000081	0,000879	0,000136	0,000046	0,000031	0,000027	0,000091	0,000055	0,000086	0,000080
AIA	-0,000019	-0,000024	0,000073	0,000041	0,000044	0,000048	0,000087	0,000074	0,000015	0,000042	0,000021	0,000068	0,000046	0,000013	0,000072	0,000136	0,000508	0,000083	0,000052	0,000082	0,000038	-0,000017	0,000050	0,000057
Alibaba Gr	0,000041	0,000026	0,000158	0,000094	0,000106	0,000145	0,000105	0,000062	0,000031	0,000144	0,000064	0,000149	0,000141	0,000060	0,000036	0,000046	0,000083	0,000770	0,000026	0,000176	0,000123	0,000032	0,000156	0,000017
Hong Kong	0,000037	0,000011	0,000045	0,000056	0,000046	0,000023	0,000049	0,000033	0,000039	0,000066	0,000033	0,000054	0,000062	0,000050	0,000006	0,000031	0,000052	0,000026	0,000148	0,000061	0,000035	0,000035	0,000052	0,000019
Longfor Pr	0,000031	-0,000005	0,000105	0,000087	0,000052	0,000063	0,000102	0,000079	0,000036	0,000134	0,000027	0,000125	0,000108	0,000023	0,000006	0,000027	0,000082	0,000176	0,000061	0,000522	0,000129	-0,000028	0,000129	0,000053
LVMH Mo	0,000163	0,000051	0,000369	0,000198	0,000097	0,000084	0,000106	0,000103	0,000080	0,000328	0,000173	0,000284	0,000087	0,000016	0,000024	0,000091	0,000038	0,000123	0,000035	0,000129	0,000386	-0,000001	0,000303	-0,000012
RWE	-0,000004	0,000012	-0,000084	-0,000031	0,000008	-0,000002	-0,000002	0,000017	-0,000014	-0,000033	-0,000038	-0,000043	-0,000014	0,000066	0,000024	0,000055	-0,000017	0,000032	0,000035	-0,000028	-0,000001	0,000222	-0,000006	0,000106
Anheuser	0,000141	0,000048	0,000485	0,000180	0,000103	0,000076	0,000112	0,000096	0,000112	0,000511	0,000260	0,000423	0,000151	-0,000007	0,000041	0,000086	0,000050	0,000156	0,000052	0,000129	0,000303	-0,000006	0,000716	0,000014
UniCredit	0,000010	-0,000010	0,000077	0,000013	0,000019	0,000016	0,000030	0,000053	-0,000031	0,000040	0,000014	0,000062	-0,000015	0,000044	-0,000038	0,000080	0,000057	0,000017	0,000019	0,000053	-0,000012	0,000106	0,000014	0,000798

Appendix 6 Optimal Number of Contracts for Hedging Interest Rate Risk Excel-Solver

Solver	#contracts	Unhedged	Hedged	Difference	% change
US	36	0.005814	0.004140	0.001670	28.72%
EUR	14	0.008093	0.011352	0.000520	6.43%
GBP	47	0.029310	0.014905	0.014405	49.15%
JPY	0	0.000119	0.000119	0	0.00%