Radboud University

Master's Thesis:

Finding the new risk-free asset

An investigation of gold, wine and corporate bonds as alternatives to government bonds

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Abstract:

This thesis sets out to find the risk-free asset. In the literature, this concept is often seen as a given and operationalized by government bond yields. This thesis first deconstructs the theoretical concept of the risk-free asset, then evaluates government bonds and gold, wine and corporate bonds as possible alternatives. Then these proxies are tested on their effectiveness in a theoretical model (CAPM) and their functioning in a Markowitz-inspired portfolio. The main finding is that corporate bonds pose as a promising alternative to government bonds as operationalization of the risk-free asset.

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Introduction

The risk-free asset is a theoretical concept that lies at the heart of several important theories in finance. It was integrated in modern portfolio theory (Markowitz, 1952), the capital asset pricing model(Lintner, 1965; Mossin, 1966; Sharpe, 1964), the Fama and French factor models (Fama & French, 1993, 2015) and other well-known models like the Black-Scholes-Merton (Fisher Black & Scholes, 1973) and the Sharpe Ratio (Sharpe, 1966). In modern portfolio theory (MPT), the risk-free asset is one of two investment categories and as such should be a significant part of investor portfolios. In the capital asset pricing model (CAPM), asset prices are dictated by their excess return over the risk-free return. Due to its importance, it is interesting to find that little is known about the risk-free asset.

Shortly after the introduction of CAPM, some attempts to find the correct risk-free asset were made, despite some authors arguing that the predictions do not materially change regardless of the risk-free asset chosen (Roll, 1969). These authors challenged the leading perception that the risk-free rate was a given, but failed to find a better operationalization than government bonds. Financial markets have developed since however, and there is a larger investable universe now. Therefore, it seems like the right time to find the new risk-free asset.

This search will take place in several steps. First, to determine what operationalization of the risk-free asset would be the best, it is important to find what the theoretical concept of the risk-free asset is. The first research question of this thesis thus is:

RQ1: 'What is the risk-free asset and what is an appropriate operationalization of this asset?'

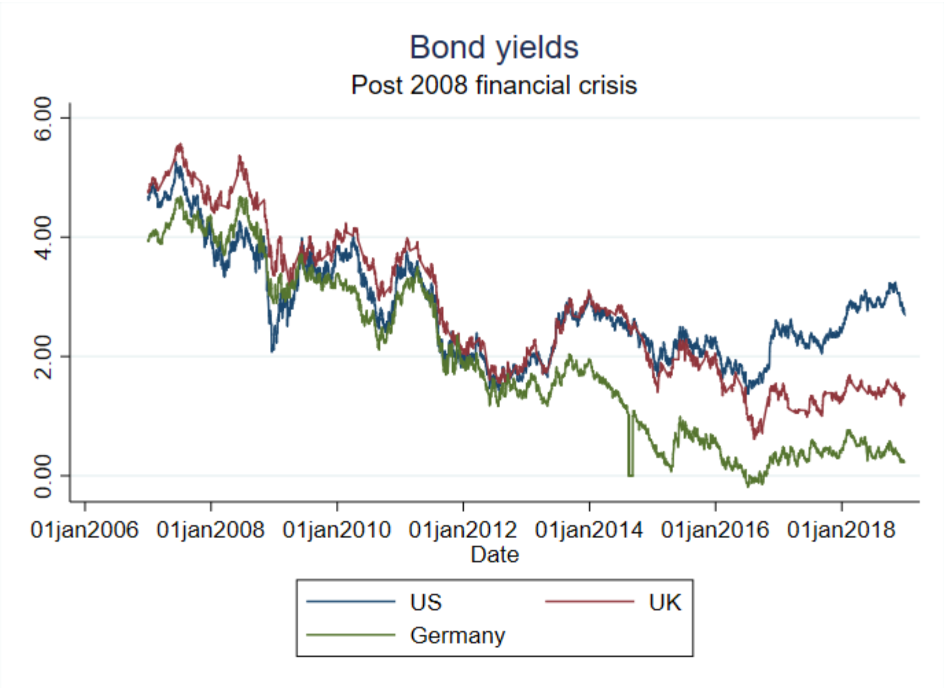
To answer this, a thorough literature review will take place in chapter I. Then, the status quo of the operationalization will be evaluated. Currently, the risk-free asset is operationalized by taking the yield on government bonds. Chapter II will evaluate whether government bonds hold to the standards set in the first chapter and try to find further support and criticism for the use of government bonds as risk-free asset. Then in chapter III, some alternative assets will be evaluated for their use as a risk-free asset. These are gold, as it is traditionally a safe haven in financial markets (Baur & McDermott, 2010; Beckmann, Berger, & Czudaj, 2015; Hood & Malik, 2013); wine, which has increasingly become more popular as investment category (Economist, 2019); and corporate bonds, which are similar to government bonds, but with more risk and more return. To counter this increased riskiness of corporate bonds, a basket of corporate bonds will be evaluated.

The risk-free asset is used in multiple valuation models. One of these is the capital asset pricing model. This model argues that the excess return of a stock over the risk-free return is solely caused by its covariance with the excess return of the market over the risk-free return. CAPM is often found not to hold(Basu & Chawla, 2010; Lettau & Ludvigson, 2001; Mackinlay, 1995). Usually, the conclusion is that the model is to blame. Therefore, CAPM has been altered numerous times to account for mistakes made by other authors (Black, 1972; Breeden, 1979; Lucas, 1978). What none of the literature has considered explicitly however, is that it might not be the model that is to blame, rather the operationalization of the risk-free asset. Therefore, this thesis will seek to apply the alternative assets found in the analysis of the first research question to the CAPM to assess whether the model is at fault or whether it is the operationalization in chapter IV. The second research question thus is:

RQ2: 'To what extent can alternative proxies of the risk-free rate improve the result of CAPM regressions?'

Then finally, the risk-free asset will be evaluated in the investor setting. As already outlined, currently government bonds are seen as a risk-free asset and therefore many portfolios consist for a significant part of government bonds. This is the outcome of Markowitz-inspired portfolios, who argued that there is an optimal combination of risky assets (stocks), which should then be combined with risk-free assets. Currently, the operationalization of government bonds brings a problem for investors. In dealing with financial crises, the central banks of several very important economic powers have adopted unorthodox measures, like quantitative easing. These programs, where central banks buy government debt from commercial banks in order to supply them with enough liquidity, have led to a period over very low, sometimes even negative interest rates, as graph 1 illustrates:

Graph 1: Government bond yields affected by quantitative easing



These low yields indicate that investing in government bonds might not be feasible for investors. Perhaps it would be possible to find other investments that reduce portfolio risk in the same way that government bonds can, with higher yields. This notion can immediately be nuanced slightly more, the true aim would be to improve the risk-return relationship, where the achieved return is divided by the risk taken on. Therefore, it would be interesting to see how the three alternative operationalizations of the risk-free asset, namely gold, wine and corporate bonds fare in this portfolio setting. These will be assessed in chapter V, which seeks to answer the third and final research question:

RQ3: 'To what extent can alternative proxies improve the risk-return relationship of portfolios?'

The findings of this thesis indicate that corporate bonds seem to be a good alternative operationalization for government bonds with respect to the risk-free asset. They hold to the same theoretical standards as found in the first three chapters. Furthermore, they significantly improve the predictive power of CAPM, despite indicating that perhaps some additional factors exist that would be good predictors of asset prices. Finally, portfolios with corporate bonds as risk-free assets outperform those with government bonds as risk-free assets with their risk-return relationship. This disparity even increases during bear markets (which are markets trading more than 20% below their most recent peak) and increases even more after the 2008 financial crisis. In fact, in the time period considered, the corporate bond portfolios have never experienced a month with negative returns.

I. The Risk-free rate

When assessing the several proxies for the risk-free rate, it seems useful to first establish what the risk free rate is. The risk-free asset is often assumed to be a given in the literature (e.g. Hamada, 1969; Lintner, 1965; Mossin, 1966; Sharpe, 1964). There have been some authors that stressed the need to find a proper risk-free asset, however they failed to reach a conclusion leading to a better alternative (e.g. Roll, 1969). To be more critical, this chapter will deconstruct the risk-free return in order to find what conditions should be met to speak of a risk-free asset. However, due to the literature taking the risk-free rate as given, some creative thinking is required, as there are no direct links to literature available. In his work, Irving Fisher often notes that the interest rate is derived from a risk-free asset. Therefore, an analysis of the interest rate could give a framework for the asset that yields the interest rate, and therefore also the risk-free rate.

1.1 Discounting rate and the pure rate of interest

This analysis will cover Irving Fisher's 1930 book "*The Theory of Interest"*, which he based on a previous publication in 1907 (Fisher, 1907). Although it seems quite clear that Fisher was not alone in researching the interest rate (in fact, he cites a rich bibliography), some practical concerns make it difficult to research further back than his 1930 book. Therefore, the citations will be to Fisher's 1930 book (Fisher, 1930), with the remark that his work is based on previous literature.

Nowadays, interest rates can be readily found on the internet. For the pure rate of interest this is not as easy however. The pure rate of interest is the theoretical rate that holds for financial markets, but is also the interest rate that works psychologically, specifically with discounting (Fishburn, 1970; Fishburn & Rubinstein, 1982; Koopmans, 1960; Lancaster, 1963). This was already recognized by Fisher (Fisher, 1930: 14), which caused him to raise the question: "What interest rate to use to measure this?" (Fisher, 1930: 15). Practically, he answers this by using government bond yields. Bond prices are namely a function of (1) the bond's benefits (payoff) and (2) the interest rate that is used to discount these benefits (Fisher, 1930: 18). Since the former is known, e.g. on a zero-coupon bond the payoffs are directly given (the payment of the principal amount), the latter becomes readily observable. Fisher assumed this as well, as he argued this interest rate could be used to discount other investments and could be used in other valuation models. In fact, the discount rate has become a key instrument in financial literature, through its application in several valuation models (Benzion, Rapoport, & Yagil, 1989) like Black-Scholes (Fisher Black & Scholes, 1973) and CAPM (Lintner, 1965; Mossin, 1966; Sharpe, 1964). Finding the right operationalization of this rate is therefore a matter of crucial importance.

Following this discussion about the importance of interest rates for discounting and the overall importance of interest rates in general, Fisher proposes a working concept for the interest rate (Fisher, 1930: 34). This working concept offers some base characteristics that should be met in order to speak of an asset that could yield the interest rate. Fisher argues that the pure rate of interest is the rate on loans or contracts that are practically devoid of chance. This would namely only leave the rate that is used to discount the repayment of the loan in full. Fisher thus notes two main chances that should be eliminated before one could speak of the pure rate of interest: (1) the chance of default and (2) the chance to use it as cash. The first chance, the chance of default, needs to be eliminated, as the chance of default would put positive pressure on the interest rate. A higher chance of default would entail more risk, and thus the investor would demand a higher compensation, which would mean a higher interest rate. The second chance that has to be eliminated is the opportunity to use the investment as cash. This would immediately rule out the interest one receives on a savings deposit. Furthermore, being able to use the investment as cash reduces the opportunity cost of the investment, putting negative pressure on the interest rate. Furthermore, the asset yielding the interest rate must be a safe loan or contract that:

- Contains definite and assured payments (Fisher, 1930: 35);
- Contains definite and assured repayments;
- Contains definite dates.

This entails that the contract needs to stipulate two (or more) money flows of a transaction, which have been secured and at pre-specified dates. This for instance rules out stocks, as they are an open-ended investment, but keeps all further 'safe investments'. These assumptions form the base for the theory of interest.

1.2. Approximations of the interest rate

After laying the foundation for the interest rate, Fisher attempts to approach the interest rate theoretically and mathematically. The theoretical part describes the assumptions that are of concern to the mathematical approximation. In total, the 1930 book approaches the interest rate three times, with increasingly complex assumptions. Fisher most likely wanted to approach the interest rate in a setting as close to reality as possible, without foregoing readability. By increasingly complicating the assumptions, the book is easier to follow and as such fulfills both requirements.

The first approximation offers a sterile theoretical setting, with perfect foresight and perfect information (i.e. no uncertainty) as its most important assumptions. Furthermore, income is given and cannot be altered. The mathematical approximation can be found in Chapter XII (Fisher, 1930: 288). These assumptions of perfect foresight and rigid income streams are relaxed in the second approximation. Individuals can modify their income stream by investing (which is lending and borrowing) to suit their needs. There is no uncertainty regarding what will happen when the income stream is chosen and modified. The mathematical justification of this approximation is found in Chapter XIII (Fisher, 1930: 302). The assumption of no uncertainty is relaxed in the third approximation of the interest rate. This introduction of uncertainty makes risk an important factor in determining interest rates. It alters the mathematics (there are many individual interest rates, instead of 'the one interest rate') and also the theoretical assumptions. The mathematical third approximation is found in Chapter XIV (Fisher, 1930: 316). Ultimately, the third approximation is the most relevant for this thesis, as it bears the closest similarity to reality.

The mathematical chapters function as justification for the assumptions regarding the interest rate. As this thesis does not seek to reproduce Fisher's work, the mathematical justification is less important than the assumptions behind it. These could namely indicate some important characteristics of the asset and market yielding the interest rate. The assumptions regarding the approximations are summarized by Fisher in six principles. A discussion of these principles may offer a framework which can be used to assess a potential risk-free asset by. The six principles are:

A: Investment Opportunity Principles (Fisher, 1930: 148; 223). Note, the investment opportunity principles are only specified for the second and third approximation.

Fisher acknowledges that there are multiple diverse investment opportunities with income. He distinguishes the difference between the rate of interest (return from trading financial assets) and the rate of return (which is return on productive investment). The rate of return is (Fisher, 1930: 499):

- Varying with the extent of individual investment. The rate of return is the return over costs made for the productive investment, so the higher the initial amount of investment, meaning higher costs, the lower the rate of return will be, which is not the case for investing in financial assets like government bonds;
- Variable and controllable by the individual. Due to the actions and decisions of the individual, he has direct influence on the rate of return on productive investment, whereas bond returns are a result from market forces and hence very little influenced by an individual investor;
- A personal, individual matter, not a public matter. The interest rate is of course a result from the market and therefore a public matter, whereas the rate of return on productive investment is depending on the individual's choices and as such a private matter;
- Directly related to production instead of trading.

Fisher thus noted that the interest rate is derived from financial assets rather than productive investment in capital goods, like machinery for instance (perhaps the argument could also be made that investment in real estate also belongs to this category). Financial assets or financial derivatives are not excluded from yielding the interest rate. From this discussion about investment opportunities, Fisher defines two principles that form the assumptions regarding this factor's effect on interest rates:

1) *Principle of Income Choice:* each individual has the opportunity in the present to choose from a given set of future income streams. These differ in terms of their income size and time structure. Individuals can then choose one of these income streams. In the second approximation, these income streams are certain, whereas in the third approximation, there is a level of uncertainty regarding the future of these income streams.
2) *Principle of Maximum Present Value:* individuals will, as stated, choose one of the future income streams in the present. They pick by comparing the present values of the income streams, which is given by the total of future cash flows in that income stream, discounted by the interest rate resulting from these six factors. They then always pick the income stream with the highest present value (second approximation). When uncertainty is introduced in the third

approximation, risk and caution factors will also play a role in discounting the income streams. This does not change the ultimate decision of picking the highest present value income stream however.

Note that in an empirical setting, this discounting would lead to a severe endogeneity problem. The present value of this principle is calculated by using a discount rate that is the result of all these six principles combined, hence the endogeneity. In the theoretical world in which Fisher poses these approximations, this is not a concern, as there is an acknowledgement that these results all happen in a sterile world, filled with assumptions (Fisher, 1930: 123).

B: Impatience Principles (Fisher, 1930: 122; 148; 224).

The rate of interest is also affected by time preference. Time preference namely affects the mental aspects of discounting, both on the individual and societal level. A good example of how time preference exists on the societal level is given by Fisher himself, when he discusses the reputation of Scotland. The northern neighbor of England is known for being thrifty, though some English, Welsh and Irish would probably say frugal. Fisher argues that Scottish education (this part does not necessarily take place at school, but might be part of the general education children receive at home) contains an important part that considers thrift. Scots value thrift as a great good, as it reserves money for their loved ones, especially their (grand)children. This anecdote indicates that there might be cultural factors that influence the rate of time preference at the national level, making for probable differences between countries. This anecdotal evidence is followed by six factors that Fisher hypothesizes to influence the time preference of individuals: (1) the individual's level of foresight, (2) the individual's capability to exercise self-restraint, (3) the habits of the individual, (4) the prospective length and the certainty of the individual's life, (5) the individual's love for his offspring and regard for posterity (the individual's level of altruism) and (6) fashion (Fisher, 1930: 504; Chapter IV, 64). These factors were considered when composing the two principles that describe the assumptions regarding impatience:

3) *Principle of Time Preference:* the rate of time preference, otherwise known as the degree of impatience of an individual, depends on the income stream characteristics (first approximation), as chosen by him and modified on the exchange (second approximation). The modifications of the income stream through borrowing and lending reveal the individual's rate of time preference, as lending and borrowing allow the individual to alter the timing of payments to better suit their need. This rate can also fluctuate depending on the risks involved with the income stream and the uncertainty with regard to the lifespan of the individual (third approximation). In the realistic third approximation, the time preference factors of foresight and the length and certainty of life become relevant due to the present uncertainty in the approximation as compared to the second approximation.
4) *Principle of Maximum Desirability:* the individual will exchange present income for future income (or vice versa) at the market rate of interest. This exchange is lending or borrowing in the chosen income stream, to make the timing of payments more suitable to the individual's

needs. This lending and borrowing is done up to the point of maximum total desirability of the individual (first approximation). After choosing the income stream with the greatest possible present value, he modifies this by exchanging, bringing his individual marginal rate of time preference close to the marginal rate of time preference at the society level, which is the interest rate (second approximation). This implies that there should not be any form of market interference, as this would obscure the process of individual rates of time preference converging to one societal rate of time preference. Introducing risk, this tendency of the individual marginal rate of time preference toward the market interest rate exists, however this level may not ultimately be attained. This is because there now is uncertainty of income streams and thus also of the maximum desirability (third approximation).

C: Market Principles (Fisher, 1930: 122; 123; 149; 225; 226).

Besides factors on a personal level, like impatience and income profiles, there are also market factors that are related to the interest rate. These market principles bring some key market characteristics with them that need to be satisfied for the market to yield a risk-free interest rate.

5) *Principle of Clearing the Market:* the market rate of interest will be such that it clears the market, i.e. that borrowing and lending (demand and supply) will be equal to each other (first and second approximation). This principle still holds after uncertainty is introduced, however then there may (and will) be defaults (third approximation). There is no clear criterion to determine whether a market is liquid, however intraday trading volumes can give an indication. If markets are cleared daily and assets are being traded, this principle can be assumed to hold.
6) *Principle of Repayment:* all loans are repaid in full, and with interest, so that the difference between the sum of cash flows and the present value is zero (first and second approximation). After uncertainty is introduced, this principle does not hold anymore. In the present, the present values are, of course, known and equal to the expected future cash flows. The issue here is that the uncertainty and possibility of default entail that the cash flows in the income stream may differ significantly from those expected at the initial calculation of the present value. In other words, the ultimate cash flows might be different from those initially expected due to the uncertainty involved (third approximation).

Fisher noted that adding more realism and thus uncertainty also entailed adding an inherent vagueness. The assumptions in the third approximation do not offer everything in black and white to the extent the first and second approximations do. However, these assumptions do reflect the most realistic world in which the interest rate is determined. Therefore, the third approximation is the most useful for this thesis.

1.3. Characteristics of the risk-free asset

Concluding, this chapter seeks to offer a framework to assess an asset by in order to determine its worth as a possible risk-free asset. It is namely this risk-free asset that yields the interest rate, which is also the discount rate in many valuation models and the risk-free interest rate in, for instance, CAPM.

Firstly, the risk-free asset should be devoid of (1) the chance of default and (2) the chance to use the asset as cash. Secondly, the asset must be a safe loan or contract that contains definite and assured payments, definite and assured repayments and definite dates. Thirdly, the assumptions made in Fisher's six principles should be matched. This means that there should be an evaluation of whether the asset either confirms, or does not contradict, the assumptions that hold for Fisher's third approximation. The six principles that will be evaluated are: (1) the Principle of Income Choice, (2) the Principle of Maximum Present Value, (3) the Principle of Time Preference, (4) the Principle of Maximum Desirability, (5) the Principle of Clearing the Market and (6) the Principle of Repayment.

If the evaluation finds that these base conditions are met and that the six principles are not contradicted or even affirmed, there seems to be a theoretical possibility for the asset to be used as a risk-free asset. For clarity, throughout the thesis, table 1 will be filled in for every asset, displaying how the assets hold up to the criteria established in this chapter and their operationalization.

Table 1: Asset criteria

Criterion		**Satisfied?**	**Satisfied after workaround?**
Devoid of two chances:	1) Chance of default		
	2) Chance to use it as cash		
The asset must contain:	1) Definite payments		
	2) Definite repayments		
	3) Definite dates		
The six principles			
	When satisfied?		
(1)	If there is investing		
(2)	Assuming rationality, holds		
(3)	If there is investing		
(4)	If there is investing		
(5)	When markets are cleared daily, no hard cutoff		
(6)	If there is guaranteed repayment		

II. Government bonds

Now that some characteristics of the interest rate and the asset yielding it have been established, it is possible to analyze assets on their applicability as risk-free asset. If assets and their markets hold up to the characteristics that were established in the previous chapter based on Fisher's work, the return from investing in such an asset might be considered the pure interest rate. This chapter will first examine government bonds based on the theoretical framework that was established in chapter I due to the status quo wherein government bonds seem to be the standard proxy for the risk-free rate. Besides this theoretical approach, there are other concerns that affect the applicability of government bonds as risk-free asset as well. These concerns include threats to the market and asset, possible opportunities to counter these threats and also the actual financial merit for the investor, by looking at yields and volatility.

Before government bonds are examined at all, some important terminology regarding bonds should be explained. Government bonds generally denote a principal amount, which is the amount payable upon maturity. This principal amount is often known as face or par value. A bond can also have a coupon rate, which is the rate of interest paid from the issuer to the owner of the bond relative to face value. As the market interest diverts from the bond's coupon rate, the value of the bond changes as well (a higher market interest rate leads to a lower bond price and vice versa). Bond yield combines the two. Bond yield is a function of the coupon payments of the bond and the difference between the market price and the face value of the bond. As such, bond yield indicates the return of a bond to an investor. It is this return that counts for Fisher. The yield is namely the return that results from borrowing and lending (i.e. modifying the income stream). Therefore, the bond yield is the return that should proxy the interest rate (e.g. Fisher, 1930; 18).

This chapter will consider government bonds from Germany, the United States and the United Kingdom. These countries were not chosen arbitrarily. The government bonds should be applicable as risk-free asset, so they needed to come from a developed country with a strong economy. The choice for the US is also common in most literature. Adding two other developed economies from the EU bloc seemed to add robustness to the tests. Germany is arguably the most important economy of the Eurozone and the UK is very interesting to consider with its own monetary policy that could affect bond yields.

2.1. Theoretical considerations

As mentioned in the previous chapter, Fisher already assumed that government bonds were a good way to proxy the interest rate. The payoff of a bond is namely a function of two factors; (1) the expected cash flows (the bond's benefits) and (2) the interest rate used to discount these cash flows. For most government bonds, these cash flows are prespecified. Therefore, one can determine the discount rate for the cash flows at any given time from the price at which the bond trades on the market. There are plenty of bonds that do contain coupon payments and the rate that is used to discount all the cash flows of this bond is the interest rate, which is closely related to the bond's yield. Interest rates are inversely related to the price of a government bond, if the price is higher, the future cash flows are discounted less, meaning a lower interest rate.

The first criterion that the risk-free asset should adhere to, is that it should be devoid of two chances; (1) the chance of default and (2) the chance to use it as cash.

1) In general, the assumption seems to be that governments are not so likely to default. This is especially true for the governments of a select few developed economies. That does not mean however that there is no absolute default risk. In fact, history has shown that several countries have defaulted on their loans, most recently Greece, which defaulted on a loan to the IMF in 2015 (Harrison & Liakos, 2015; Maltezou & Bartunek, 2015). One could rightfully argue that Greece does not have the safe characteristics of the US. The United States of America have however also defaulted somewhat recently, although to what extent the delay in payments to some investors in 1979 constitutes a default remains a topic of debate (Austin, 2016). What it does show however, is that the risk of default can never be eliminated completely, also not on government debt. In fact, there is a stream of literature investigating risk premiums on government bonds, which should not be present when these instruments would be a perfect risk-free asset (the key is in the name already). There is plenty of research establishing that there are risk premiums on government bonds (e.g. Alesina, Broeck, Prati, & Tabellini, 1992; Ardagna, Caselli, & Lane, 2004; Bernoth, Hagen, & Schuknecht, 2012; Haugh, Olivard, & Turner, 2009) although this remains a controversial topic in the literature. Most of the literature finds that there is an explicit risk premium when the government debt of the country is already high. Haugh et al. (2009) conduct both a literature review, as well as their own analysis. There is one research that explicitly lists the effects of a one percentage point increase in government debt for the three countries that are examined in this thesis (Chinn & Frankel, 2005), whose risk premiums were directly placed in a table by Haugh et al. (2009):

Table 2: Debt risk premium

Country	1%-point increase has a …… increase in interest
USA	5 bps
Germany	5-8 bps
UK	10-16 bps

The table displays the effect of a one percentage point increase of the debt/GDP ratio of a government on the interest of a ten year government bond. Bps are basis points, which are industry standard for denoting interest changes.

Table 2 illustrates that there are differences in the risk-perception of the government bonds that are considered in this thesis. American government bonds are slightly less sensitive to debt/GDP ratio increases than German government bonds. The difference with British government bonds is much bigger. These associated risk premiums are relatively old however, the research was conducted in 2005. As noted however, this field of literature is still highly debated and there is little research that explicitly lists the found risk premiums, most conclude on an aggregate OECD level. Therefore, this older work was chosen to give an indication of the presence of risk premiums on government bonds.

Now that the marginal effect of debt/GDP increases on interest rates is established, it is valuable to see what debt/GDP ratios are present in the United States of America, the United Kingdom and Germany. Some descriptive statistics of the debt/GDP ratios of these countries are found in table 3.

Table 3: Descriptive statistics of Debt/GDP ratio

Country	**Years**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
USA	24	104.860	92.450	25.145	72.129	83.889	134.173	138.599
UK	24	71.044	49.229	29.449	42.476	47.509	102.210	119.381
Germany	23	69.500	68.083	10.334	54.124	60.462	78.964	88.106

Measures of central tendency and dispersion of the debt/GDP ratio of several countries. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.
Data retrieved from OECDSTAT on 4-5-2019. Time period from 1995-2017 (Germany) or 1995-2018 (UK and USA).

What becomes apparent here, is that there are significant differences over time, where the median value of the UK debt/GDP ratio is nearly half of the American ratio. This adds to the debate what rate would be an appropriate risk-free rate, as government bonds should all be risk-free. U.S. government bonds have the lowest relative debt increase elasticity (table 2), despite having the highest relative government debt. A possible reason for this might be the dollar's international status as reserve currency. This dominance started at the adoption of the Bretton Woods system in 1944 and remained as legacy in the period after its 1971 collapse. The position of the dollar has not changed since, which might affect its risk premium in a negative manner (Chinn & Frankel, 2005). It would be wrong to conclude, given this discussion, that government bonds are strictly free from a default risk. There is risk pricing in the bond market, even for bonds denominated in the world's leading reserve currency, the US dollar. Fisher does state that a risk-free asset should be a "very safe asset" (Fisher, 1930: 35), which the government bonds of the US, UK and Germany are. Taking the strictest approach however, one should be cautious with the conclusion that these bonds are theoretically risk-free.

2) Government bonds are generally not legal tender. As such, the claim can be made that there is no chance to use government bonds as cash. On the other hand, bonds are generally liquid. Furthermore, there are some bonds (T-bills) with such short maturity that they are counted as cash equivalents in some sets of accounting principles, most notably IFRS, which is an

internationally recognized set of accounting principles (Iasplus.com, 2017) in a similar fashion to deposit accounts at banks. All in all, one could strongly make the claim that this chance is eliminated enough to not hinder the qualification of government bonds, if these bonds do not qualify as cash equivalents in said accounting principles. This strictly speaking means that the bonds need a maturity longer than 3 months, but more generally that the bonds need a maturity of one year or more.

There are also three contractual characteristics that are crucial for an asset to qualify as a risk-free asset, as established in the first chapter. These characteristics refer to the specific contract details of the asset or financial derivative thereof. These requirements are:

- Definite and assured payments. This condition holds for government bonds. Once the bond is bought, the payment is definite. The fact that the investor can resell the bond on the market does not change this fact. The investor that buys the bond has 'assured' the payment, as the whole present value (which is the market value) of the bond is paid at the time of 'signing the contract', which is buying the bond.
- Definite and assured repayments. This characteristic is conditional on the preceding discussion regarding the riskiness of government bonds. When one concludes from this discussion that government bonds can be considered risk-free, the payments of a government bond are indeed definite and assured. The timing and amount of the repayment is also specified in the contract, as a bond has a set maturity date. As explained, one must be careful to draw that conclusion, as there is a theoretical possibility of a sovereign default, further indicated by the risk premiums found by other authors (Alesina et al., 1992; Ardagna et al., 2004; Bernoth et al., 2012; Haugh et al., 2009).
- The dates are, as mentioned set. The contract starts at the acquisition of the bond, and ends at the specified maturity.

So in terms of cash flows, government bonds could perhaps be considered a risk-free asset. The previous chapter also extensively discussed the six principles that affect interest rates. These principles form the assumptions about the universe in which Fisher finds the interest rate. If a government bond (or any other asset) does not violate the assumptions contained in these six principles, the asset might be a risk-free asset, as it could yield the interest rate.

A) ***Investment Opportunity Principles***: the fact that investors actually do invest in government bonds indicates that these two principles can be assumed to hold. Investors will have 'chosen' an income stream, which can be operationalized as their life income. They can then modify their income stream through buying and selling bonds (borrowing and lending) to make the income profile fit their preferences. Assuming that these individuals are rational, which is an assumption Fisher also makes (e.g. Fisher, 1930: 321), these individuals will have chosen the income stream with the highest present value, as the Principle of Maximum Present Value dictates. Rather than have a significant impact on government bonds as risk-free assets, the assumptions regarding the investment opportunity principles do not seem to be violated by government bonds. That makes for a qualification as risk-free asset based on these principles.

B) ***Impatience Principles***: assuming that government bonds are unlikely to default, as per the discussion earlier in this chapter, one could perhaps argue that these government bonds are risk-free. That could mean that the impatience principles could be more important factors in determining the interest rate, as there is little to no risk premium to speak of. For investors, it is proven that there is a large degree of home bias (e.g. Ahearne, Griever, & Warnock, 2004; Cooper & Kaplanis, 1994; Coval & Moskowitz, 1999; Kang & Stulz, 1995; Lewis, 1999), which is also present in the bonds market (Lane, 2005; Tesar & Werner, 1995). That is a violation of the rationality assumption that was made previously, which is caused by the difference in theoretical and empirical findings. This means that differences in interest rates might be partially explained by cultural differences in the degree of time preference. This is indicated by two examples. The first is the anecdote cited from Fisher's book regarding thrift in Scottish education (Fisher, 1930: 337). There are also differences in saving rates between countries, as table 4 illustrates:

Table 4: Saving/GDP ratios

Country	**Years**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
USA	48	4.828	4.383	2.858	-2.514	2.966	6.932	10.987
UK	48	3.465	3.340	2.642	-1.427	1.658	4.279	10.961
Germany	48	8.551	8.429	2.720	4.059	6.309	9.806	16.540

Measures of central tendency and dispersion of the saving/GDP ratio of several countries. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.
The savings rate is defined as: "the difference between disposable income plus the change in net equity of households in pension funds and final consumption expenditure." OECD (2019), Saving rate (indicator). doi: 10.1787/ff2e64d4-en.
Data retrieved from OECDSTAT on 4-5-2019. Time period from 1995-2017.

This indicates that there are differences in savings rate between countries. Literature has not found a clear link between saving behavior and cultural factors however (e.g. Carroll, Rhee, & Rhee, 1994), contrary to Fisher's expectations. It does not rule out that there could be other factors, like those highlighted by Fisher (namely the level of foresight, level of self-restraint, habits, prospective length of life, level of altruism and fashion), that determine differences in time preference between countries (Fisher, 1930: 504; Chapter IV, 64). These will then have an effect on the interest rate on government bonds, and assuming there is home bias, these differences will mainly affect the interest rate of government bonds of the own sovereign.

C) **Market Principles**: then finally there are two market principles that the market of the risk-free asset should adhere to in order to yield an interest rate. Firstly, markets should be effectively cleared, as per the Principle of Clearing the Market. Markets are cleared when the price is such that supply matches demand and transactions happen. A possible indicator of this could be the average intraday trading volume of the government bonds. This namely indicates how much debt is exchanged every day, which in turn shows whether the market prices clear the market in a satisfactory manner. Most literature on market clearing focuses on determining clearing prices (e.g. Fehr, Kirchsteiger, & Riedl, 1993; O'Neill, Sotkiewicz, Hobbs, Rothkopf, & Stewart, 2005), where the argument is made that when transactions happen, apparently clearing was satisfactory, as the price was right to clear the market. Therefore, intraday trading volumes, both relative and absolute, only do so much to indicate market clearing, but they offer the best estimate there is currently. Table 5 displays the intraday trading volume of the bonds both in absolute terms as well as in relative terms to the total amount of government debt outstanding:

Table 5: Average intraday trading volume

Year	**Germany**	**UK**	**USA**
2017	€20 billion	£33 billion	$393 billion
Relative	0.945%	1.848%	1.918%

Intraday trading volumes of government debt is displayed in absolute and relative terms (trading volume/outstanding government debt). Data retrieved on 5-5-2019 from Deutsche Finanzagentur (German bonds), UK Debt Management Office (UK bonds) and Sifma.org (American bonds). Data on total government debt was retrieved on 22-5-2019 from Eurostat (Germany and UK) and FRED (USA).

As the table shows, around 1 percent of German government debt is traded every day, and almost double that is traded for UK and US government debt. This indicates that markets seem to be cleared in a satisfactory manner, as at least 1 percent of debt can be traded every day. The other market principle, the Principle of Repayment, has been discussed plenty in this chapter. There cannot be a full conclusion that government bonds are risk-free, as there are found risk-premiums, as well as other theoretical concerns. These concerns weigh on the conclusion whether this principle holds for government bonds. As established before however, the hesitant assumption will be that government bonds are very safe contracts, though not completely risk-free. Therefore, this final principle holds weakly for government bonds.

From the theoretical considerations, that is testing government bonds against Fisher's criteria, there are indications that government bonds are not completely risk-free. There is a theoretical possibility of a sovereign default, which is priced in the market with the risk premiums that can be found in table 2. This possibility does seem to be very small, especially for Germany, the United Kingdom and the United States of America. Based on this theoretical review, the conclusion can be that government bonds seem suitable as risk-free asset, but that there is enough doubt to make it valuable to assess other alternatives as well.

2.2 Other important considerations

Besides the theoretical review based on Fisher's criteria for a risk-free asset that were established in Chapter I, there are other important factors to consider. For instance, is there a financial merit for investors to integrate government bonds in their portfolios to reduce the risk (or improve the risk-return relationship of their portfolio)? Or could there be other threats for investors when buying government bonds that are not captured in the theoretical review based on Fisher? These issues will be addressed in the following.

2.2.1 Independently priced?

Firstly, market interest rates on government bonds should be a function of the market, as explained when discussing the Principle of Maximum Desirability in Chapter I. As Fisher described, interest rates are the discount rates resulting from an individual's rate of time preference. By acting on the market, this marginal discount rate will then converge to the market rate of interest, which is the interest rate (and discount rate) that applies to the society as a whole. That is all in accordance with theory, as there are only market forces active. Fisher did not explicitly mention the role of central banks in this process, however. As mentioned in the introduction, especially around the financial crisis of 2008, central banks took extreme market measures to boost inflation, mostly by buying large amounts of government bonds, lowering the interest rates and injecting banks with more liquidity. And as graph 1 shows, the yield on government bonds dropped dramatically as a result of these policies. That poses a significant weakness for investors, as they become more exposed to central bank policy. The policies of the European Central Bank, the Bank of England and the Federal Reserve Bank are generally priced in ex ante, indicating that the market can predict these policies. That does not reduce the risk associated with policy however, as the central banks do not have investor interest as their core focus.

Another example of this unwanted central bank risk is the recent popularity of modern monetary theory, sometimes known as neo-chartalism. In this form of policy making, proponents argue that government debt is not problematic for a government, as long as the central bank of that country has full independence. That would namely mean that the central bank can buy all the bonds that the country gives out, providing unlimited demand for bonds (central banks can namely print money), thereby also lowering the interest rate that the government has to pay (Fullwiler, Kelton, & Wray, 2012; Mitchell, 2005; Tcherneva, 2002). This way of monetary financing has some merit, as it makes for a government that can be more decisive and effective, however there are plenty of criticisms (e.g. Krugman, 2011; Murphy, 2019). For investors, it would eliminate the possibility of investing in government bonds, as all of the debt is either bought by the central bank, or the interest rates become so low that there is no practical justification for investing anymore. Furthermore, there is of course the worry that too loose monetary policy leads to hyperinflation, as examples from Weimar Germany (Dornbusch & Fischer, 1986; Salemi, 1979), or more recently Zimbabwe (Coomer & Gstraunthaler, 2011; Hanke & Krus, 2012) show. Proponents of modern monetary theory argue that the inflation control should come from fiscal policy, so the government would either raise taxes or cut spending. The question that remains however, is whether there would be the political will to take the blame for tax increases or spending cuts in order to slow down inflation.

2.2.2 Financial merit

As mentioned, loose monetary policy has already been adopted. Besides the initial arguments that can be made against this, which are listed in chapter 2.2.1., there is also merit in finding out what the actual effect of such policies was. Therefore, this section will look at how the yield of German, UK and US government bonds has developed over time. Data was gathered for the bond rates of three selected countries, the United States of America, the United Kingdom and Germany. These countries were selected based on their relevance for their respective regions. The USA and the UK each form their own economic block in their own region, whereas Germany is one of the, if not the, most important economy in the European Union. Data was retrieved from the Saint Louis Federal Reserve's database (FRED). The time period of this data is 1960 – 2018, as this offers the broadest time period possible in the database. This gives the most opportunity to examine bond yield behavior in a crisis through an increased likelihood of crises captured in the data. For a first glance, some summary statistics can offer a clear indication.

Table 6: Summary statistics bond yields 1960-2018

Variable	**N**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
Germany	708	5,793	6,300	2,560	-0,150	4,115	7,700	10,800
UK	708	7,458	7,015	3,698	0,742	4,736	10,275	16,340
USA	708	6,115	5,810	2,853	1,500	4,040	7,755	15,320

Measures of central tendency and dispersion of the yield on ten year government bonds of Germany, the United Kingdom and the United States. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.
Data retrieved from the Federal Reserve Economic Database (FRED).

Table 6 highlights several phenomena. First, countries have very different yields over time, as indicated by their mean and minimum and maximum values. Perhaps most telling is the minimum of yields, where German bonds were considered to be so safe that investors accepted a negative yield to store money. Furthermore, German yields seem to be slightly lower than its British and American counterparts, with lower volatility of its yields as well. Second, it is also worth noting that the German yield distribution is skewed to the left (mean < median), whereas the distributions of the UK and the US are skewed slightly to the right (mean > median). This means that German bonds have more outliers in the higher spectrum of the yield distribution, showing a general tendency to be judged very safe (or Germany has very low inflation), whereas the UK and US bonds seem to have lower rates as outliers, showing a tendency to higher rates (or higher inflation that is compensated).

Another way that shows these relations rather clearly, is through a graphic representation. The FRED database offers an indication for the time periods the US was in a recession. Since this might have an impact on bond yields, for instance through a monetary policy response, these periods are marked in the graph. To see whether these periods are also relevant for the other countries, the correlations between the bond yields may give an indication. In table 7, the correlations between the several yields are shown:

Table 7: Correlation between interest rates

	Germany	*UK*	*USA*
Germany	1		
UK	0.880	1	
USA	0.774	0.891	1

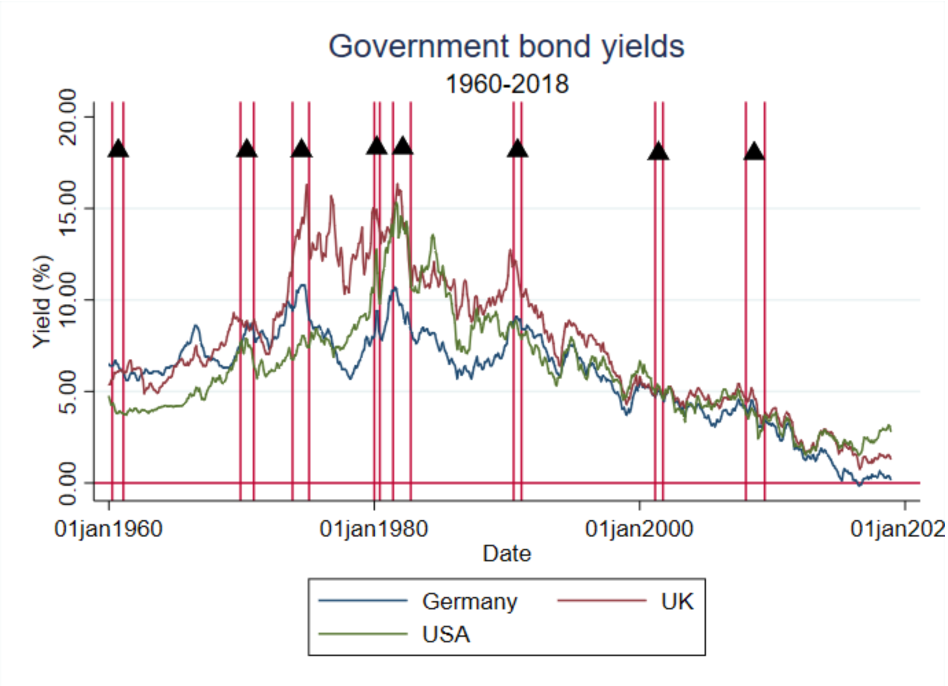
The correlations are high enough to assume that periods of recession in the USA are also relevant for the other countries, as their bond yields might drop 75% of what US bond yields would drop. Furthermore, increasing globalization increases the likelihood of contagion, making the periods of US recessions also relevant for the other countries. To be more precise, the correlations between the yields on government bonds can also be examined only during the time of recession. This is depicted in table 8:

Table 8: Correlation between interest rates during US recessions

	Germany	*UK*	*USA*
Germany	1		
UK	0.926	1	
USA	0.755	0.852	1

The correlations decrease slightly during times of crisis. Yet, the bond yield correlations are high enough to warrant a graphic representation of the bond yield developments between 1960 and 2018. The periods that were recessions in the US, according to the Saint Louis Fed, are marked by vertical lines and black triangles. Furthermore, there is a horizontal line that marks the zero per cent bond yield. As seen in table 6, German yields drop below this threshold, making it a relevant point to mark.

Graph 2: 10 year bond yields for Germany, the UK and USA



What becomes apparent from the graph, is that leading up to a recession, interest rates seem to be high. Then the yields seem to decrease somewhat during the recession and then start a decreasing trend after the recession. Perhaps this is also seen in the summary statistics if differentiated for a US recession.

Table 9: Summary statistics bond yields during US recessions and without recessions

Variable	**N**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
During recessions								
Germany	97	7,536	8,400	2,433	3,020	5,020	9,400	10,800
UK	97	9,685	8,910	4,284	3.25	5.204	13,820	16,340
USA	97	7,532	7,390	3,667	2,420	4,010	8,750	15,320
Without recessions								
Germany	611	5,516	6,200	2,471	-0,150	4,010	7,400	10,500
UK	611	7,105	6,760	3,472	0,742	46,535	9,770	15,670
USA	611	5,890	5,710	2,637	1,500	4,040	7,480	14,100

Measures of central tendency and dispersion of government bond yields of Germany, the United Kingdom and the United States of America during periods of recessions and periods without recessions in the United States. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.
Data retrieved from FRED.

Table 9 indicates indeed that during the recession, interest rates are higher (the values in the top panel of the table are much higher than in the bottom panel). In terms of peaks, this barely is the case, but for the lower values (first and third quartile, mean and median), the values during the recessions are higher. This could have several causes:

1) Government bonds are generally perceived as the risk-free asset. During a recession, there tends to be a risk-off, where investors are willing to take on less risk for their investments. Then due to increased demand, bond prices will increase, positively affecting the yield. This will lower the interest rate however (as bond prices and interest rates are inversely related), so once there is a new issue of government bonds at the lower interest rate, overall yields will decrease.
2) This delay in yield decrease may also come from the delayed response of the central bank. In general, central banks meet every quarter to determine their monetary policy, especially their interest rate policy. This means that the policy might not respond as quickly to the recession as perhaps would be preferred.

All in all, it seems that government bonds have a decent nominal yield. Investors may expect to achieve somewhere between 5.5% and 7.5% nominal return on their investment. Furthermore, the returns seem to be very stable, which is indicated by the low standard deviations. That makes the returns more certain and more predictable, which is something investors will appreciate. The situation after the financial crisis of 2008 is depicted in table 10:

Table 10: Summary statistics bond yields after the 2008 crisis

Variable	**N**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
Germany	132	1.644242	1.465	1.294973	-0.15	0.415	2.965	4.52
UK	132	2.525298	2.2154	1.102724	0.7421	1.5575	3.5393	5.2103
USA	132	2.621364	2.535	0.668867	1.5	2.08	3.065	4.1

Measures of central tendency and dispersion of government bond yields of Germany, the United Kingdom and the United States of America after the 2008 recession. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.
Data retrieved from FRED.

From table 10, it becomes clear that the financial merit seems to decrease after the 2008 crisis. Nominal mean returns are now much lower than over the whole period. What's perhaps more worrying for investors, is that the standard deviation is also much lower. This indicates that the low interest rates have been rather constant trend since the crisis, significantly posing problems for the financial merit of investing in bonds.

2.3 Conclusions

This chapter started with a theoretical review of government bonds. From this review, the conclusion is that there is decent support for the use of government bonds as the risk-free asset. This decent support is caused by the violation of the rather strict assumption that the risk-free asset must be 100% risk-free. As table 2 shows, the market pays risk premiums on government bonds, meaning that the market does not perceive the bonds as being completely risk-free. Furthermore, practice has shown that sovereign defaults do happen and even though they are deemed unlikely for the likes of Germany, the United

Kingdom and the United States of America, there is both a theoretical and practical possibility that these happen.

Other characteristics, as derived from Fisher in chapter I, did offer support for the use of government bonds as risk-free asset. This claim would be made if government bonds either supported the six principles that affect the interest rate or at the very least did not contradict the principles. The other characteristics, being the two chances that needed to be eliminated before one could speak of the risk free asset and the three contract characteristics have mixed support. This again is crucially weakened by the possibility of a sovereign default.

There are also other important factors that may influence the suitability of government bonds as risk-free asset. The independence of interest rates as a pure functions of the market has always been threatened by central bank policies, but the increasing support for extreme central bank policies like modern monetary theory pose a much more fatal risk for government bond investors. Furthermore, the financial merit of investing in government bonds has decreased significantly after 2008. The nominal yields are dramatically low, with little changes and yield volatility between 2008 and 2018.

From a more practical perspective, using government bond yields as proxy for the risk-free interest rate makes sense. Bond yields are readily available for researchers and investors both. Markets are liquid enough to prevent liquidity traps and markets seem to be efficiently cleared.

Considering all evidence and discussion in this chapter, there is merit in evaluating alternative assets as a possible proxy for the risk-free asset in the next chapter. One could relax the assumption of needing 100% risk-free assets, in which case government bonds would suffice. Ultimately, this thesis will collect the evidence for the alternative risk-free assets and then conclude whether government bonds have been used as the best proxy rightly in the literature.

Table 11: Summary of government bond analysis

	Criterion	**Satisfied?**	**Satisfied after workaround?**
Devoid of two chances:	1) Chance of default	~	Yes
	2) Chance to use it as cash	Yes	
The asset must contain:	1) Definite payments	Yes	
	2) Definite repayments	~	Yes
	3) Definite dates	Yes	
The six principles			
	When satisfied?		
(1)	If there is investing	Yes	
(2)	Assuming rationality, holds	Yes	
(3)	If there is investing	Yes	
(4)	If there is investing	Yes	
(5)	When markets are cleared daily, no hard cutoff	Yes	
(6)	If there is guaranteed repayment	~	Yes

This table displays a summary of the criteria making an asset risk-free. Criteria that are satisfied get assigned "Yes", criteria that are not strongly supported get "~" and criteria that are not supported get "No".
Satisfied after workaround shows that the asset could function as risk-free asset after a suitable solution for a particular problem is found. This is elaborated upon in the chapter rather than in the table.

III. Alternative assets

In the previous chapter, it became apparent that government bonds might not be the best proxy for the risk-free assets, both on a theoretical level (from Fisher's characteristics of the interest rate bearing asset) and on the practical level (because of very low bond yields). Therefore, this chapter will examine several alternative assets on their theoretical qualifications and some other important concerns, similar to the analysis presented in chapter II.

What some of the alternative assets lack however, is that they are not presented in the form of a contract, which is a specified necessity according to Fisher (Fisher, 1930; 35). According to chapter I, the asset yielding the interest rate must be a (very) safe contract. This might hold for government bonds, but does not hold when investing in real assets. One could argue that this is less critical when holding real assets. Contracts are namely put in place to guarantee transfers of cash, whereas holding real assets does not pose this problem. Owning gold means that the value of the asset is in your possession regardless. Therefore, Fisher's criterion that the risk-free asset must be a contract is something that could be relaxed. There is another reason why a contract is useful however. Some criteria of the risk-free asset also require a fixed holding period and guarantees on repayment. Therefore, it is useful to discuss how contracts can still assist in creating a risk-free asset from real assets. This solution lies in financial derivatives. There are derivatives, which are essentially contracts, that could offer a guaranteed return, based on the return of the underlying asset. One of such derivatives could be a forward. A forward is a contract where two parties specify a transaction to take place in the future, at a specified time, against a specified price (the forward rate), thereby fixing the terms of the transaction and removing any uncertainty about the future. Besides forwards, futures are a derivative that offer an over-the-counter (OTC) version of forwards. Futures are standardized and traded on markets. To reduce default risk, futures require the counterparty (the buying party) to deposit a margin, which can be seen as a down payment and type of collateral. Futures are settled daily, meaning that differences between the current market price and the price upon maturity are either added to – or deducted from – the margin. The benefit of futures in this sense is that some of the default risk is removed and that there will generally be no transaction of goods at maturity of the future, instead the transaction is settled in cash. For many investors, this is fine, as they are looking to get the financial gain on the asset rather than the asset itself. Another derivative that could be useful to assess alternative assets by is an exchange traded fund (ETF). ETF's are financial products that mirror a basket of goods, stocks or bonds (generally indices of these goods, stocks or bonds) and are traded on an exchange. This makes it easier for investors to invest in many (diversified) assets at once, without giving the hassle of compiling this basket themselves by buying all assets individually. There are companies that invest in a portfolio of assets, which investors can participate in. If these activities would be stored in an ETF, barriers to entry and liquidity problems for investors would become significantly smaller.

The above discussion serves to counter any eventual and justified criticism that the assets under investigation are not the contracts that Fisher envisioned when discussing the asset that yields the interest rate. At this point, this thesis will assume that a suitable financial derivative can be made, like a future, forward or ETF from the assets that will be discussed in this chapter. This will not blindly be assumed however, the assessment needs to be made whether it would be realistic that a derivative would be created in terms of technical ability and financial feasibility.

3.1. Gold

Gold is traditionally a safe haven (Baur & McDermott, 2010; Beckmann et al., 2015; Hood & Malik, 2013). This means that during recessions, investors store their wealth in gold, causing strong negative correlations between gold and other factors (Batten, Ciner, & Lucey, 2010; Reboredo, 2013). Therefore, gold might be considered an important candidate in finding the new risk-free asset.

3.1.1. Theoretical considerations

The first criterion for the risk free asset, is that it should be devoid of two chances, namely the chance of default and the chance to use the asset as cash. The default risk with gold itself is not necessarily present, as the asset has no real way to default (unless the popularity of gold suddenly disappears). By entering a derivative contract, the investor might expose himself to at least a small portion of default risk, even though there could be mitigating circumstances like paying a margin and daily settlement that aim to reduce this default risk. Furthermore, there has been a rise of central clearing counterparties (CCPs). These are expensive networks of large investors, who pay a margin to the CCP. In exchange for this, the CCP will take over any remaining obligations when a member of the network defaults and thus provides a default insurance for the other members of the CCP network. It is important to note however, that CCPs are only accessible for large institutional investors. If there would be a possibility to have a centrally cleared derivative of gold, the chance of default can be negated. If not, there is a risk of default. They are not, as of yet, open to private individuals joining the network, most likely because of expertise and risk factors. The chance to use the asset as cash has disappeared, at least in most Western economies and definitely in the United States, United Kingdom and Germany. After the collapse of the Bretton Woods system in 1971, the value of the dollar, and soon also of most other currencies, was not tied to the value of gold anymore. This drop of the gold standard means that individuals cannot go to the central bank to exchange their gold for cash anymore. As a result, there is no chance to use gold as cash directly, although gold has such a universal value that the asset is highly liquid.

Secondly, the risk free-asset must be a safe loan or contract that contains definite and assured payments, definite and assured repayments and definite dates. For investing in the asset gold itself, these criteria do not hold. Firstly, gold is not a contract, nor does buying gold give guaranteed payments or bring with it a specified maturity date. Secondly, one could argue based on the above discussion how safe gold is. As mentioned in the beginning of this chapter however, there are also financial derivatives of these assets. Futures and forwards have specified (re)payments and a definite date. There is some default risk however. If these assets were to be traded through a CCP, that risk can be eliminated as well. In that case (a centrally cleared financial derivative of gold), these criteria do hold.

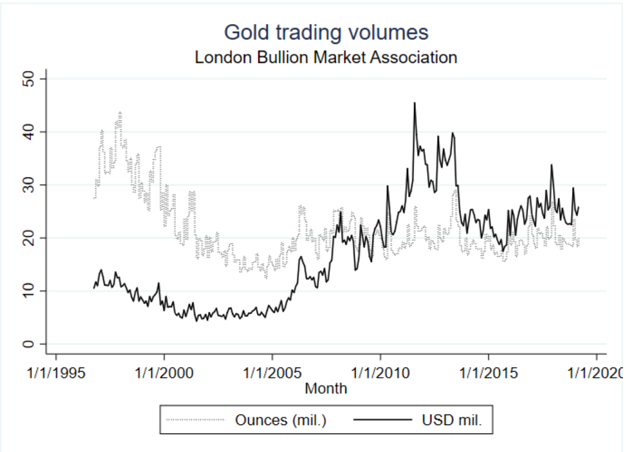
Finally, for the theoretical assessment of gold as a risk-free asset, there are the six principles of the interest rate that should be considered.

A) ***Investment principles***: similar to government bonds, the fact that investors have chosen to invest in gold means that these two principles (the Principle of Income Choice and the Principle of Maximum Present Value) can be assumed to hold, or at the very least do not seem to be violated.

B) ***Impatience principles***: the rate of time preference are rather personal characteristics. What can be concluded from the yield that gold has brought over time (as indicated by graphs 4 and 5 and tables 12 and 13), is that gold is affected by impatience principles. Apparently, investors require a yield for investing in gold, meaning that they are affected by impatience when they exchange money for gold. The step of converting gold back into money seems to be barrier enough to affect the Principle of Time Preference. Furthermore, the Principle of Maximum Desirability dictates that individuals modify their income stream through lending and borrowing, where the marginal rate of time preference moves closer to the market rate of interest (which is the societal marginal rate of time preference). This can also be done with gold, where borrowing would mean going short on gold (borrowing gold and selling it so the individual obtains cash, to later buy the gold back in exchange for cash and returning the gold) and lending would mean going long on gold (buying gold, i.e. lending out money in exchange for gold, and reversing that transaction later).

C) ***Market principles***: the final two principles are the market principles. The first is the Principle of Clearing the Market, meaning that the gold prices in this case are such that the market is effectively cleared. The argument when dealing with government bonds was that there had to be a large intraday trading volume. For gold, this trading volume is intramonth, and is depicted in graph 3:

Graph 3: Gold trading volumes by millions of ounces or millions of dollars[1]



[1] Data accessed from the London Bullion Market Association on 23-5-2019.

Graph 3 shows that there are large amounts of gold traded each month, both in terms of ounces as well as total price volume. In this case, examining the trading volume in terms of their weight (so ounces) seems more appropriate, as it eliminates the effects of price increases or decreases in the total volume traded. From this graph, the conclusion is that the volume is such that the Principle of Clearing the Market is satisfied. The Principle of Repayment has been discussed before. Through some financial derivatives and new market structures (with CCPs), this principle could be satisfied.

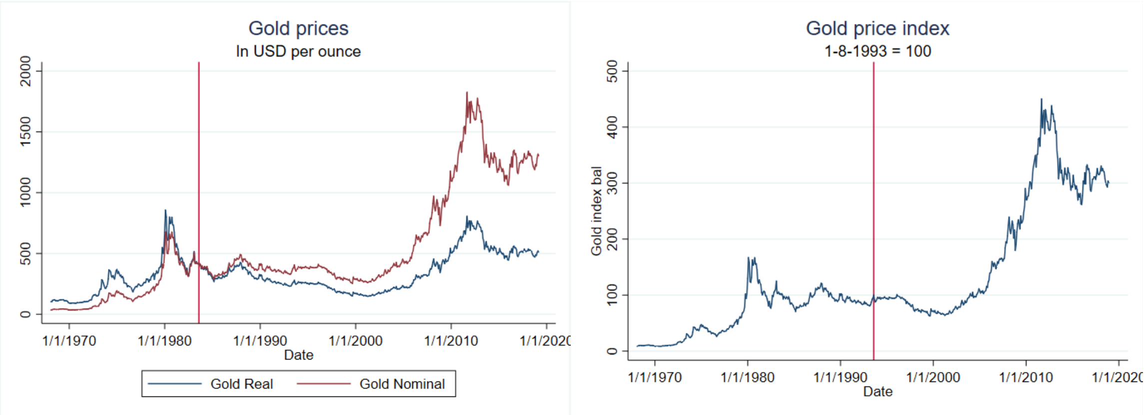
The theoretical discussion leads to mixed conclusions. As an asset purely, gold cannot satisfy the necessary theoretical characteristics of a risk-free asset. One argument is that this is because of gold itself not being a loan or a contract, something which Fisher specified. Another, perhaps more important argument is that there is a risk when investing in gold. Financial derivatives and new market structures (like adding CCPs) could be an outcome in this situation, however the question remains as to the extent this is accessible for individual investors. There are other important factors affecting the suitability of gold as a risk-free asset, which will be discussed next.

3.1.2. Other important considerations

Gold has, as mentioned at the start of this sub-chapter, served as a safe-haven for a long time (Baur & McDermott, 2010; Beckmann et al., 2015; Hood & Malik, 2013). This means that it has a lot of correlations to other assets and market factors that could be an important consideration for investors. For instance, movements in the oil market have an effect on the gold price (Reboredo, 2013). This adds significant risk to gold, as well as great diversification opportunities. It poses a risk because the complexity of the market entails that there is a lot of information that affects the gold prices. The mechanisms in which this happens are also opaque, except for the fact that gold tends to be the safe haven (Batten et al., 2010). In that sense, the safe haven characteristics of gold seem to be both a blessing and a curse, as it lets investors profit when other assets are underperforming, however it might also put a negative pressure on a portfolio when other markets are doing fine. What side of this balance the risk of gold will point to will become clear in Chapter V, when there will be a comparison between bonds and gold (and other assets) based on their risk-return relation and their effect on the risk-return relation of several portfolios.

Another important factor to consider is the financial merit that may lie in investing in gold, in a similar fashion as was established for government bonds. There are several ways to capture this. First, a graphical representation can show the development of gold prices. Gold bullion prices are determined twice per day in auction at the London Bullion Market Association. They are auctioned in US dollar and published at midnight, hence a delay in gold prices. As the gold prices are published per day, the gold price reflects the value relative to the US dollar at that day (LMBA, n.d.). Therefore, inflation might play a role. In graph 4 the nominal and real gold prices are shown, having 1-8-1983 as CPI benchmark date. This is done in two different ways, first by showing the pure gold bullion prices per ounce, and second by showing an index of the gold price.

Graphs 4 & 5: Gold prices in USD per troy ounce and Gold price index



Graphs 4 and 5 show a similar price development when looking at nominal prices, and slightly less extreme increases for real prices. For the price index depicted in graph 5, the base year is taken in the middle of the dataset, which is August 1st, 1993. This is purely arbitrary. For other comparisons, the base year of return indices will be set equal to each other. It becomes apparent that gold prices have a strong increasing trend, being three times the value of the base year in 2018. Gold prices are also seen to be decreasing in several instances. To give another indication of the development of gold prices, in similar fashion to the analysis of bond yields, a table of the gold prices with measures of central tendency and dispersion can be drawn.

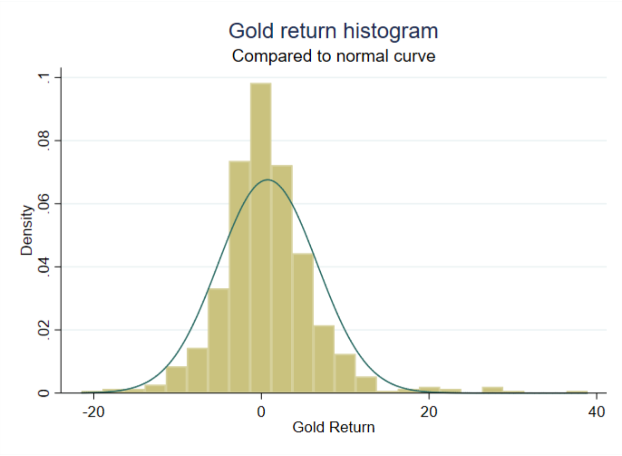
Table 12: Gold price returns

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
Balanced Gold index	611	127.414	93.222	106.122	8.584	67.369	155.515	450.117
Gold MOM % Return	611	0.748	0.088	5.904	-21.468	-2.552	3.248	38.920

Measures of central tendency and dispersion of the month-on-month (MOM) return on gold and the Gold price index (100 = 1-8-1993). Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.

Table 12 shows several things. Firstly, there are two ways to measure the returns. The first is the balanced gold index, where the middle of the observations was taken as the base year to construct the index. There is a clear time trend in the data. What it shows is that the value of gold has differed tremendously in recent times. This is especially indicated through the very high standard deviation. Furthermore, the median is lower than the mean, indicating that there is pressure from the right hand side (the highest 50% of observations). That would mean that prices have had an exponential growth from the base year on, something that is clearly indicated in graph 5. What the index does not show and the month-on-month return does show, is that there is a significant possibility that the value of the investment decreases dramatically. In fact, the dispersion measures show that the possibility of getting negative returns is almost 50%. If the outcomes of the central tendency and dispersion were plotted in a bell curve, the fit might almost be exact. To test this, graph 6 shows the histogram of the gold MOM returns, compared to the normal curve:

Graph 6: Gold return histogram



Graph 6 shows that indeed, gold prices are largely captured by the normal curve. There is a higher concentration in the middle values, with returns around 0. Also apparent is that there is quite some density underneath the upside of the returns distribution. That shows that there are some outliers in the returns distribution that tend to be positive for investors. That does not rule out the possibility that these tail-events happen on the other tail, which would be a large loss for investors.

Something that makes gold perhaps a better investment choice than government bonds is that there is little potential for dilution. With gold, the supply is largely limited. Unless a major new gold vein is found, the maximum total supply is fixed. That means that the value might only increase, as long as gold attracts people and investors. With bonds, there can always be new issues of government debt, making a batch of bonds with a lower interest rate less attractive.

So far, the comparison with government bonds might not have been very fair however. For bonds, the yield on 10 year bonds was taken, which is the return an investor gets whilst holding bonds with a 10 year maturity to their maturity. For the gold returns, so far the only examination has been what the month-on-month return was. As discussed already, the return that can be achieved on gold is heavily dependent on the holding period. Therefore, in order to have a fair comparison, it would be best to create the 10 year holding returns for gold. As bond yield examines the expected yield of the 10 year bond, the 10 year yield on holding gold will be calculated by:

$$Yield_t = \frac{Price_{t+10years} - Price_t}{Price_t} * 100\%$$

This means that there are quite some observations (months) dropped, as for the final 10 years of observations, there can be no calculations (future gold prices are unknown). To deal with that loss of observations, also a 5 year holding period is considered. This gives more observations, which reduces the risk of drawing conclusions from a too small sample size. A table of summary statistics shows:

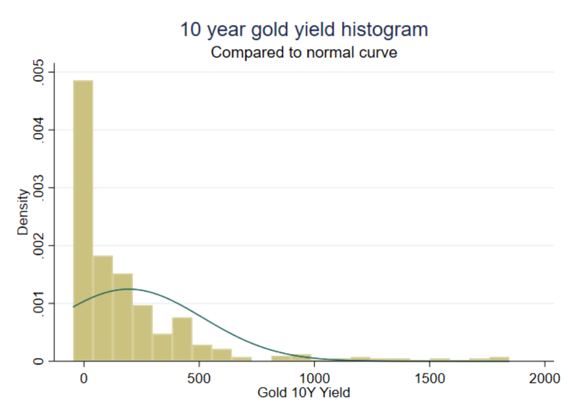
Table 13: 5 and 10 year gold returns

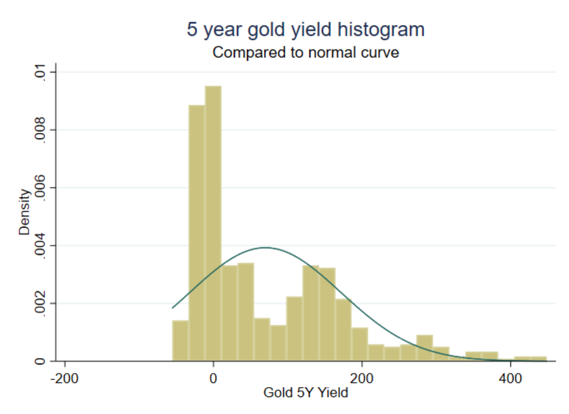
Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
MOM return (%)	611	0.748	0.088	5.904	-21.468	-2.552	3.248	38.920
10Y Yield	491	194.082	86.621	320.239	-46.593	-3.039	241.835	1845.162
5Y Yield	551	69.805	28.604	101.628	-55.240	-9.134	138.149	448.763

Measures of central tendency and dispersion of the month-on-month (MOM) return on gold, 10 year holding period returns of gold and 5 year holding period returns of gold. For the 10 year yield, observations go from 1-2-1968 to 1-12-2008, for the 5 year yield, observations go from 1-2-1968 to 1-12-2013. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.

Table 13 shows that with a ten year holding period, the return on a gold investment on average is 194%. That means that investing in gold can nearly triple the investment in ten years. Furthermore, there is still a possibility of getting a negative return, however with the values that show the first and third quartile, the suspicion arises that the dispersion is no longer normal, in this case indicating a potentially higher likelihood of having a positive return rather than a negative return. This can of course be checked by plotting the observations in a histogram. The data of 10 year holding period returns stops at the end of 2008. This makes it difficult to assess the development of returns post 2008 crisis. This problem disappears when examining the 5 year holding period return. Logically, the returns are much lower when holding an asset with increasing prices for a shorter period of time. It would also be interesting to see what the density plot of the five year yield would look like:

Graphs 7 & 8: Histogram of 5 and 10 year gold returns





Indeed, graph 7 shows that the normal distribution of gold returns disappears when a ten year holding period is concerned rather than a month-on-month calculation. The density distribution shows mainly positive returns, but when looking at the tail on the negative side, something very interesting happens. There is a very fat negative tail, as the normal distribution really does not hold with this density plot. There are a lot of highly positive outliers, as indicated by the density below the positive tail. Graph 7 overall indicates that under a normal distribution, there are a lot of unobserved negative values, perhaps posing a significant risk for gold investors. Graph 8 shows that the density dispersion of the five year yield is much different from the dispersion of the ten year yield. There is a large density slightly below zero. From table 13, the chance is at least 25% that an investor has a negative return over a five year holding period. This is relatively high. Furthermore, the histogram shows that the density dispersion is much less normal now. There still is more positive tail than negative tail however, indicating the possibility of more negative returns assuming that the five year holding period returns should be normally distributed.

3.1.3. Conclusions

The case for gold is mixed at best. As far as the theoretical analysis is concerned, gold cannot serve as a risk-free asset, unless there is a suitable financial derivative. Some derivatives, like futures and forwards, could be the safe contract that is necessary to speak of a risk-free asset. To eliminate default risk for these derivatives, they should be centrally cleared, something that is done by CCPs for institutional investors, but as of yet unavailable to small individual investors. If those conditions would be met, perhaps gold could act as a risk-free asset in a theoretical sense.

But theory does not tell the whole story. There are also other important concerns that weigh on the suitability of gold as a risk-free asset. The potential of losing money with an investment in gold seems to be much higher than with government bonds. This risk seems large based on month-on-month returns, however when considering the yield over a ten year holding period, the returns become more positive. On average, the investment in gold can nearly triple in a ten year period, based on previous returns. Still, there is a significant chance (over 25%) of having a negative return on investment. This negative tendency is even larger when examining a five year holding period.

Overall, gold cannot be called a better risk-free asset than government bonds, simply due to the relatively large chance to make a loss on the investment. Nevertheless, it would be interesting to examine the performance of gold in a theoretical setting (CAPM) and its portfolio performance. This will be done later in the thesis.

Table 14: Summary of gold analysis

	Criterion	**Satisfied?**	**Satisfied after workaround?**
Devoid of two chances:	1) Chance of default	Yes	
	2) Chance to use it as cash	Yes	
The asset must contain:	1) Definite payments	~	Yes
	2) Definite repayments	~	Yes
	3) Definite dates	~	Yes
The six principles			
	When satisfied?		
(1)	If there is investing	Yes	
(2)	Assuming rationality, holds	Yes	
(3)	If there is investing	Yes	
(4)	If there is investing	Yes	
(5)	When markets are cleared daily, no hard cutoff	Yes	
(6)	If there is guaranteed repayment	~	Yes

This table shows a summary of the criteria making an asset risk-free. Criteria that are satisfied get assigned “Yes”, criteria that are not strongly supported get “~” and criteria that are not supported get “No”.
Satisfied after workaround shows that the asset could function as risk-free asset after a suitable solution for a particular problem is found. This is elaborated upon in the chapter rather than in the table.

3.2 Wine

Another alternative investment category is wine, more specifically fine wine. Wine is produced every year and the quality of the wine is dependent on region, weather and grapes used (Dimson, Rousseau, & Spaenjers, 2015). The production capacity is limited, and after the wine is bottled, the quality of the batch can be established. This leads to a situation where pure wine lovers will pay extra based on the region and year the wine was produced in. These bottles tend to increase in value over time (Dimson et al., 2015). These characteristics have led to an increasing consideration to invest in fine wines.

The fine wine market has in fact become so lucrative, that there are now companies offering to invest in wine for the investor. This is fairly similar to an ETF, an investor buys a share of the fine wine portfolio of the portfolio manager, similar to how an ETF sells shares that allow the investor to track a certain basket of stocks or bonds. Also, there are market makers that have set up a wine exchange similar to a stock exchange. One of such companies is Liv-Ex (LivEx, n.d.-a). The company serves as a market maker through its trading platform and as a result of these activities, it has a treasure of data. The company used this to create several fine wine indices, which can be found on information platforms like Bloomberg. For the analysis of fine wine investment, one of these Liv-Ex indices is adopted, namely the Live-EX FW100. The company itself calls the index the industry leading benchmark, as it is a combination of the 100 most sought after fine wines. The index is not composed arbitrarily. The determination of what wines to use is a function of market activity and market interest in those wines. The value of the index is composed by taking the mid-price. This means that the platform takes the average of the highest bid and the lowest ask price. This is then verified by a valuation committee to ensure the robustness of the resulting price (LivEx, n.d.-b). As of yet, there is no ETF based on the Liv-Ex F100, however in the discussion about the suitability of a risk-free asset, this thesis will assume that it is possible to invest in the index as a whole.

3.2.1. Theoretical considerations

The first criterion of the risk free asset, is that it has to be devoid of two chances, the chance of default and the chance to use the asset as cash. The chance of default does somewhat exist. The problem with the value of wine is that the price should reflect the fundamental value of the asset in the same way that the stock price should do this. For stocks, some say there are other factors influencing price, however (Fama & French, 1993, 2015). One could argue that perhaps the book-value (plus some expectations about future values) of the stock might be its fundamental value. This cannot be established with fine wines. Therefore, one could argue that investors might ‘default’ on the premium that is paid for the wine. As wine is a physical good, there is less risk that a counterparty might default. The chance to use the asset as cash is very low. Wine is generally not a currency, and as such this chance is comfortably non-existent.

The risk-free asset must also be a safe loan or contract that contains definite payments, definite repayments and definite dates. That is difficult with investing in wine or in a wine ETF. Further financial derivatives could solve this issue, for instance through a future or forward on the ETF. That is tricky reasoning however, as it requires two steps more than currently possible. As discussed with gold however, forwards and futures can be assumed to hold to these criteria, especially when centrally cleared. As of yet, wine, nor the Liv-Ex FW 100 index adheres to these criteria.

The final set of criteria comes from the principles of the interest rate.

A) ***Investment opportunity principles***: as mentioned in the previous two analyses, the investment opportunity principles are difficult to assess. The fact that there is investment in wine would mean that the Principle of Income Choice and the Principle of Maximum Present Value hold.
B) ***Impatience principles***: time preference and wine investing are closely related. Wine prices increase with the age of wine (Dimson et al., 2015). If investors know this, there are two options for investors. Either they pay a higher price to buy old wine in the expectation that the price will increase further, or they pay a lower price to buy a young bottle of wine. In that case, the expected holding period for wine will be much higher. Similar to gold, the act of buying wine (lending money) or selling wine (borrowing money) can be placed into the context of the Principle of Time Preference. If the actors are rational, they will also fulfill the Principle of Maximum Desirability by timing the investments in such a way that the payoffs and cash flows will suit the investor the best.
C) ***Market principles***: the two market principles seem to hold in the wine market and with Liv-Ex more specifically. The Liv-Ex platform has between 20 and 30 million pound sterling in both orders and offers. The market prices of wine will in the end be such that orders are executed, as per the laws of demand and supply. Following from that, the Principle of Clearing the Market is fulfilled. The other market principle is the Principle of Repayment. This is difficult when investing in wine, as there is no pre-specified moment at which to sell, unless a forward or future is adopted. Then, the Principle of Repayment can hold in the same sense that it could with gold, through a CCP. Taking a stricter approach, Liv-Ex has a guarantee that trades are completed, taking care of transport and guaranteeing payment, which would limit default risk as well.

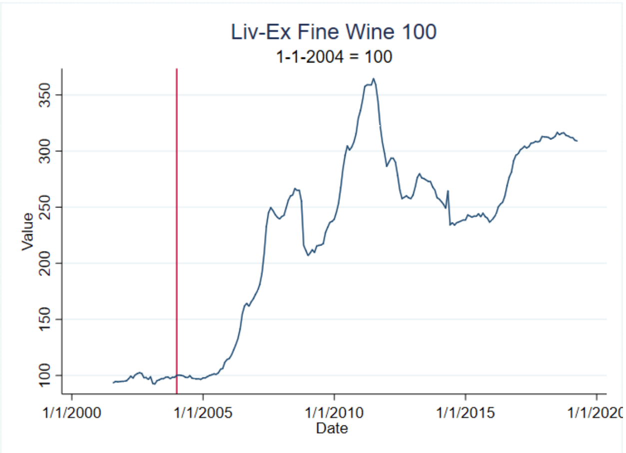
The conclusions of the theoretical review of fine wines are mixed. There are quite some ‘ifs’ that would ensure a conclusion that fine wines could be the new risk-free asset. Important to note here is that these developments are not unattainable. In fact, it is only a question of whether adopting this would be profitable enough to justify offering an ETF and futures on the ETF. The theoretical analysis should not yield all of the conclusions however. Therefore, the next part will attempt to identify other threats and opportunities to wine as a risk-free asset.

3.2.2. Other important considerations

The value of wine is mainly determined by its age, region and the weather that in which the grapes were grown (Dimson et al., 2015). As such, climate change poses a large threat to wine in the future (Ashenfelter & Storchmann, 2010; Bernetti, Menghini, Marinelli, Sacchelli, & Sottini, 2012; Mozell & Thach, 2014; H R Schultz & Stoll, 2010; Hans R Schultz & Jones, 2010). Climate change may affect for instance the temperature in which the grapes grow, which can be either for better or worse. Furthermore, different types of UV waves and other radiations could affect the taste of the grapes, and as such the taste of the wine. This threat of climate change can affect investing in wine in two ways, one positive and one negative. If future wine will be of an inferior quality because of climate change, older wines will become more popular, and as such their prices will increase. That is good for investors. That effect should not be assumed to be linear however. If new wine is of such an inferior quality that people start preferring other drinks, the price of older wines may be negatively affected. Furthermore, the increasing price could make wine a luxury good, which could have a mixed effect on the future prices.

Of course, similar to the other assets under evaluation, it is also important to establish whether there is financial merit in investing in wine. The easiest way to indicate wine returns is through a graphical representation. The Liv-Ex fine wine 100 index has 1-1-2004 as base moment. This is marked in the graph showing the development of the wine index by a vertical line in graph 9.

Graph 9: Wine index



Graph 9 shows that wine prices have developed strongly since 2004. There are also some deep troughs in the graph however. Dimson et al. (2014) found that wine is correlated to stock markets to some degree, and for instance the drop in the wine index around 2008 does show this. Month on month, the price developments look differently, which is shown in table 15:

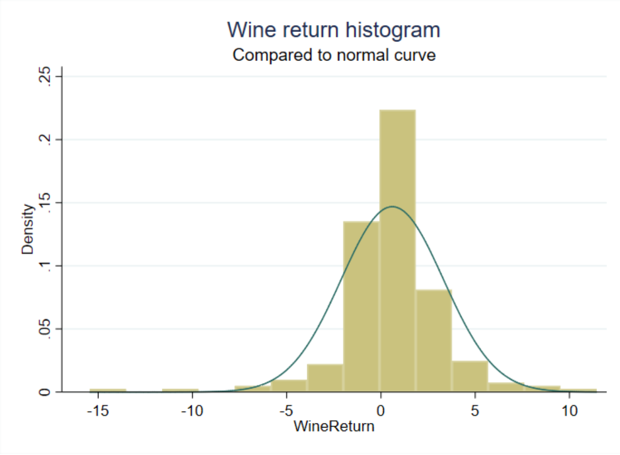
Table 15: Wine returns

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
Wine Index	213	220.538	242.110	83.103	92.292	115.088	286.330	364.690
% MOM Return	212	0.603	0.430	2.717	-15.441	-0.459	1.711	11.446

Measures of central tendency and dispersion of the month-on-month (MOM) return on the wine index and the absolute values of the wine index. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.

The row in the table that shows the month-on-month return has a similar pattern as with gold (in table 12). Furthermore, as graph 9 shows, the holding period of the wine investment is also an important factor in determining the successfulness of the investment. Based on the measures of central tendency and dispersion of the wine index returns, it would be interesting to see a histogram of these returns.

Graph 10: Histogram of wine index returns



Graph 10 shows that the returns of the Liv-Ex fine wine index are somewhat normally distributed. Here again the middle density block is a little too high. Perhaps more worrying for wine investors compared to gold investors is the negative tail in the normal curve, where for gold there was a positive tail. That does not mean that these spikes in positive return could not happen in wine, just like negative tail events are not excluded for gold returns. The mean MOM return of wine is not very high, however as the wine index plot indicates, for a longer holding period this is less of a problem.

Similar to gold, it would make a fairer comparison to analyze wine returns when examining a longer holding period. First, the ten year holding period will be examined. Important to note however, is that the Liv-Ex fine wine 100 index is not very old yet. Therefore, there are not a lot of observations, which already becomes apparent by looking at table 15. In fact, the amount of observations for a ten year holding period of wine is below 100. Nevertheless, this makes the best comparison, therefore this will be the first comparison that is drawn. Furthermore, as with gold, to add observations a shorter holding period of five years is considered.

Table 16: 5 and 10 year wine returns

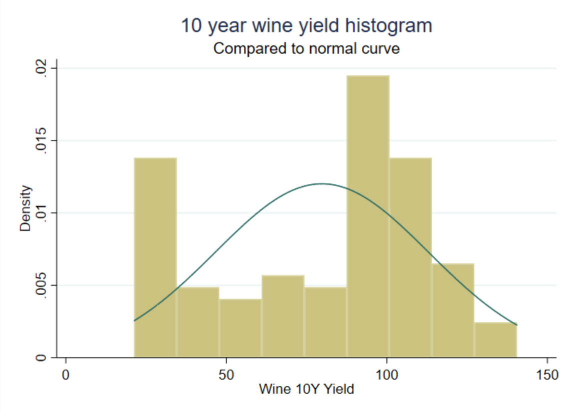
Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
MOM return (%)	212	0.603	0.430	2.717	-15.441	-0.459	1.711	11.446
10Y Yield	93	79.760	94.541	33.220	21.285	52.021	103.653	140.485
5Y Yield	153	62.850	22.254	71.990	-31.823	4.943	134.278	201.430

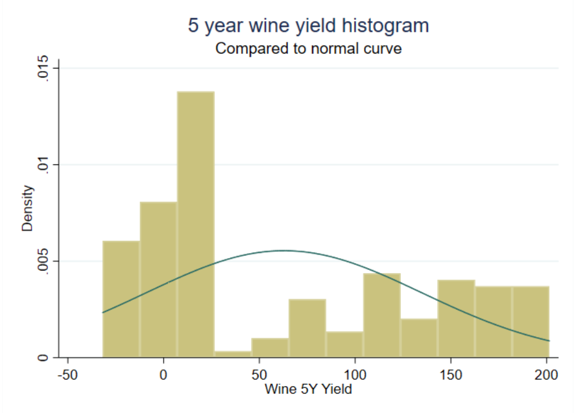
Measures of central tendency and dispersion of the month-on-month (MOM) return on wine, the 10 year holding period return of wine and the 5 year holding period return of wine. For the 10 year holding period, observations go from 1-8-2001 to 1-4-2009 and for the 5 year holding period return from 1-8-2001 to 1-4-2014. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.

Table 16 shows that over ten year holding periods, wine returns are strong. Perhaps more importantly, over the ten year holding periods that were examined, there have been no periods with negative returns. On average, the yield of holding the 100 fine wines included in the Liv-Ex index was almost 80%, with a minimum holding period return of over 20%. The results of the ten year holding period returns seem to be somewhat normally distributed, which can be tested by plotting the density graph 11. The table also shows that taking a five year holding period significantly increases the amount of observations.

That makes the five year yield more useful for statistical testing later on in this thesis. Furthermore, there is now a possibility of having a negative return on the investment, however it seems like the possibility is rather small, as at the 25% threshold the return is already positive. Variance of the returns has increased quite a lot. Graph 12 could show what the density of the return distribution looks like.

Graphs 11 & 12: Histogram of 5 and 10 year wine returns





Graph 11 shows that the ten year wine return does not follow a normal distribution. Most density seems to be at the right hand side of the average, but the tail on the lower side of the distribution also has a lot of density underneath. As mentioned already however, there are no negative returns for any of the ten year holding period returns of wine investment. As noted, the amount of months that are observed is rather low, with 93 months under consideration. Therefore, it is difficult to draw statistically valid conclusions from these returns. Similar to gold then, it is also interesting to examine shorter holding periods. This could solve the absence of enough observations. Graph 12 quite clearly shows that the density distribution is not normal. Both tails are rather fat, with a rather prominent negative tail and a normal curve that does not nearly seem confirmed by the density plot. The summary statistics show that the first quarter of returns already has positive returns.

3.2.3. Conclusions

Wine seems to have some important qualities that might favor it as a possible risk-free asset. From a theoretical point of view, there are some 'ifs' that have to be satisfied before investing in wine could be a risk-free asset. First of all, there is no financial product (yet) that allows investors to buy the Liv-Ex index without purchasing all the bottles either directly or through a manager. An ETF that has a wine portfolio that mirrors the Liv-Ex index would be the first step. There is a threat of possible market interference if this happens on a large scale however. Another option would be to make futures or forwards that are settled in cash that derive their value from the Liv-Ex wine index. Then there would be the safe contract that could constitute the risk-free asset. These 'ifs' are not unrealistic, they could be easily attainable, however whether that happens depends on the profitability of those contracts and the possibility of profit for both sides of the derivative.

Other considerations that could affect whether wine can be a risk-free asset are climate change and the financial merit. Climate change can pose either a risk or an opportunity for wine producers.

Some regions may become unsuitable for wine grapes and some regions might prove to become suitable to grow grapes. Radiation and temperature might also affect the taste of grapes and other factors. All in all, this could increase the future demand for older wines, as the future quality is uncertain whereas the past quality is known. On the financial merit, analysis shows that over 10 year holding periods, the yield of Live-Ex wine has not been negative. The amount of observations is rather low however. Therefore, also an analysis was conducted on the returns of a five year holding period of wine. In this shorter period, negative yields have happened. Overall however, there seems to be a strong financial argument to invest in wine, perhaps as a risk-free asset.

How wine holds up relative to other possible risk-free assets will be examined later on in this thesis. It will be examined based on the use as risk-free asset in valuation theory (CAPM) and its investment use in portfolios.

Table 17: Summary of wine analysis

Criterion		Satisfied?	Satisfied after workaround?
Devoid of two chances:	1) Chance of default	Yes	
	2) Chance to use it as cash	Yes	
The asset must contain:	1) Definite payments	~	Yes
	2) Definite repayments	~	Yes
	3) Definite dates	~	Yes
The six principles			
	When satisfied?		
(1)	If there is investing	Yes	
(2)	Assuming rationality, holds	Yes	
(3)	If there is investing	Yes	
(4)	If there is investing	Yes	
(5)	When markets are cleared daily, no hard cutoff	Yes	
(6)	If there is guaranteed repayment	~	Yes

This table shows a summary of the criteria making an asset risk-free. Criteria that are satisfied get assigned “Yes”, criteria that are not strongly supported get “~” and criteria that are not supported get “No”.
Satisfied after workaround shows that the asset could function as risk-free asset after a suitable solution for a particular problem is found. This is elaborated upon in the chapter rather than in the table.

3.3. Corporate bonds

A final, and perhaps most logical alternative to government bonds as risk-free asset that is considered in this thesis, are corporate bonds. Corporate bonds possess some characteristics that are very similar to government bonds, yet bring higher yields. Corporate bonds can be classified, much like government bonds, into two categories; investment grade and high yield. High yield bonds are generally known as junk bonds, as they are often deemed too risky for large institutional investors. Investment grade bonds are rated anywhere between AAA to BBB- (for Fitch and S&P) and between AAA and Baa3 (for Moody's).

There are several ways to invest in corporate bonds. One could try and hold the bonds directly, like one would do with government bonds. A safer, more diversified manner to invest in corporate bonds would be investing in a corporate bond ETF. The benefit of this is that there is less idiosyncratic risk, as companies are generally more likely to default than sovereign governments. One of such indices, that consists of only investment grade corporate bonds, is the "iShares iBoxx $ Investment Grade Corporate Bond ETF" (LQD). Many of this ETF's most important characteristics are implied in the name. The ETF consists of dollar-denominated corporate bonds, that are all investment grade. The ETF had its inception in 2002. Due to its diversified character and ease to invest in, the proxy for corporate bonds will be this iShares IG corporate bond ETF.

3.3.1. Theoretical considerations

The first criterion is that the risk-free asset is that it is a safe contract which is devoid of two chances; the chance of default and the chance to use the asset as cash. The chance of default is definitely possible with corporate bonds, however due to the diversified nature of the iShares ETF, this general ETF has a low chance of default. The fund has nearly 2000 constituents, making it very robust to idiosyncratic default risk (iShares, n.d.). The chance to use the asset as cash is virtually non-existent. As an ETF, the asset is highly liquid and as such can be converted into quick cash, however there is no opportunity to make payments with this ETF, successfully eliminating the chance to use this asset as cash.

Then there are the three contractual characteristics that the asset bearing the risk-free rate should adhere to. These requirements are that the contract contains:

- Definite and assured payments: this holds true for the corporate bonds in the same fashion that it holds true for government bonds. For the ETF itself, this is different. The definite and assured payment is offered when the investor invests in the ETF;
- Definite and assured repayments: this again is the same for corporate bonds in the index as government bonds, however corporate bonds tend to be more risky. Therefore, the assured character of the corporate bond is lower than that of government bonds. As mentioned however, the ETF is more robust to these shocks. It does bring in the risk that there are no buyers when the stake in the ETF is sold, which is the definite part of the repayment. Furthermore, buying a

stake in an ETF is an open-ended investment. This constraint could be avoided by again buying a forward or a future that derives its value from the ETF.

- Definite dates, which, again, is not necessarily the case when investing in the ETF. If the assumption is taken that there is an investment in a derivative that depends on the value of the ETF, the dates are set.

That leaves with the final set of theoretical characteristics of the risk-free asset, namely the principles of the interest rate.

A) ***Investment opportunity principles***: as has been the case with all evaluations of the investment opportunity principles, the fact that there is money being invested shows that the Principle of Income Choice and the Principle of Maximum Present Value might hold. There is no indication that either of these two principles is violated, which is the minimum threshold to speak of a risk-free asset in this analysis.

B) ***Impatience principles***: the impatience principles refer to the actual modifying of the chosen income stream through investing. Again, here the argument could be made that as there is investing in the asset, individuals are in the business of modifying their income stream through borrowing and lending. The borrowing would in this case refer to shorting the ETF, meaning that shares of the ETF are borrowed and sold for cash. At a later moment, the shares are bought back and returned, at which point the borrowing has ended. This reasoning is more difficult and perhaps slightly more far-fetched than the reasoning behind investing in government bonds and much more far-fetched than the reasoning behind borrowing and lending cash. Considering all, the conclusion is that the Principle of Time Preference and the Principal of Maximum Desirability are not violated, which is the weakest theoretical support for the asset's use as risk-free asset.

C) ***Market principles***: on a daily basis, around 2.5% of the ETF's outstanding shares are traded. That means that the price of the ETF is such that the market is effectively cleared, meaning that the Principle of Clearing the Market can be assumed to hold. The Principle of Repayment is less clear. The counterparty in an exchange that trades ETFs can only trade if there is enough balance, and thus repayment is guaranteed. For the futures and/or forwards that should be used to make the ETF a risk-free asset, repayment is less clear. That could change if the market for those derivatives would be centrally cleared. There is no clear indication that the Principle of Repayment does not hold, so which is the minimum to accept the principle.

The theoretical analysis shows that there is relatively good support for the use of corporate bonds, more specifically a corporate bond ETF as risk-free asset. The main disqualification for the ETF is that there is no fixed end date to the contract, and that the open ended investment thus has no specified maturity, something that is necessary according to Fisher's theoretical qualifications of the risk-free asset. This can easily be solved by creating financial derivatives (like futures and forwards) who's payoffs depend on the value of the ETF, which is not inconceivable, as long as there is enough demand for this service.

3.3.2. Other important considerations

The most important consideration with respect to this corporate bond index is the financial merit. First, examining the returns of the corporate bond index could give interesting insight in what the month-on-month returns of the bond index would be.

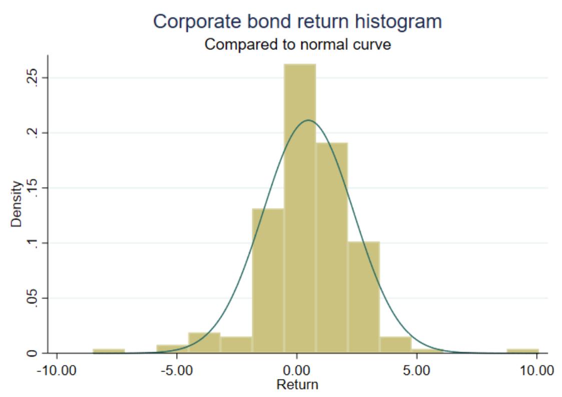
Table 18: Corporate bond index returns

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
Value	202	197.624	194.710	53.583	115.669	145.012	247.518	290.976
MOM (%) return	201	0.478	0.545	1.887	-8.496	-0.425	1.383	10.082

Measures of central tendency and dispersion of the value of the corporate bond index and the month-on-month (MOM) returns obtained from holding this index.. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.

Table 18 shows that the index has a strong value. Interpreting the value of the corporate bond index itself is difficult, as the minimum value is 115. Most index values start at 100. Therefore, the month-on-month index return is perhaps more telling. The return shows perhaps a roughly normal distribution, meaning that there is a significant chance of having negative month-on-month returns. That suspicion can be confirmed by looking at the histogram of month-on-month returns:

Graph 13: Histogram of MOM index returns



Graph 13 shows that indeed the returns of the corporate bond index are roughly normally distributed. The same criticism on the use of MOM returns as on those of wine and gold can be applied however, namely that the yield on government bonds considered a ten year holding period. Therefore, similar to the analysis of wine and gold, it would be fairest to examine the returns over such a holding period for corporate bonds with a holding period of the ETF of five and ten years.

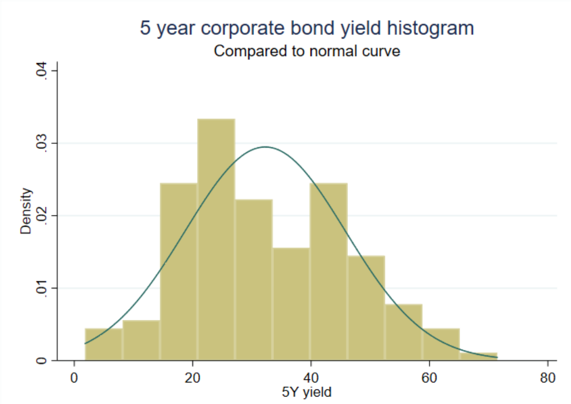
Table 19: 5 and 10 year corporate bond returns

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
MOM (%) Return	201	0.478	0.545	1.887	-8.496	-0.425	1.383	10.082
10Y Yield	82	80.442	78.058	7.492	67.126	74.680	84.770	100.629
5Y Yield	142	32.255	29.003	13.534	1.827	21.372	43.278	71.450

Measures of central tendency and dispersion of the value of the month-on-month (MOM) returns obtained from holding this index, the 10 year holding period returns from holding this index and the 5 year holding period return. Observations run from 1-8-2002 to 1-5-2009 for the 10 year holding period and from 1-8-2002 to 1-5-2014 for the 5 year holding period. Central tendency measures are the mean and median, dispersion measures are the standard deviation, minimum and maximum values and the quarter values.

Table 19 shows firstly that the return over a ten year holding period of this index is rather high, considering the constituents of this index are all investment grade corporate bonds, which are deemed to be more risky than safe government bonds, yet their investment grade qualification means that the bonds are still rather safe. Furthermore, there are no negative returns for holding the index over a ten year period. There are two important remarks to be made with this observation however. The first is that there are only 82 observations when examining the ten year holding period return, due to the relative short existence of the index. The second is indicated in the footnote of table 19, namely that the observations only run to the first of May, 2009. That means that the recession which took a hold of the US economy in 2008 might not have come into full effect for the companies in the index. Therefore, examining the returns on a five year holding period might hold some extra merit. The table also shows that taking five year holding period returns significantly improves the amount of months under observation. This does cost in terms of the yield however. Most returns are halved. Interestingly, also the volatility of these returns increased from having shorter yield periods. Still however, there are no periods where holding this index of corporate bonds yielded negative returns, although the minimum value does come close. It would be interesting to see whether this low observation is an outlier or a significant part of the return distribution. This can be seen in graph 14:

Graph 14: 5 year corporate bond index returns



Graph 14 shows a rather fat tail (plenty of space between the x-axis and the curve) towards the 0 return observations, indicating from a normal distribution point of view that it is relatively likely that some negative returns might happen in the future over five year holding periods.

3.3.3. Conclusions

It seems that corporate bonds, perhaps through the chosen iShares corporate bond index, can be a suitable risk-free asset. It has most characteristics in common to government bonds, but individual corporate bonds tend to have a higher risk-profile. That means that individual corporate bonds tend to default earlier than individual government bonds. Interestingly however, by piling nearly 2000 corporate bonds, there are diversification benefits that could seriously mitigate the default risk of corporate bonds. That makes the ETF very much in contention to be a risk-free asset. Similar to other assets, there needs to be a financial derivative that poses as the required safe contract that Fisher identifies as the risk-free asset, as investing in an ETF is an open-ended investment, which the risk-free asset should not be.

From a financial point of view, a corporate bond index is also a very interesting alternative to government bonds as a risk-free asset. The potential for negative returns over a holding period of five years is there, however in the current dataset, it has not happened. Over a ten year holding period, these returns are even higher. The observations for this ten year holding period are not enough to confidently make strong claims about this however.

Table 20: Summary of corporate bond analysis

Criterion		Satisfied?	Satisfied after workaround?
Devoid of two chances:	1) Chance of default	Yes	
	2) Chance to use it as cash	Yes	
The asset must contain:	1) Definite payments	~	Yes
	2) Definite repayments	~	Yes
	3) Definite dates	~	Yes
The six principles			
	When satisfied?		
(1)	If there is investing	Yes	
(2)	Assuming rationality, holds	Yes	
(3)	If there is investing	Yes	
(4)	If there is investing	Yes	
(5)	When markets are cleared daily, no hard cutoff	Yes	
(6)	If there is guaranteed repayment	~	Yes

This table shows a summary of the criteria making an asset risk-free. Criteria that are satisfied get assigned “Yes”, criteria that are not strongly supported get “~” and criteria that are not supported get “No”.
Satisfied after workaround shows that the asset could function as risk-free asset after a suitable solution for a particular problem is found. This is elaborated upon in the chapter rather than in the table.

3.4. Conclusion

The previous three chapters sought to answer the first research question of this thesis, namely: *What is the risk-free asset and what is an appropriate operationalization of this asset?*. Chapter I offered a deconstruction of the risk-free asset on a theoretical level, establishing a framework that was then used to evaluate government bonds and gold, wine and corporate bonds as operationalizations of the risk-free asset. Government bonds were analyzed based on this framework in chapter II. Chapter III finally tested the possibility of using gold, wine and corporate bonds on a theoretical level, also highlighting some important other concerns that could affect their applicability as risk-free asset. It seems that government bonds and corporate bonds are the best possible proxies. Government bonds are strictly speaking not risk-free, however they are very safe contracts that offer a nearly guaranteed repayment for investors. The same goes for the corporate bond ETF that was examined in this chapter. Corporate bonds in itself are more risky than their sovereign counterparts, but adding nearly 2000 bonds from different firms brings significant diversification benefits that have yet to experience negative returns.

IV. The Capital Asset Pricing Model

Now that the risk-free rate has been examined on a theoretical level and after an evaluation of the common proxy government bonds and three possible alternatives to this proxy, it should be established how well these proxies work. This leads to testing the second research question, which is:

RQ2: 'To what extent can alternative proxies of the risk-free rate improve the result of CAPM regressions?'

This chapter will start with a discussion about the Capital Asset Pricing Model, as well as a justification for using the simple-form CAPM. Then the chapter will continue with empirical analysis, testing CAPM with government bond yields, as well as with the alternative asset returns that were established in chapter III.

4.1. Theory on CAPM

The Capital Asset Pricing Model is a result of several works of literature published around the same time (Hamada, 1969; Lintner, 1965; Mossin, 1966; Sharpe, 1964). They build on modern portfolio theory (MPT), as introduced by Harry Markowitz (Markowitz, 1952). According to MPT, investors are risk averse. If offered the same return for a less risky asset, they will take the less risky asset. Combining several risky assets leads to diversification benefits. Through combining risky assets, investors can determine the optimal risk-return profile of risky assets. That leads to the efficient frontier, which is a line of combinations of risky assets with the same risk-return combination, but with different levels of risk. Investors can then invest according to their risk-preferences. If there is a risk-free asset, the risk-return line of this asset is the tangency line that touches the efficiency frontier. This is the most optimal portfolio to hold, called the market portfolio, which will be held by all (rational) investors.

This logic was applied to asset pricing in the 1960s. As all investors hold the market portfolio, so all risky assets in the same proportions, ultimately the supply of assets to the market will be in the same proportions as their size in the market portfolio (i.e. relative supply equals relative demand). The portfolios of investors consist of the risk-free asset and a collection of risky assets (namely the market portfolio). CAPM states that any asset should be priced according to its relative sensitivity to market risk, that is, the beta of the asset. The beta is calculated as follows:

$$\beta_i = \frac{Cov(R_i, R_m)}{Var(R_m)},$$

where β_i is the beta of asset *i*, $Cov(R_i, R_m)$ is the covariance between the return of asset *i* and the return of the market and $Var(R_m)$ is the variance of the market return. Intuitively, the beta measures how much the return of asset *i* changes relative to the return of the market. According to MPT and the starting point of CAPM, investors hold the market portfolio, which is perfectly diversified. Because there is a risk-free asset, a risk-reward ratio can be calculated. The expected return of the asset *i* should be explained fully by its beta, in other words, the expected return $E(R_i)$ can be deflated by its beta, which gives the market return (any other risks on the asset will be diversified away by adding it to the portfolio, therefore only its sensitivity to market returns remains). That means that:

$$\frac{E(R_i) - r_f}{\beta_i} = E(R_m) - r_f,$$

where $E(R_i)$ is the expected return on asset i, r_f is the risk-free rate, β_i is the beta of asset i¸ and $E(R_m)$ is the expected market return. This is the mathematical representation of the intuition just explained. This mathematical representation can be rewritten to the standard form CAPM formula:

$$E(R_i) = r_f + \beta_i[E(R_m) - r_f],$$

where $E(R_i)$ is the expected return on asset i, r_f is the risk-free rate, β_i is the beta of asset i¸ and $E(R_m)$ is the expected market return.

CAPM has been not without its critique (Basu & Chawla, 2010; Lettau & Ludvigson, 2001; Mackinlay, 1995). One of the most important arguments that is continuously made against CAPM is that the model seems to be hard to prove through empirical testing. What this research seeks to prove, is that it might not be the model that is at fault for failing to correctly predict expected returns, rather it might be the fault of the operationalization of the risk-free asset. As becomes clear from discussions in chapters II and III, there are other assets that might be a better operationalization of the risk-free asset than government bonds. Because this could devalue the criticisms based on lack of empirical support, it is not necessary to look at altered versions of CAPM. These were namely constructed to improve the statistical relevance of the model. With a proper operationalization, this problem could disappear, making the base CAPM a proper model to test.

Testing the simple form CAPM is rather straightforward. Similar to Black et al. (1972), rearranging the model will lead to a simple regression that has some assumptions. The regression model is:

$$R_{it} - r_{ft} = \alpha_{it} + \beta_{it}\left[R_{mt} - r_{ft}\right] + \varepsilon_{it},$$

where $R_i - r_f$ is the excess return of the asset over the risk-free return, α_i is the intercept, $\beta_i\left[R_m - r_f\right]$ is the market sensitivity effect of the asset and ε_i is the error term. The assumptions of CAPM are that there is one source of risk pricing, which is the market risk (the rest can be diversified away). That means that the null-hypothesis of the model is that both α_i and β_i are 0. Thus, per the expectations of CAPM, after a regression, the value of α_i should not be significant and the coefficient of β_i should be significant and close to 1. That way, the null hypothesis is only rejected for β_i. If those two requirements are met, the CAPM can be assumed to hold (Black, Jensen, & Scholes, 1972). Furthermore, Roll's critique of having a constant risk-free rate (Roll, 1969) is also negated with this model.

Similar to earlier testing of CAPM, the model was tested on a selection of 25 stocks. These stocks were chosen on the basis of their data availability. Upon closer inspection, these companies seemed to offer a rather diversified selection of industries. There is of course the possibility of a survivor-bias in the dataset, as default companies will have had their listing removed. For the functioning of CAPM, this does not pose a problem however. The most important concern with respect to the functioning of CAPM is having enough observations. The market return is the only assumed determining factor of the stock return, therefore industries are irrelevant. Nevertheless, if there would be a hidden variable bias in the regression, having diversified industries is a good bonus to the data.

As the regression formula shows, the testing should be done with the returns of the stocks. Therefore, simple monthly returns were calculated as follows:

$$R_{it} = \frac{R_{it} - R_{it-1}}{R_{it-1}} * 100\%,$$

The same formula was applied when calculating market returns. Descriptive statistics of the stock and market returns can be found in appendices A and B. The risk-free rates of return are the same as introduced and analyzed in chapters II and III. This means that the yield on a 10 year government bond is compared with the 5 year holding period returns of gold, wine and corporate bonds.

A first set of regressions was ran, which lead to some interesting outcomes (these are presented in Appendix C). There seemed to be an indication of an unidentified data problem. To establish which error, some diagnostic statistical tests were conducted. A Durbin-Watson test was conducted to investigate the possibility of autocorrelation (Durbin & Watson, 1950). The results of this test showed that there was no reason to expect autocorrelation in the dataset. Then a Dickey-Fuller test was conducted to establish whether the issue may lie in non-stationarity (Dickey & Fuller, 1979). On a visual inspection of the data, there seemed to be no time trend, however the Dickey-Fuller test showed that the data was plagued by non-stationarity. To correct for this problem, a first differences approach was taken. The first differences are calculated as follows:

$$FDX_{it} = X_{it} - X_{it-1},$$

where FDX_{it} are the first differences of variable X at time t, X_{it} is the value of variable X at time t and X_{it-1} is the value of variable X at time t-1.

After the first differences transformation, the diagnostic tests were conducted again. The Durbin-Watson test did still not indicate autocorrelation and the Dickey-Fuller test did not indicate a time trend in the dataset. Chapter III shows that the 5 year holding period returns do not follow a normal distribution. A visual inspection was conducted to see whether taking logarithmic values of changes would improve this distribution. The visual inspection indicated that taking the change of price logarithms did not improve the normality of the density distribution. Therefore, no further transformations were added to the dataset.

4.2. Testing CAPM for U.S. stocks

As baseline analysis in this thesis, similar to literature standards, the US is examined. Therefore, the regression was conducted with 25 stocks listed on the New York Stock Exchange (NYSE). As market return indicator, returns of the broad S&P500 stock index were selected. The S&P is a better market indicator than the Dow Jones Industrial Average or the NASDAQ, as it offers a more diversified selection of industries and companies. The regressions were conducted four times for each company, one with government bonds and three with the alternative risk-free assets. Due to table size constraints, these four regressions are presented in two separate tables.

Table 21: US CAPM regression results for government bonds and gold

Company	**Government bonds**					**Gold**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
Abbott	1.276	4.454	-0.007	-0.100	465	0.574	1.584	0.813	24.413	406
3M	0.981	3.620	-0.072	-1.152	465	0.310	0.904	0.724	22.976	406
Boeing	1.000	2.581	0.314	3.504	465	0.476	1.102	0.816	20.584	406
Caterpillar	1.188	2.841	-0.137	-1.422	465	0.518	1.072	0.676	15.257	406
Coca-Cola	1.091	3.924	0.032	0.500	465	0.521	1.467	0.815	25.006	406
Deere	0.969	2.489	0.147	1.633	465	0.411	0.919	0.783	19.040	406
Ford	0.872	1.592	0.199	1.577	465	0.681	1.112	0.736	13.082	406
GE	0.658	1.964	0.066	0.851	465	0.421	1.087	0.758	21.292	406
IBM	0.744	2.156	-0.007	-0.094	465	0.252	0.604	0.790	20.635	406
Kellog	0.903	3.136	0.022	0.335	465	0.361	0.991	0.802	23.990	406
Pepsi	1.174	4.244	-0.025	-0.394	465	0.557	1.559	0.787	23.960	406
TI	2.310	4.375	-0.113	-0.923	465	1.637	2.636	0.756	13.256	406
JP Morgan	0.878	2.037	0.256	2.576	465	0.404	0.827	0.789	17.591	406
McDonalds	1.284	4.499	0.040	0.601	465	0.666	1.870	0.785	24.008	406
HP	1.068	2.315	0.131	1.231	465	0.535	1.021	0.773	16.043	406
J&J	1.227	4.472	-0.093	-1.465	465	0.566	1.574	0.750	22.683	406
Disney	1.161	3.152	0.252	2.962	465	0.764	1.827	0.792	20.626	406
FedEx	1.114	2.689	0.189	1.973	465	0.669	1.424	0.822	19.051	406
Apple	2.013	3.194	0.164	1.117	456	1.550	2.158	0.830	12.532	397
AT&T	0.633	2.023	0.005	0.072	420	0.142	0.361	0.780	21.336	362
Xerox	0.318	0.638	0.266	2.310	465	-0.018	-0.032	0.782	15.448	406
Motorola	1.076	2.344	0.113	1.069	465	0.469	0.878	0.828	16.872	406
AE	0.436	1.690	0.078	1.308	465	-0.236	-0.729	0.807	27.147	406
Chevron	0.814	2.727	-0.049	-0.715	465	0.212	0.576	0.763	22.498	406
DowDupont	0.894	1.836	0.090	0.799	465	0.262	0.526	0.760	16.620	406
Average	1.043	2.840	0.074	0.726	-	0.508	1.093	0.781	19.838	-

Results of 50 CAPM regressions with government bonds and gold as risk free assets respectively, US stocks and the S&P 500 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table 21 shows the result of the regressions of US firms with government bonds and gold as risk-free assets. The left panel of the table shows the problem that is found in the literature very often, namely that CAPM does not hold. Based on the t-values of the α, the null-hypothesis that α is 0 can strongly be rejected. Furthermore, the value of β is far from close to 1 and rather often insignificant, meaning that the null-hypothesis that should be rejected is not and the null-hypothesis that is assumed to hold is rejected. The right panel of table 21 shows that only in some cases the null-hypothesis that α is 0 is rejected. The null-hypothesis that β is 0 can strongly be rejected. According to the expectations of CAPM, the value of the β-coefficient should be close to 1. The values appear to lie between 0.676 and 0.83. That is reasonably close to 1, however it does indicate that there is a significant possibility of an omitted variable bias in the CAPM model. Furthermore, it is important to note that the values of β are highly significant. The t-values in this case are more telling that the p-values, because the latter are all virtually 0. Interestingly however, the t-values of β in the gold regression are already much lower than in the initial regression in the appendix (C).

Table 22: US CAPM regression results for wine and corporate bonds

Company	**Wine**					**Corporate Bonds**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
Abbott	0.340	0.657	0.765	14.258	153	0.315	0.637	0.640	9.476	143
3M	0.693	1.263	0.708	12.440	153	0.427	0.771	0.568	7.497	143
Boeing	0.690	1.082	0.889	13.419	153	0.642	1.021	0.784	9.124	143
Caterpillar	1.238	1.563	0.706	8.575	153	1.213	1.438	0.639	5.542	143
Coca-Cola	0.293	0.638	0.733	15.357	153	0.141	0.313	0.595	9.682	143
Deere	1.129	1.555	0.764	10.140	153	1.055	1.405	0.609	5.933	143
Ford	0.711	0.532	0.908	6.547	153	0.907	0.649	0.781	4.092	143
GE	-0.137	-0.200	0.767	10.787	153	-0.152	-0.222	0.599	6.406	143
IBM	0.450	0.695	0.758	11.278	153	0.556	0.924	0.546	6.647	143
Kellog	0.352	0.834	0.843	19.267	153	0.152	0.369	0.712	12.626	143
Pepsi	0.346	0.754	0.742	15.562	153	0.255	0.544	0.633	9.887	143
TI	0.533	0.666	0.845	10.161	153	0.636	0.811	0.709	6.612	143
JP Morgan	0.421	0.552	0.812	10.244	153	0.607	0.808	0.652	6.343	143
McDonalds	0.763	1.490	0.777	14.613	153	0.785	1.523	0.633	8.984	143
HP	0.484	0.581	0.827	9.574	153	0.616	0.766	0.717	6.524	143
J&J	0.380	0.819	0.711	14.740	153	0.260	0.602	0.540	9.130	143
Disney	0.789	1.336	0.858	13.996	153	0.904	1.543	0.785	9.795	143
FedEx	0.954	1.491	0.699	10.516	153	0.669	1.012	0.644	7.128	143
Apple	3.120	3.520	0.836	9.087	153	3.319	3.777	0.647	5.381	143
AT&T	-0.043	-0.069	0.746	11.538	153	0.064	0.110	0.527	6.687	143
Xerox	0.468	0.533	0.896	9.827	153	0.455	0.539	0.780	6.759	143
Motorola	0.272	0.336	0.851	10.113	153	0.398	0.482	0.724	6.406	143
AE	0.023	0.049	0.818	16.723	153	0.146	0.315	0.653	10.286	143
Chevron	0.638	1.187	0.757	13.573	153	0.711	1.350	0.574	7.962	143
DowDupont	0.625	0.656	0.870	8.796	153	0.629	0.635	0.771	5.701	143
Average	0.621	0.901	0.795	12.045	-	0.628	0.885	0.659	7.624	-

Results of 50 CAPM regressions with wine and corporate bonds as risk free assets respectively, US stocks and the S&P 500 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table 22 shows rather similar results to the right panel of table 21. The left panel of table 22 shows the wine regression results. In some instances, again the null-hypothesis with regards to α is rejected. That leads to the possibility of an omitted variable bias. The other null-hypothesis, namely with regards to β, can be firmly rejected when using wine returns as risk-free asset. These values of β are closer to 1 and still highly significant. In the right panel the results of the regressions with corporate bonds are shown. For these regressions, the same story holds. Interestingly, the value of β becomes slightly lower. Also the t-values of the corporate bond regressions are lower than those seen for the gold and wine regressions.

4.3. Robustness test: U.K. and EU regressions

Following the general theme of this thesis, the analysis will not only be conducted for American stocks. To rule out any cultural or institutional bias, this sub-chapter will analyze the regressions for British and European stocks.

4.3.1. Testing CAPM for U.K. stocks

For the UK regressions, there was again a selection of 25 stocks listed on the London Stock Exchange (LSE). Similar to the stocks selected in the US regressions, the companies were selected based on data availability. Upon closer inspection, the final selection offered a broad and diversified set of companies. As market return, the FTSE100 index returns were chosen. The FTSE100 is the broad large company stock index in the UK.

Table 23: UK CAPM regression results for government bonds and gold

Company	**Government bonds**					**Gold**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
BP	0.326	0.764	1.035	14.015	293	0.194	0.537	0.979	31.499	233
Barclays	2.044	2.750	1.450	11.264	293	0.541	0.823	1.036	18.328	233
Diageo	-0.836	-2.299	0.682	10.820	293	0.360	1.087	0.970	33.990	233
HSBC	1.182	2.855	1.232	17.185	293	0.336	0.921	0.991	31.571	233
Sainsbury's	-1.399	-2.744	0.716	8.113	293	-0.259	-0.600	0.929	24.947	233
Rolls Royce	1.282	2.137	1.183	11.383	293	0.827	1.660	1.020	23.785	233
RELX	-0.365	-0.681	0.794	8.533	293	0.299	0.622	0.949	22.921	233
Pearson	0.055	0.102	0.981	10.450	293	0.237	0.563	0.990	27.320	233
Morrison's	-1.499	-2.835	0.599	6.545	293	0.149	0.321	0.925	23.210	233
Aviva	1.007	1.924	1.279	14.119	293	-0.030	-0.063	0.931	23.082	233
BAE Systems	4.090	0.612	0.764	0.659	293	6.256	1.008	0.977	1.829	233
Barrat	2.633	2.837	1.422	8.847	293	1.050	1.265	0.985	13.777	233
BT	0.353	0.569	1.115	10.400	293	0.052	0.096	0.946	20.381	233
Ferguson	1.789	2.863	1.343	12.410	293	0.411	0.722	0.976	19.922	233
GlaxoSmithKlyne	-1.418	-3.641	0.604	8.953	293	0.165	0.464	1.019	33.290	233
Halma	0.370	0.755	0.914	10.752	293	0.511	1.181	1.021	27.392	233
Johnson Matthey	0.818	1.550	1.087	11.896	293	0.637	1.432	1.004	26.201	233
Kingfisher	-0.062	-0.082	0.919	7.100	293	0.553	0.841	0.961	16.975	233
Marks&Spencer	-1.172	-2.062	0.779	7.912	293	-0.180	-0.369	0.949	22.598	233
Persimmon	1.069	1.399	1.035	7.827	293	0.924	1.412	0.931	16.521	233
Rentokil	0.205	0.320	0.949	8.552	293	0.029	0.051	0.976	19.773	233
RBS	1.393	1.841	1.409	10.750	293	-0.120	-0.179	0.973	16.850	233
Sage Group	1.937	2.902	1.133	9.799	293	1.582	2.656	0.995	19.397	233
Severn Trent	-2.009	-4.107	0.458	5.406	293	0.106	0.229	0.934	23.455	233
Smiths Group	-0.147	-0.330	0.934	12.070	293	0.159	0.414	0.973	29.399	233
Average	0.466	0.296	0.993	9.830	-	0.592	0.684	0.974	22.737	-

Results of 50 CAPM regressions with government bonds and gold as risk free assets respectively, UK stocks and the FTSE100 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table 23 shows interesting differences compared to table 21. In the left panel, it is very likely that both null hypotheses are rejected. In table 21, it was very difficult to reject the null hypothesis with respect to β. That changes in table 23. The operationalization with government bonds as risk-free assets is not perfect however, as the null hypothesis with respect to α is also rejected. To accept CAPM only the β should reject the null hypothesis. The right panel also shows some interesting differences. In table 21, the value of β was much further removed from 1 than in table 23. Furthermore, there are less instances where the null hypothesis with respect to α is rejected in table 23 than in table 21. Overall, CAPM seems to hold better in this first robustness test.

Table 24: UK CAPM regression results for wine and corporate bonds

Company	**Wine**					**Corporate Bonds**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
BP	-0.095	-0.218	0.943	18.494	151	-0.161	-0.354	0.984	12.887	141
Barclays	-0.023	-0.026	1.224	11.480	151	-0.232	-0.243	1.461	9.132	141
Diageo	0.470	1.404	0.905	23.051	151	0.391	1.164	0.808	14.307	141
HSBC	-0.114	-0.309	0.974	22.449	151	-0.252	-0.657	1.010	15.677	141
Sainsbury's	-0.253	-0.573	1.038	20.082	151	-0.238	-0.523	0.960	12.551	141
Rolls Royce	1.407	2.443	1.120	16.584	151	1.281	2.141	1.219	12.135	141
RELX	0.056	0.150	0.950	21.701	151	0.026	0.068	0.851	13.132	141
Pearson	0.199	0.433	1.030	19.068	151	0.232	0.503	0.967	12.465	141
Morrison's	-0.030	-0.057	0.885	14.483	151	-0.077	-0.143	0.733	8.093	141
Aviva	-0.142	-0.225	1.112	15.023	151	0.033	0.052	1.210	11.186	141
BAE Systems	0.176	0.347	0.906	15.244	151	0.051	0.097	1.090	12.327	141
Barrat	1.203	1.084	1.125	8.640	151	0.702	0.611	1.500	7.789	141
BT	0.220	0.412	1.043	16.637	151	0.352	0.649	1.032	11.338	141
Ferguson	0.665	0.919	1.120	13.202	151	0.277	0.368	1.157	9.150	141
GlaxoSmithKlyne	-0.230	-0.575	0.895	19.105	151	0.000	0.000	0.737	11.411	141
Halma	0.834	1.748	1.007	18.002	151	0.928	1.937	0.909	11.305	141
Johnson Matthey	0.749	1.731	1.046	20.613	151	0.616	1.388	1.210	16.263	141
Kingfisher	0.385	0.615	0.961	13.106	151	0.230	0.398	0.929	9.557	141
Marks&Spencer	0.312	0.506	0.912	12.628	151	0.201	0.328	0.765	7.423	141
Persimmon	1.295	1.549	0.973	9.921	151	0.870	1.005	1.170	8.051	141
Rentokil	-0.372	-0.527	1.105	13.360	151	-0.516	-0.689	1.175	9.353	141
RBS	-1.195	-1.297	1.253	11.596	151	-1.385	-1.428	1.498	9.204	141
Sage Group	0.606	1.185	0.999	16.655	151	0.555	1.170	1.113	13.974	141
Severn Trent	0.357	0.662	0.842	13.307	151	0.410	0.733	0.699	7.441	141
Smiths Group	0.216	0.487	0.868	16.734	151	-0.102	-0.220	1.091	14.024	141
Average	0.268	0.475	1.010	16.047	-	0.168	0.334	1.051	11.207	-

Results of 50 CAPM regressions with wine and corporate bonds as risk free assets respectively, UK stocks and the FTSE100 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table 24 tells the same story as table 22. The main difference seems to be that the values of β are closer to 1 in table 24 than in table 22. Overall, the conclusion of the UK robustness test seems to be that CAPM is better fitted to the data from UK stocks than with the data of US stocks.

4.3.2. Testing CAPM for E.U. stocks

For the EU regressions, the stock selection was rather more complicated. There is not a European exchange. Therefore, the selection focused on large European companies from several large stock exchanges throughout Europe, excluding the UK. The 25 companies also seem to be a diversified group of stocks, reducing industry specific risks. As market return, in this case the choice was made to take the European stock index STOXX600, which is a EU version of the FTSE100 and the S&P500.

Table 25: EU CAPM regressions for government bonds and gold

Company	**Government bonds**					**Gold**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
Nestle	0.550	2.583	0.519	10.795	348	0.341	1.247	0.966	38.457	287
Novartis	0.477	1.724	0.438	7.008	284	0.205	0.553	0.969	31.255	222
Allianz	0.583	1.014	0.040	0.309	269	0.021	0.028	0.898	14.628	215
Siemens	0.460	0.925	1.443	13.109	266	0.847	1.316	1.063	20.463	205
Unilever	0.535	1.702	0.567	7.991	286	0.261	0.674	0.906	27.823	224
ASML	2.496	2.143	1.576	5.933	245	3.139	2.020	1.072	8.838	183
Airbus	1.165	2.125	1.372	10.666	207	1.345	1.810	1.010	17.818	145
Santander	-0.107	-0.268	1.457	15.669	226	0.103	0.208	1.065	28.333	164
AB INBEV	0.795	1.802	0.739	7.263	216	1.075	1.882	1.045	24.132	154
L'Oreal	0.610	1.929	0.610	8.262	227	0.567	1.307	0.978	29.580	165
BASF	0.610	1.858	1.173	15.293	227	0.986	2.384	0.976	30.960	165
BNP Paribas	0.067	0.180	1.384	16.463	302	0.407	0.920	1.051	27.628	240
Iberdrola	0.532	1.349	0.623	6.759	227	0.457	0.880	0.946	23.897	165
Deutsche Telekom	0.035	0.071	0.920	8.439	264	-0.061	-0.098	1.008	20.354	202
Adidas	0.934	1.979	0.879	8.296	246	0.805	1.436	0.979	22.471	184
ENEL	0.072	0.208	0.721	8.948	229	-0.230	-0.536	0.973	29.605	167
Daimler	-0.161	-0.404	1.553	17.575	266	0.143	0.277	1.065	25.619	205
UBS	-0.331	-0.765	1.399	14.383	280	-0.088	-0.166	1.010	22.994	218
ING	-0.073	-0.172	1.891	19.697	285	0.415	0.709	1.075	21.897	224
Philips	2.296	1.345	1.551	4.022	285	3.130	1.448	1.060	5.847	224
Intesa Sanpaolo	0.142	0.241	1.605	12.043	285	0.421	0.581	1.108	18.205	224
Heineken	0.568	1.743	0.549	7.468	285	0.259	0.625	0.992	28.567	224
BMW	0.376	0.894	1.291	13.901	265	0.735	1.432	1.039	25.200	203
Unibail	0.364	1.127	0.558	7.500	335	0.292	0.736	0.931	25.959	274
Deutsche Bank	-0.554	-1.165	1.651	15.713	265	0.131	0.228	1.036	22.542	203
Average	0.498	0.967	1.060	10.540	-	0.628	0.876	1.009	23.723	-

Results of 50 CAPM regressions with government bonds and gold as risk free assets respectively, European stocks (minus the UK) and the STOXX600 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table 25 shows similar results to those presented in table 23 and therefore differs from table 21. There are several instances in which the null hypothesis with respect to α is rejected in both the left and right panel. In fact, the right panel of table 25 shows more instances in which there is a significant α in the EU dataset than in the right panels of tables 21 and 23. The values for β are consistently very close to 1 however.

Table 26: EU CAPM regressions for wine and corporate bonds

Company	**Wine**					**Corporate Bonds**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
Nestle	0.341	0.946	0.862	21.742	151	0.420	1.317	0.581	11.487	141
Novartis	0.060	0.153	0.822	19.081	151	0.064	0.173	0.625	10.638	141
Allianz	0.831	0.953	0.625	6.513	151	0.614	0.845	0.438	3.795	141
Siemens	0.641	1.210	1.153	19.760	151	0.385	0.765	1.282	16.028	141
Unilever	0.257	0.653	0.825	19.090	151	0.180	0.459	0.702	11.249	141
ASML	1.135	1.431	1.282	14.688	151	1.146	1.449	1.350	10.750	141
Airbus	1.195	1.658	1.022	12.901	150	0.957	1.329	1.354	11.835	141
Santander	-0.001	-0.002	1.192	21.667	151	-0.033	-0.068	1.378	17.628	141
AB INBEV	1.053	1.828	0.967	15.252	151	1.000	1.645	1.039	10.758	141
L'Oreal	0.279	0.711	0.892	20.626	151	0.246	0.631	0.780	12.596	141
BASF	0.965	2.268	1.038	22.151	151	0.813	1.917	1.123	16.673	141
BNP Paribas	0.241	0.450	1.089	18.445	151	-0.023	-0.042	1.273	14.629	141
Iberdrola	0.264	0.496	0.927	15.831	151	0.255	0.464	0.865	9.893	141
Deutsche Telekom	-0.182	-0.324	0.963	15.536	151	-0.007	-0.013	0.801	9.776	141
Adidas	1.178	2.394	0.912	16.846	151	0.865	1.769	1.049	13.517	141
ENEL	-0.215	-0.504	0.928	19.756	151	-0.191	-0.431	0.872	12.401	141
Daimler	0.602	1.024	1.157	17.869	151	0.261	0.438	1.328	14.018	141
UBS	-0.310	-0.504	1.097	16.185	151	-0.530	-0.842	1.339	13.378	141
ING	-0.080	-0.104	1.317	15.507	151	-0.220	-0.305	1.867	16.287	141
Philips	0.104	0.207	1.159	21.022	151	-0.094	-0.197	1.349	17.874	141
Intesa Sanpaolo	0.255	0.383	1.105	15.051	151	0.047	0.073	1.346	13.007	141
Heineken	0.049	0.114	0.985	21.011	151	-0.013	-0.030	0.907	13.241	141
BMW	0.825	1.577	1.068	18.550	151	0.492	0.919	1.178	13.862	141
Unibail	0.864	1.834	0.866	16.699	151	0.735	1.502	0.862	11.090	141
Deutsche Bank	-0.153	-0.235	1.167	16.287	151	-0.443	-0.660	1.327	12.452	141
Average	0.408	0.745	1.017	17.523	-	0.277	0.524	1.081	12.754	-

Results of 50 CAPM regressions with wine and corporate bonds as risk free assets respectively, European stocks (minus the UK) and the STOXX600 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

The results presented in table 26 seem to be consistent with those in table 24 and therefore largely robust. Thus interestingly, the fit of CAPM seems to be better with EU and UK stocks than with US stocks, where the fit to UK stocks seems to be the best fit to CAPM.

4.4. Conclusions

The previous two sub-chapters have offered some interesting insights. The CAPM analysis was done in three stages to add some robustness to the results. One of the outcomes is that the rejections of CAPM in literature seem very logical, as most of the literature considers US stocks. From table 21 can indeed be concluded that CAPM is strongly rejected. There are very significant alphas in the model. What tables 23 and 25 show however, is that this rejection of CAPM becomes much weaker, perhaps even invalid, when examining UK and EU returns.

Another interesting outcome follows from corporate bonds. These seem to lie in-between government bonds and the other two alternative risk-free assets. The regression using the corporate bond

ETF still shows some significant alphas, despite being much less than in the government bond regressions. Furthermore, the beta-hypotheses of CAPM hold when using corporate bonds as risk-free asset and the corporate bonds regressions seem to be plagued less by the very high t-values that were found for gold and wine. Still, the 99% confidence level has a critical t-value of 2.326, where those found in the corporate bond regressions are around five times that.

This leads to perhaps the most interesting result presented in this chapter. Namely, the beta of the CAPM regressions is highly significant when using wine or gold as risk-free asset. This is logical when the calculations of the independent and dependent variable and the values of those are considered. It does mean that there is a significant risk of not measuring correct values. On the other hand, it could also be the outcome that should result from CAPM. The correlation between the dependent and independent assets is very high, but it does not lead to multicollinearity as there is only one independent asset in the simple-form CAPM.

This chapter set out to answer the second research question of this thesis, namely: '*To what extent can alternative proxies of the risk-free rate improve the result of CAPM regressions?'.* The conclusion to this research question is simple, namely to a great extent. Subchapters 4.2. and 4.3. show that the theoretical predictions that CAPM makes are displayed much more prominently when using any of the three alternative risk-free assets. Perhaps corporate bonds make the weakest improvement, as there are still some stocks that have a strong, significant alpha. Even for corporate bonds, the far majority of the 25 stocks that were examined in the three datasets did not have a significant alpha however. The outcomes of regressions using wine and gold as risk-free assets are overwhelmingly in favor or CAPM. There is a concern that these regressions are perhaps plagued by some additional statistical problem. That might be the result of the returns not being distributed normally, something that a linear regression does assume. Altering this by taking the change of log-prices did not improve the normality of the density distribution however.

V. Portfolio performance

Now that the applicability of the alternative risk-free assets on a theoretical model is established and the first and second research questions are answered, there is one final step this thesis must make. The third research question namely still needs to be answered. This research question related to how risk-free assets are practically used in a classic portfolio configuration. The third research question is:

RQ3: 'To what extent can alternative proxies improve the risk-return relationship of portfolios?'

The goal of this research question is to examine whether it is possible to have a better risk-return relationship in a portfolio when using gold, wine or corporate bonds as risk-free asset.

5.1. Portfolio theory

This thesis will examine portfolios that follow the classic portfolio composition theory. This is based on Markowitz (1952). Markowitz' modern portfolio theory (MPT) has strong relations with the CAPM logic, which is based on MPT. MPT states that investors can hold risky assets and a risk-free asset. Risky assets can have their idiosyncratic risk diversified away, leading to a portfolio that only has the market risk left. The optimal combinations of risky assets form an efficient portfolio frontier.

From the risk-free rate, a tangency line can be drawn that touches this efficient portfolio frontier. This line is called the securities market line (SML). The tangency point where the SML touches the efficient portfolio frontier is then the market portfolio, the best combination of risky and risk-free assets. This is the portfolio that all rational investors hold. As mentioned in chapter 4.1., all rational investors hold the market portfolio. This means that ultimately the portfolios that investors hold all reflect the market in the proportions of market capitalization. This leads to the assumption in this thesis that the market portfolio is simply the stock index that was also chosen as market return in chapter IV. The stock index (like the S&P500 for US stocks) reflects the market value of all firms listed on it, which shows the similarities with the description of the market portfolio. That is a rather strong assumption, as the market portfolio should in fact include all investable assets (Markowitz, 1952), but that is a theoretical reality that cannot be operationalized. To construct the efficient frontier and the SML, there have to be at least two assets in the portfolio. As the combination of risky assets is assumed to be captured by the index in this thesis, it is not possible to construct that efficient frontier. The methodology will instead be used by drawing efficient frontiers of a combination of the risky and risk-free asset.

MPT will thus be reduced to a rather simple portfolio construction. There is one combination of risky assets and a risk-free asset that can be invested in. For this chapter, there will be two arbitrarily set levels of risk-free assets in the absence of the SML indicating the optimal level. One level is at 40% risk-free asset, the other at 60% risk-free asset. The performance of portfolios will be compared with the performance of a 100% stock portfolio.

The performance analysis will be in three parts. The first shows the performance of the portfolios over the maximum available data period. Performance is captured by the mean return of the portfolio. Risk is measured by the standard deviation of the returns. As an additional test, there will be a calculation that could determine the suitability of a risk-free asset. The aim is to find a better risk-return relationship, and the easiest way to establish this is by dividing the mean return by the standard deviation of these returns (in a formula similar to the Sharpe ratio (Sharpe, 1966)). That formula thus yields how much return is received for the risk taken on. The second panel will show the portfolio performance during bear markets. A bear market is a situation where the market is 20% or more below its most recent peak. Risk-free assets are especially useful in those periods, as they could shield the overall portfolio from some negative returns. Therefore, it is very interesting to see what the portfolios will do during bear markets. To determine these bear markets, the official bear market periods of the US were taken and converted into a dummy. These were also assumed to hold for the UK and the EU, based on the correlations in tables 7 and 8. The third panel of the performance tables will show the performance after the 2008 financial crisis. This is relevant due to the very low government bond yields that were established in chapter II. Therefore, it is interesting to see whether the alternative assets yield a satisfactory level of return relative to the risk that is taken on, especially compared to government bonds.

Summarizing, the performance is measured by the mean returns of the portfolio. Furthermore, the risk of the portfolio is assessed by examining the standard deviation. Because the risk-free asset should both add return as well as reduce risk, the mean return will be divided by the standard deviation to assess the overall suitability of the asset as risk-free asset.

5.2. U.S. portfolios

First the performance of portfolios for the US investor will be examined. The risky asset portion of the portfolio will thus be an ETF of the S&P 500. As risk-free assets, US government bonds, gold, wine and a corporate bond index ETF are examined.

Table 27: US portfolio performance for 40% risk-free asset portfolios

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
100% Stocks	466	0.780	1.107	4.261	-21.782	-1.653	3.471	13.177
40% G-bonds	466	2.911	2.909	2.874	-9.525	1.319	4.720	11.515
40% Gold	466	10.904	1.430	24.076	-24.024	-4.668	17.703	79.678
40% Wine	153	25.367	10.076	28.902	-12.610	2.699	52.158	80.563
40% C-bonds	142	13.233	12.612	5.441	1.695	9.087	17.454	29.657
In bear markets								
100% Stocks	94	-1.654	-1.314	5.144	-16.793	-5.383	1.618	10.238
40% G-bonds	94	1.793	2.269	3.730	-8.664	-0.692	4.246	11.279
40% Gold	94	17.332	15.509	22.720	-19.827	-4.333	38.844	63.158
40% Wine	39	14.453	3.624	21.788	-12.610	0.440	33.165	57.346
40% C-bonds	27	15.894	17.454	5.054	3.843	11.835	19.763	23.947
Post 2008 crisis								
100% Stocks	132	0.577	1.107	4.331	-16.793	-1.638	2.945	10.590
40% G-bonds	132	1.395	1.571	2.595	-8.664	0.165	2.882	7.300
40% Gold	132	1.748	0.330	9.843	-14.660	-3.939	2.551	39.054
40% Wine	76	1.410	3.098	7.379	-12.610	-3.365	6.872	15.143
40% C-bonds	77	13.697	12.611	5.481	5.634	9.228	17.897	29.657

Measures of central tendency and dispersion of US-related portfolios. Measures of central tendency are the mean and median, measures of dispersion are the standard deviation, minimum and maximum value and the first and third quartile values.
The stock returns follow the S&P500 index, other portfolios are 60% stocks, 40% risk-free asset. G-bonds are the yields on US government bonds, Gold are the five year holding period returns of gold, Wine is measured by the five year holding period return of the LIVEXFW100 index and C-bonds are the five year holding period returns of the iShares IG corporate bond ETF.
Returns are divided in three panels. The first panel shows the returns of the maximum observable values in the dataset, the second panel shows the returns in bear markets and the third panel shows the returns after the 2008 crisis.

Table 27 shows the three panels that reflect different situations. The first panel shows the performance of portfolios over their maximum observable time periods. All portfolios yielded positive average returns. The 100% stocks portfolio yielded some very negative results in some months. Interestingly, the portfolio that contained corporate bonds as risk-free assets has not had a month of negative returns in the time period observed. The portfolios using gold and wine as risk-free assets had strong mean results, but those results were too volatile to be adequate as risk-free assets due to their high standard deviations. So the comparison is drawn between corporate bonds and government bonds. The calculation dividing the mean return by the standard deviation of returns is a suitable first indicator. For government bonds, this would lead to a ratio of (2.911 / 2.874 =) 1.013. For corporate bonds, this is much higher at (13.233 / 5.441 =) 2.432. Furthermore, an F-test was conducted to see whether the mean returns are significantly different. This test yielded a very significant result, with the p-value being almost 0. Therefore, the conclusion can be drawn that the mean return of the corporate bonds portfolio is significantly different (and better) from the government bond portfolio.

The second panel shows the performance in bear markets. Note that the amount of months that were observed is significantly lower, too low to draw strong statistical conclusions from. That will not be done in this case, however the reasoning that there is a large potential of missing data and thus conclusions might not be valid if the sample size is too small, still holds. The performance of the corporate bond portfolio seems to have even increased, despite the others not doing so. Due to the very low amount of observations of this portfolio, there is a possibility that these negative performances simply are not captured in the dataset, but they might still be possible.

The third panel shows the portfolio performance post 2008 crisis. Again, the strong performance of the corporate bond ETF is a positive exception compared to the other portfolios. The highest values of the index ETF were apparently post crisis and the mean return compared to that of other portfolios is much higher, against a similar risk to the stock portfolio.

Table 28: US portfolio performance for 60% risk-free asset portfolios

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
100% Stocks	466	0.780	1.107	4.261	-21.782	-1.653	3.471	13.177
60% G-bonds	466	3.976	3.731	2.603	-4.599	2.269	5.780	11.799
60% Gold	406	18.280	3.642	38.155	-33.267	-9.697	32.744	118.020
60% Wine	153	37.861	13.680	43.219	-18.173	3.444	80.658	120.852
60% C-bonds	142	19.574	17.837	7.900	3.140	13.244	25.839	39.498
In bear markets								
100% Stocks	94	-1.654	-1.314	5.144	-16.793	-5.383	1.618	10.238
60% G-bonds	94	3.516	2.963	3.470	-4.599	1.070	6.307	11.799
60% Gold	90	28.021	25.644	34.361	-28.406	-3.971	61.888	90.896
60% Wine	39	23.213	6.885	32.604	-18.074	2.298	49.591	85.775
60% C-bonds	27	25.689	27.917	6.896	11.266	18.814	30.814	36.153
Post 2008 crisis								
100% Stocks	132	0.577	1.107	4.331	-16.793	-1.638	2.945	10.590
60% G-bonds	132	1.804	2.016	1.753	-4.599	0.858	2.878	5.963
60% Gold	72	4.022	-3.999	20.040	-19.978	-11.767	18.814	58.975
60% Wine	76	1.892	3.794	10.395	-18.173	-2.870	10.491	17.727
60% C-bonds	77	20.322	18.038	7.997	8.139	13.244	27.105	39.498

Measures of central tendency and dispersion of US-related portfolios. Measures of central tendency are the mean and median, measures of dispersion are the standard deviation, minimum and maximum value and the first and third quartile values.
The stock returns follow the S&P500 index, other portfolios are 40% stocks and 60% risk-free asset. G-bonds are the yields on US government bonds, Gold are the five year holding period returns of gold, Wine is measured by the five year holding period return of the LIVEXFW100 index and C-bonds are the five year holding period returns of the iShares IG corporate bond ETF.
Returns are divided in three panels. The first panel shows the returns of the maximum observable values in the dataset, the second panel shows the returns in bear markets and the third panel shows the returns after the 2008 crisis.

Table 28 mainly shows that the risk associated with the alternative asset portfolios increases when increasing their share in the portfolio. This seems highly counter-intuitive when these assets are supposedly risk-free. Partially this is because of the rather strict definition of risk that is adopted in this analysis (namely standard deviation) compared to the broader definition employed in the rest of the thesis. However, when looking at the mean returns, there is an important nuance that has to be placed with this observation. The mean returns have namely increased as well. The nuance here is thus that there seems to be some form of positive volatility, meaning that the alternative assets have been doing better than stocks. Again, average returns of gold and wine do not seem to be interesting when looking at their return/risk ratio and their standard deviation compared to the other risk-free assets. The 100%

stocks portfolio still has the same ratio (1.013), the ratio for the corporate bond portfolio has increased slightly to (19.574 / 7.900 =) 2.477.

Again, the strong performance of the corporate bond portfolio in low yield periods (second and third panels in table 28) is noteworthy. It seems that for the US portfolios, investing in corporate bonds is a much better hedge than government bonds.

5.3. Robustness test: U.K. and E.U. portfolios

Now that the performance of US portfolios is established, for robustness purposes also the performance of portfolios consisting of UK and EU stocks and the risk-free assets should be investigated.

5.3.1. U.K. portfolios

The first set of portfolio's that will be examined are the UK portfolios. The market index, which will proxy the stock combination, is the FTSE100.

Table 29: UK portfolio performance for 40% risk-free asset portfolios

Variable	Months	Mean	Median	S.D.	Min.	p25	p75	Max.
100% Stocks	294	0.359	0.695	3.844	-13.024	-1.790	2.842	8.857
40% G-bonds	294	1.918	2.034	2.476	-5.986	0.461	3.553	8.043
40% Gold	234	22.531	18.308	28.868	-17.831	-5.800	51.998	79.684
40% Wine	153	25.273	10.100	29.038	-14.362	2.114	49.878	82.556
40% C-bonds	142	13.155	12.084	5.681	1.500	8.803	17.350	28.766
In bear markets								
100% Stocks	64	-1.723	-1.784	4.957	-13.024	-4.867	1.256	8.542
40% G-bonds	64	0.758	0.880	3.018	-5.986	-1.445	2.706	6.971
40% Gold	60	29.333	30.485	19.397	-14.208	17.841	46.484	58.131
40% Wine	39	15.007	5.886	21.972	-14.362	-1.134	32.106	64.551
40% C-bonds	27	16.810	16.238	5.819	3.231	12.124	20.920	27.356
Post 2008 crisis								
100% Stocks	132	0.111	0.435	3.982	-13.024	-2.376	2.739	8.453
40% G-bonds	132	1.077	0.983	2.374	-5.986	-0.636	2.537	6.602
40% Gold	72	2.674	-3.126	13.466	-14.208	-7.289	11.398	36.627
40% Wine	76	1.247	2.613	7.545	-14.362	-3.922	7.313	12.385
40% C-bonds	77	13.539	11.738	5.931	3.367	9.104	17.344	28.766

Measures of central tendency and dispersion of UK-related portfolios. Measures of central tendency are the mean and median, measures of dispersion are the standard deviation, minimum and maximum value and the first and third quartile values.
The stock returns follow the FSE100 index, other portfolios are 60% stocks and 40% risk-free asset. G-bonds are the yields on UK government bonds, Gold are the five year holding period returns of gold, Wine is measured by the five year holding period return of the LIVEXFW100 index and C-bonds are the five year holding period returns of the iShares IG corporate bond ETF.
Returns are divided in three panels. The first panel shows the returns of the maximum observable values in the dataset, the second panel shows the returns in bear markets and the third panel shows the returns after the 2008 crisis.

Table 29 shows the performance of the 40% risk-free asset portfolios. Again, the risk associated with wine and gold is higher than their average return over the maximum observable period. Therefore, it is again more interesting to compare the risk-return relationships of government bonds and corporate bonds. The return/risk ratio of the government bond portfolio is (1.918 / 2.476 =) 0.775, whereas the ratio of the corporate bond portfolio is (13.155 / 5.681 =) 2.316. So for the UK 40% risk-free asset portfolios, the corporate bonds portfolio is much more superior to the government bond portfolio than it is for the US portfolio.

Then the second panel showing the portfolio performance in bear markets. The return/risk ratio for the government bond portfolio becomes worse, whereas that of the corporate bond portfolio improves. The ratio also becomes larger than 1 for gold, showing that gold is a suitable hedge for FTSE performance. Wine still does not seem like a good choice to add to a portfolio as risk-free asset. Again, it is important to note that in this second panel, the amount of months that is investigated is significantly lower than in the first panel, meaning that no strong conclusions should be drawn from these observations.

In the third panel, again it is interesting to see the performance of the gold and wine portfolios drop so significantly, whereas the corporate bonds portfolio still seems strong.

Table 30: UK portfolio performance for 60% risk-free asset portfolios

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
100% Stocks	294	0.359	0.695	3.844	-13.024	-1.790	2.842	8.857
60% G-bonds	294	2.698	2.721	1.997	-2.467	1.219	4.033	7.636
60% Gold	234	33.575	26.126	43.317	-23.286	-8.556	78.801	118.024
60% Wine	153	37.799	13.339	43.315	-19.662	3.371	80.796	122.181
60% C-bonds	142	19.522	17.941	8.097	1.609	13.043	25.621	42.054
In bear markets								
100% Stocks	64	-1.723	-1.784	4.957	-13.024	-4.867	1.256	8.542
60% G-bonds	64	1.999	1.990	2.103	-2.467	0.392	3.473	6.186
60% Gold	60	44.837	45.664	28.742	-18.846	26.233	70.859	86.678
60% Wine	39	23.583	9.962	32.721	-18.278	0.544	48.663	92.555
60% C-bonds	27	26.300	26.895	7.399	10.825	19.084	31.372	42.054
Post 2008 crisis								
100% Stocks	132	0.111	0.435	3.982	-13.024	-2.376	2.739	8.453
60% G-bonds	132	1.559	1.432	1.645	-2.467	0.432	2.605	5.676
60% Gold	72	3.924	-4.233	20.256	-19.361	-11.191	19.653	55.715
60% Wine	76	1.783	3.514	10.558	-19.662	-3.994	10.949	15.553
60% C-bonds	77	20.217	17.841	8.367	7.842	13.628	26.752	42.054

Measures of central tendency and dispersion of UK-related portfolios. Measures of central tendency are the mean and median, measures of dispersion are the standard deviation, minimum and maximum value and the first and third quartile values.
The stock returns follow the FSE100 index, other portfolios are 40% stocks and 60% risk-free asset. G-bonds are the yields on UK government bonds, Gold are the five year holding period returns of gold, Wine is measured by the five year holding period return of the LIVEXFW100 index and C-bonds are the five year holding period returns of the iShares IG corporate bond ETF.
Returns are divided in three panels. The first panel shows the returns of the maximum observable values in the dataset, the second panel shows the returns in bear markets and the third panel shows the returns after the 2008 crisis.

The performances shown in table 30 exhibit a similar story to those in table 28, namely one of increasing variance when increasing the share of the ‘risk-free asset’. Besides this, the patterns are very similar. Gold and wine do not seem to be appropriate risk-free assets based on the performance criteria and the corporate bond portfolio seems to consistently outperform the government bond portfolio.

These insights add robustness to the findings based from the US performance analysis. To add further robustness and to complete this chapter, also the performance of EU portfolios will be examined.

5.3.2. EU portfolios

Finally, the performance of EU portfolios is evaluated. Similar to the previous two analyses, the main change are the government bond yields that were used (for EU these are German bond yields) and the stock return, which in this case is the STOXX600, the broad European stock index.

Table 31: EU portfolio performance for 40% risk-free asset portfolios

Variable	Months	Mean	Median	S.D.	Min.	p25	p75	Max.
100% Stocks	348	0.418	0.993	4.387	-14.135	-1.930	3.205	13.472
40% G-bonds	348	1.886	2.127	2.810	-6.729	0.079	3.692	10.210
40% Gold	288	17.948	6.095	27.837	-17.236	-5.809	44.645	79.818
40% Wine	153	25.230	9.453	29.145	-16.314	2.131	50.267	82.553
40% C-bonds	142	13.137	12.367	5.557	1.210	8.737	17.301	31.996
In bear markets								
100% Stocks	68	-2.779	-2.445	5.644	-14.135	-6.755	1.155	9.371
40% G-bonds	68	0.078	0.023	3.459	-6.729	-2.731	2.526	7.406
40% Gold	64	26.851	26.560	20.445	-14.091	12.803	44.804	58.628
40% Wine	39	14.417	4.855	22.169	-16.314	-0.547	33.087	65.048
40% C-bonds	27	16.085	16.636	5.504	1.925	12.337	19.697	24.424
Post 2008 crisis								
100% Stocks	132	0.019	0.661	4.351	-13.270	-2.221	2.719	13.472
40% G-bonds	132	0.669	0.739	2.596	-6.410	-0.591	2.186	9.335
40% Gold	72	2.558	-2.830	13.145	-14.091	-7.169	11.269	35.933
40% Wine	76	1.155	2.616	7.662	-16.314	-4.883	7.682	15.614
40% C-bonds	77	13.456	12.324	5.701	3.556	9.205	16.845	31.996

Measures of central tendency and dispersion of EU-related portfolios. Measures of central tendency are the mean and median, measures of dispersion are the standard deviation, minimum and maximum value and the first and third quartile values.
The stock returns follow the STOXX600 index, other portfolios are 60% stocks and 40% risk-free asset. G-bonds are the yields on German government bonds, Gold are the five year holding period returns of gold, Wine is measured by the five year holding period return of the LIVEXFW100 index and C-bonds are the five year holding period returns of the iShares IG corporate bond ETF.
Returns are divided in three panels. The first panel shows the returns of the maximum observable values in the dataset, the second panel shows the returns in bear markets and the third panel shows the returns after the 2008 crisis.

Table 31 shows a similar theme to that of tables 27 and 29. Again, in the first panel, it seems obvious that gold and wine are sub-optimal ‘risk-free’ assets, whereas corporate bonds offer a superior return/risk ratio, namely (13.137 / 5.557 =) 2.364 for corporate bonds versus (1.886 / 2.810 =) 0.671 for government bonds. The ratios are very close to those obtained in the first UK analysis (based on table 29). Again it seems that the impact of alternative assets is larger for EU and UK datasets than for US datasets.

The second panel of table 31 shows that during bear markets, the yield of the government bond portfolio nearly disappears, whereas the average yield of the corporate bond portfolio even increases. Similar to the UK results however, gold also seems to be an effective hedge in bear markets, where the return/risk ratio becomes larger than 1 during bear markets, as compared to a ratio below 1 over the whole time period. Again, there it is important to note that the amount of months under observation is very low, for corporate bonds even less than half of the observations of the government bonds. Having more observations might change the outcomes of the analysis significantly.

The third panel finally shows the performance post 2008 crisis. Here gold seems to be a very bad risk-free asset, as the median value of the portfolio returns is negative. Furthermore, wine seems like a bad risk-free asset, whereas government bonds and corporate bonds are fine. Overall, corporate bonds seem to be a better risk-free asset based on portfolio performance than government bonds however.

Table 32: EU portfolio performance for 60% risk-free asset portfolios

Variable	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
100% Stocks	348	0.418	0.993	4.387	-14.135	-1.930	3.205	13.472
60% G-bonds	348	2.620	2.728	2.288	-3.075	1.000	4.257	9.614
60% Gold	288	26.677	7.575	41.731	-22.889	-8.316	68.878	118.113
60% Wine	153	37.770	13.167	43.378	-20.569	3.092	79.925	122.178
60% C-bonds	142	19.510	17.648	7.973	1.416	12.940	25.811	41.258
In bear markets								
100% Stocks	68	-2.779	-2.445	5.644	-14.135	-6.755	1.155	9.371
60% G-bonds	68	1.507	1.505	2.484	-3.026	-0.209	3.152	7.130
60% Gold	64	41.641	41.663	30.049	-18.769	21.016	69.451	87.818
60% Wine	39	23.189	9.211	32.834	-19.227	0.125	48.225	92.887
60% C-bonds	27	25.817	27.002	7.105	9.954	19.415	30.349	40.020
Post 2008 crisis								
100% Stocks	132	0.019	0.661	4.351	-13.270	-2.221	2.719	13.472
60% G-bonds	132	0.994	0.948	1.814	-3.075	-0.051	1.995	7.267
60% Gold	72	3.847	-4.193	20.030	-19.104	-11.657	20.432	54.631
60% Wine	76	1.722	3.706	10.621	-20.569	-4.225	11.302	16.685
60% C-bonds	77	20.161	17.577	8.178	7.968	13.238	26.519	41.258

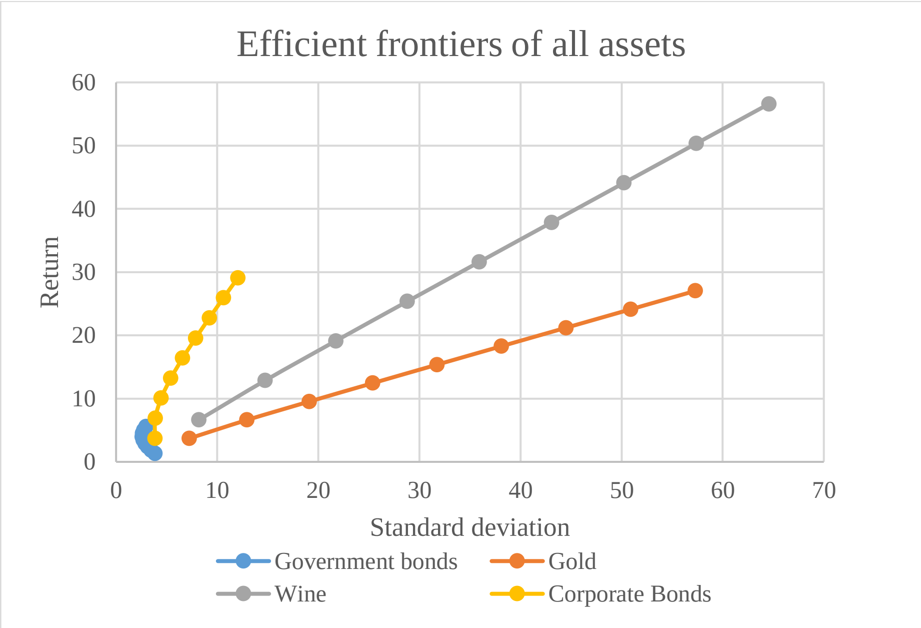
Measures of central tendency and dispersion of EU-related portfolios. Measures of central tendency are the mean and median, measures of dispersion are the standard deviation, minimum and maximum value and the first and third quartile values.
The stock returns follow the STOXX600 index, other portfolios are 40% stocks and 60% risk-free asset. G-bonds are the yields on German government bonds, Gold are the five year holding period returns of gold, Wine is measured by the five year holding period return of the LIVEXFW100 index and C-bonds are the five year holding period returns of the iShares IG corporate bond ETF.
Returns are divided in three panels. The first panel shows the returns of the maximum observable values in the dataset, the second panel shows the returns in bear markets and the third panel shows the returns after the 2008 crisis.

Table 32 again shows increasing yields and increasing variances of the portfolios when the share of risk-free assets increase in the portfolio. There again is a significant outperformance from corporate bonds to government bonds, which is amplified in bear market, similarly to gold. The results seem to be in accordance with those presented in tables 28 and 30.

5.4. Efficient frontiers

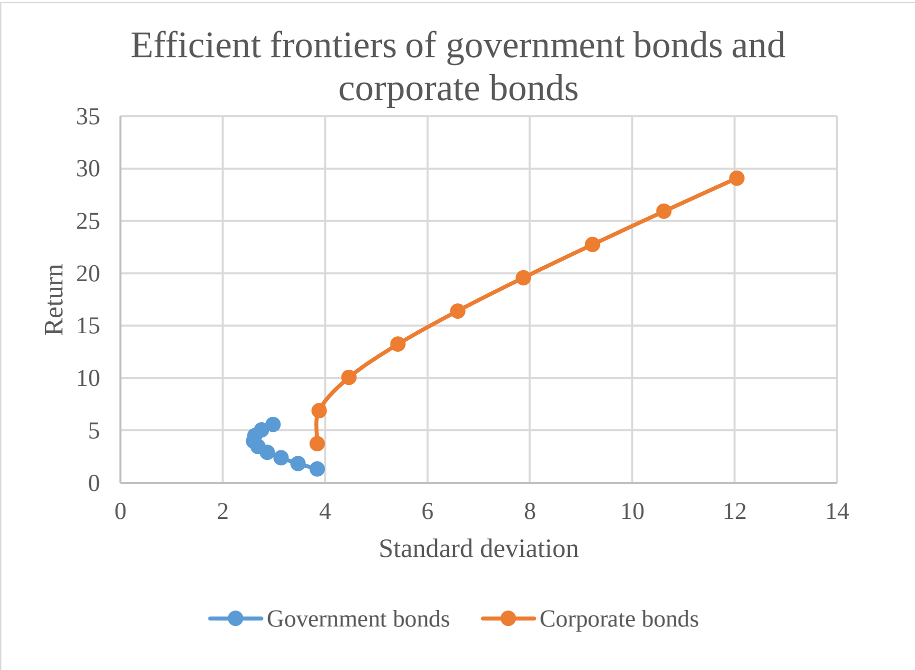
As argued in the beginning of this chapter, the logic behind combining several risky assets into an efficient frontier could also be applied to making an efficient frontier from portfolios that consist of both risky and risk-free assets. In this two-asset setting, varying weights will be assigned to both the risky asset (index) and the risk-free asset (government bonds, gold, wine or corporate bonds) and the mean return and standard deviation of the portfolios will be calculated. These will then be plotted in an efficient frontier. This shows the relation of the portfolios between portfolio risk (standard deviation of returns) and return (mean portfolio returns. This analysis was only conducted for the US sample as a way to visualize some of what was discussed in this chapter.

Graph 15: Efficient frontiers of all asset portfolios



Graph 15 indicates several interesting things. Firstly, it is almost impossible to distinguish the efficient frontier of the portfolios with government bonds. The possible return that can be achieved with this investment is very low, however it is also accompanied by very low risk. Intuitively, the best portfolio would be closest to the Y axis and the furthest possible removed from the X axis. Secondly, graph 15 highlights again that with gold and wine there are high returns, however they also come with more risk (again, this might be positive risk, fluctuations in price that are only highly positive could also happen). Therefore, it is more interesting, especially considering all the discussions preceding this section, to compare government bonds with corporate bonds.

Graph 16: Efficient frontiers of government bonds and corporate bonds



Graph 16 once again illustrates the superiority of corporate bonds over government bonds. The returns that are possible with corporate bonds portfolios are higher than those that can be attained with the government bond portfolios. This comes at the cost of higher risk however. Considering that in earlier analyses in 5.2. and 5.3. there have been no periods of losses of corporate bond portfolios, that might be a risk worth taking.

5.5. Conclusions

The performance analyses were done in threefold for robustness. The results of those analyses are very robust indeed. The only strong difference between the analyses is the hedging power of gold in the portfolios. For the UK and the EU, gold suddenly got a return/risk ratio higher than 1 during bear markets, which was not the case in the US. Gold's risk-return relation other than that was not strong enough to warrant it being considered as a good alternative for government bonds as risk-free asset in a Markowitz-inspired portfolio however.

This chapter set out to answer the third research question in this thesis, namely: *'To what extent can alternative proxies improve the risk-return relationship of portfolios?'.* The answer to this is rather simple, namely that corporate bond can serve as a risk-free asset in a Markowitz portfolio, whereas gold and wine cannot. In fact, corporate bond portfolios outperform government bond portfolios when their return/risk ratio is taken into account.

VI. Conclusion and Discussion

This thesis set out to answer three research questions relating to the risk-free asset. The analysis that was conducted was faced with some limitations, which will be discussed. Finally, this final chapter will discuss some of the opportunities for future research resulting from this analysis.

6.1. Conclusion

The first research question sought to find what the risk-free asset should be and what would be an appropriate operationalization of this theoretical construct. This was summarized in a research question: '*What is the risk-free asset and what is an appropriate operationalization of this asset?*'. Answering this research question started with a deconstruction of the theoretical concept of the risk-free asset. The basis of this theoretical concept was the work by Irving Fisher, as his 'Theory of Interest' describes the interest rate, which is derived from a risk-free asset. In chapter I of this thesis, the decomposition of this theoretical concept lead to a framework that offered characteristics of the risk-free asset. Chapter II then presented the analysis of the current operationalization of the risk-free asset, namely government bonds. Finally chapter III analyzed three alternatives as proxy of the risk-free asset, namely gold, wine and corporate bonds. From this analysis, it seemed that both government bonds and corporate bonds are appropriate operationalizations of the risk-free asset. Government bonds seem less attractive due to the low yields, especially in comparison to corporate bonds. Furthermore, there are some threats regarding to the market functioning of government bonds that pose a risk in this operationalization. Corporate bonds on the other hand seem to be plagued less by these issues, especially when holding a corporate bond ETF as discussed in the thesis.

The second research question sought to apply these new insights on the operationalization of the risk-free asset to theory. The theoretical model that was chosen was the capital asset pricing model (CAPM). This model is often criticized due to its lack of evidence from empirical testing. The second research question was: '*To what extent can alternative proxies of the risk-free rate improve the result of CAPM regressions?'*. All three alternative assets were found to greatly improve the results of CAPM regressions, that is, the model fit became much better when using any of the three alternative proxies compared to when using government bonds as risk-free assets. The data was corrected for non-stationarity problems, however the assets did not hold to a normal distribution. This might be the cause of the high significance that was found when adopting the alternative proxies.

Finally the third research question examined the impact of these findings on investor portfolios. Several Markowitz-inspired portfolios were constructed in order to answer the research question: '*To what extent can alternative proxies improve the risk-return relationship of portfolios?'*. Gold and wine were found to have too high volatility to be considered improving this relationship. Corporate bonds on the other hand greatly improved the risk-return relationship in comparison to government bonds. This was also shown when conducting an F-test.

Overall, the findings of these three research questions indicate that perhaps corporate bonds are a better operationalization of the risk-free asset than government bonds. Owning a basket of corporate bonds satisfies all theoretical requirements of the risk-free asset, it greatly improves the predictions made in in the CAPM and it has a superior risk-return relationship in a portfolio setting.

6.2. Limitations

As has been acknowledged, this analysis is not free of its limitations. The main limitation to this research lies in the CAPM examination. The results of the regressions were highly significant. This is an indication of some problem in the data, probably the non-normality of the asset returns. There was an attempt to fix this by examining the changes of log-prices, but this did not change the normality of the density distribution.

Also, the outcomes of the CAPM analyses indicated that perhaps there is an omitted variable bias within the dataset. Therefore, it would be interesting to see how the results would look like in another model, like the Fama-French three factor model. That goes beyond the scope of this thesis however, so it proves a starting point for further research.

Another limitation are the assets under consideration. It would also have made sense to examine other assets, like art and rare stamps. Stamps are shown to exhibit strong, consistent returns (Dimson et al., 2015; Veld & Veld-Merkoulova, 2007). However, due to a discontinuation of the leading stamp index (the Stanley-Gibbons 100) there was a strong data limitation. It was also difficult to find data of art. This is another alternative investment category that proves highly valuable (Goetzmann, Renneboog, & Spaenjers, 2011; Pénasse, Renneboog, & Spaenjers, 2014; Renneboog & Spaenjers, 2009). The few datasets there are of art investing were too expensive to be considered for this thesis.

6.3. Further research

This thesis laid the foundation for further research. There is a strong indication that perhaps other researches operationalize the risk-free asset in a wrong way. That would mean that other models using the risk-free rate, might yield different outcomes when operationalized with corporate bonds. One of the main models to be investigated would be the Fama-French three factor model. As acknowledged in section 6.2., there is an indication of an omitted variable bias. That would mean that a model containing more price determining factors, like the Fama-French model, could offer more explanatory power.

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Appendix A – Summary statistics of stocks

Table A1: Summary statistics of all stocks used in the regressions

Company	Month	Mean	Median	S.D.	Min.	p25	p75	Max.
US stocks								
Abbott	465	1.250	1.250	6.007	-20.737	-2.365	5.288	22.124
3M	466	0.899	1.063	5.705	-27.829	-2.476	4.000	25.795
Boeing	466	1.204	1.468	8.304	-34.570	-3.917	6.738	48.438
Caterpillar	466	1.032	1.002	8.869	-35.906	-4.624	6.835	40.136
CocaCola	466	1.084	1.088	5.854	-19.331	-2.380	4.566	22.280
Deere	466	1.055	0.960	8.241	-29.857	-3.802	6.332	25.525
Ford	466	0.999	0.327	11.604	-57.885	-5.128	6.034	127.376
GE	466	0.679	0.327	7.072	-29.843	-3.279	4.485	25.124
IBM	466	0.689	0.356	7.315	-26.190	-3.724	4.844	35.380
Kellog	465	0.900	0.947	6.050	-21.298	-2.645	4.421	25.258
Pepsi	466	1.150	0.911	5.832	-28.411	-1.843	4.525	19.712
Texas Instruments	466	2.160	1.633	11.207	-32.500	-4.957	8.376	54.293
JPMorgan	465	1.063	0.690	9.171	-34.677	-3.906	6.624	31.765
McDonalds	466	1.299	1.356	5.992	-25.673	-2.277	4.972	18.257
HP	466	1.141	0.898	9.775	-31.989	-5.088	6.715	35.390
Johnson & Johnson	466	1.136	1.108	5.774	-18.060	-2.500	4.697	18.807
Disney	466	1.344	1.501	7.839	-28.710	-3.256	5.631	33.750
FedEx	466	1.200	1.072	8.860	-29.550	-4.324	6.287	37.476
Apple	456	2.117	1.554	13.231	-57.744	-5.801	9.875	45.378
AT&T	421	0.614	0.768	6.258	-19.121	-2.919	4.444	27.662
Xerox	466	0.490	0.550	10.613	-43.750	-4.414	5.745	76.649
Motorola	466	1.128	0.966	9.734	-33.494	-4.851	7.570	30.733
American Electric	466	0.468	0.749	5.384	-17.766	-2.934	3.932	22.851
Chevron	466	0.714	0.735	6.363	-17.746	-3.012	4.545	36.296
DowDupont	466	0.920	0.595	10.311	-45.134	-4.344	5.147	89.798
UK stocks								
BP	294	0.547	0.279	6.745	-35.550	-3.983	4.665	27.297
Barclays	294	0.650	0.163	11.105	-45.207	-4.830	5.400	90.203
Diageo	294	0.745	0.818	4.964	-16.896	-2.063	3.680	15.503
HSBC	294	0.654	0.183	7.242	-32.515	-3.561	4.833	27.041
Sainsbury's	294	0.056	0.758	6.817	-23.382	-4.496	4.423	29.397
Rolls Royce	294	0.945	0.703	8.831	-40.367	-3.887	5.899	36.364
RELX	294	0.791	0.558	7.277	-25.170	-2.830	4.857	44.152
Pearson	294	0.508	0.756	7.803	-25.612	-3.595	4.391	33.857
Morrison's	294	0.449	0.326	6.960	-47.799	-3.425	4.209	17.746
Aviva	294	0.286	0.705	8.356	-28.357	-4.030	4.786	45.896
BAE Systems	294	5.364	0.913	84.348	-93.324	-3.463	6.140	1437.289
Barrat	294	1.319	0.744	12.877	-63.979	-5.009	7.918	62.258
BT	294	0.246	0.344	8.851	-28.554	-4.520	5.302	46.381
Ferguson	294	0.833	0.955	9.408	-55.026	-3.955	5.911	31.167
GlaxoSmithKlyne	294	0.485	0.427	5.358	-15.422	-3.267	4.052	18.248
Halma	294	1.067	1.176	6.847	-25.200	-3.177	5.542	21.256

Johnson Matthey	294	0.873	0.621	7.845	-30.963	-4.049	5.039	26.516
Kingfisher	294	0.594	0.000	10.117	-31.077	-4.044	4.929	86.681
Marks & Spencer	294	0.059	-0.353	7.619	-24.067	-4.342	4.408	30.136
Persimmon	294	1.281	0.455	10.209	-34.372	-4.460	7.795	29.351
Rentokil	294	0.776	1.108	8.731	-34.783	-3.549	5.212	47.753
RBS	294	0.106	0.572	11.161	-62.291	-4.969	5.761	70.612
Sage Group	294	1.792	1.730	9.725	-23.572	-3.674	6.265	56.996
Severn Trent	294	0.502	1.018	6.274	-30.339	-2.840	4.386	27.340
Smiths Group	294	0.473	0.517	6.618	-30.519	-3.379	4.858	19.940
EU stocks								
Nestle	352	0.802	0.807	4.525	-13.372	-1.966	3.509	17.110
Novartis	289	0.720	0.631	5.003	-13.218	-2.374	3.721	23.891
Allianz	269	0.581	1.709	9.325	-39.738	-4.829	5.565	39.537
Siemens	270	1.055	0.973	10.347	-29.338	-4.199	5.839	68.278
Unilever	290	0.839	0.613	5.810	-15.372	-2.171	3.694	19.966
ASML	250	2.733	1.262	19.418	-40.364	-4.651	8.132	231.823
Airbus	212	1.569	1.722	9.771	-24.871	-4.589	7.680	32.678
Santander	232	0.024	0.786	8.647	-24.082	-4.148	4.703	40.077
ABINBEV	221	0.802	1.337	7.323	-34.493	-3.480	4.998	28.627
L'Oreal	232	0.708	0.717	5.409	-16.372	-2.276	3.706	22.817
BASF	232	0.689	0.533	7.154	-22.756	-3.390	5.003	25.362
BNP Paribas	302	0.705	0.833	8.913	-30.672	-4.427	5.962	31.195
Iberdrola	232	0.666	0.571	6.487	-21.148	-3.185	4.755	21.808
Deutsche Telekom	269	0.367	0.378	8.909	-33.399	-4.308	4.942	43.230
Adidas	251	1.114	1.096	8.380	-26.976	-3.827	6.605	23.814
ENEL	234	0.132	0.003	6.066	-17.409	-3.569	3.949	23.473
Daimler	271	0.474	0.398	9.582	-31.825	-5.373	5.941	42.269
UBS	285	0.298	0.099	9.512	-42.184	-5.467	5.560	49.065
ING	290	0.831	1.330	10.964	-51.540	-4.194	6.468	70.747
Philips	290	3.041	0.787	29.156	-79.828	-4.326	6.252	336.006
Intesa Sanpaolo	290	0.872	0.520	12.135	-31.727	-5.035	7.267	109.184
Heineken	290	0.823	0.775	6.062	-22.500	-2.028	4.222	25.039
BMW	270	0.843	0.668	9.000	-26.292	-4.541	6.856	26.542
Unibail	340	0.583	0.570	6.331	-21.157	-3.780	4.876	30.656
Deutsche Bank	270	0.018	-0.338	10.716	-40.567	-6.475	6.663	45.813

Appendix B – Summary statistics of stock indices

Table A2: Summary statistics of the stock indices as used in the regression

Market	**Months**	**Mean**	**Median**	**S.D.**	**Min.**	**p25**	**p75**	**Max.**
S&P500	466	0.780	1.107	4.261	-21.782	-1.653	3.471	13.177
FTSE100	294	0.359	0.695	3.844	-13.024	-1.790	2.842	8.857
STOXX	353	0.453	1.032	4.391	-14.135	-1.914	3.222	13.472

Appendix C – Initial regression results

The results presented in this appendix correspond to the tables in chapter IV. They are presented in the same order.

Table A3: US CAPM regression results for government bonds and gold

Corresponds to table 21

Company	**Government bonds**					**Gold**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
Abbott	-3.177	-7.542	0.314	5.623	465	0.357	0.862	0.996	169.943	405
3M	-3.486	-8.399	0.323	5.893	466	-0.095	-0.233	0.991	171.312	406
Boeing	-1.820	-3.310	0.579	7.964	466	0.138	0.284	0.993	144.318	406
Caterpillar	-3.186	-5.145	0.355	4.334	466	-0.177	-0.315	0.984	123.750	406
Coca-Cola	-3.283	-8.109	0.327	6.102	466	0.373	0.925	0.998	174.580	406
Deere	-2.301	-4.088	0.516	6.941	466	-0.077	-0.152	0.988	137.903	406
Ford	-2.558	-3.336	0.479	4.722	466	0.577	0.837	1.002	102.523	406
GE	-3.653	-7.669	0.333	5.290	466	0.298	0.667	1.000	157.683	406
IBM	-3.497	-6.908	0.361	5.388	466	-0.133	-0.281	0.992	147.787	406
Kellog	-3.618	-8.736	0.297	5.404	465	0.004	0.011	0.992	168.139	405
Pepsi	-3.445	-8.491	0.284	5.294	466	0.307	0.745	0.995	170.263	406
TI	-2.261	-2.989	0.316	3.165	466	1.511	2.168	1.002	101.363	406
JP Morgan	-2.243	-3.686	0.525	6.510	465	0.150	0.273	0.995	127.390	405
McDonalds	-2.944	-7.047	0.350	6.335	466	0.281	0.686	0.991	170.747	406
HP	-2.645	-4.058	0.436	5.057	466	0.121	0.205	0.991	118.509	406
J&J	-3.527	-8.544	0.271	4.967	466	0.309	0.733	0.996	166.810	406
Disney	-2.125	-4.086	0.495	7.204	466	0.644	1.357	1.000	148.651	406
FedEx	-2.348	-3.978	0.481	6.159	466	0.342	0.649	0.994	132.869	406
Apple	-0.980	-1.107	0.552	4.666	456	0.559	0.699	0.970	86.173	396
AT&T	-3.786	-8.653	0.221	3.437	421	-0.190	-0.408	0.995	158.394	361
Xerox	-2.573	-3.660	0.571	6.150	466	-0.470	-0.763	0.989	113.198	406
Motorola	-2.617	-4.015	0.444	5.149	466	0.378	0.635	1.001	118.754	406
AE	-3.487	-9.038	0.404	7.923	466	-0.635	-1.709	0.991	188.086	406
Chevron	-3.462	-7.597	0.362	6.017	466	-0.271	-0.634	0.989	163.014	406
DowDupont	-2.651	-3.811	0.476	5.178	466	-0.126	-0.224	0.993	124.081	406
Average	-2.867	-5.760	0.403	5.635	-	0.167	0.281	0.993	143.450	-

Results of 50 CAPM regressions with government bonds and 5 year holding period gold returns as risk free assets respectively, US stocks and the S&P 500 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table A4: US CAPM regression results for wine and corporate bonds

Corresponds to table 22

Company	**Wine**					**Corporate Bonds**				
	α	t-value	β	t-value	Months	α	t-value	B	t-value	Months
Abbott	-0.008	-0.010	0.999	131.142	153	-3.275	-2.677	0.893	25.632	142
3M	0.136	0.173	0.996	120.868	153	-2.992	-2.134	0.899	22.526	142
Boeing	0.048	0.056	0.993	110.860	153	0.025	0.017	0.982	23.120	142
Caterpillar	0.165	0.152	0.987	86.565	153	-2.245	-1.115	0.898	15.669	142
Coca-Cola	0.179	0.267	1.001	141.837	153	-4.276	-3.770	0.868	26.886	142
Deere	0.503	0.510	0.993	95.881	153	-2.940	-1.629	0.880	17.126	142
Ford	1.409	0.796	1.015	54.598	153	-3.952	-1.218	0.851	9.213	142
GE	-0.577	-0.617	0.997	101.527	153	-2.315	-1.373	0.938	19.537	142
IBM	0.262	0.295	1.000	107.246	153	-4.416	-2.982	0.850	20.169	142
Kellog	-0.038	-0.066	0.995	163.204	153	-2.487	-2.452	0.920	31.862	142
Pepsi	-0.224	-0.339	0.995	143.478	153	-3.500	-2.999	0.888	26.722	142
TI	-0.133	-0.125	0.992	88.592	153	-1.598	-0.856	0.935	17.574	142
JP Morgan	-0.248	-0.241	0.993	92.084	153	-2.020	-1.116	0.924	17.914	142
McDonalds	0.372	0.521	0.996	132.983	153	-3.662	-2.930	0.865	24.320	142
HP	-0.923	-0.837	0.980	84.702	153	-2.511	-1.322	0.906	16.757	142
J&J	0.087	0.128	0.999	139.660	153	-3.789	-3.284	0.881	26.813	142
Disney	0.522	0.659	0.998	120.085	153	-0.972	-0.698	0.944	23.816	142
FedEx	-0.038	-0.042	0.989	105.215	153	-2.110	-1.313	0.919	20.091	142
Apple	2.140	1.817	0.987	79.879	153	-0.813	-0.391	0.875	14.777	142
AT&T	-0.642	-0.743	0.995	109.629	153	-4.435	-3.051	0.866	20.922	142
Xerox	-0.319	-0.274	0.987	80.581	153	-0.469	-0.235	0.974	17.156	142
Motorola	-0.487	-0.452	0.991	87.593	153	-0.316	-0.160	0.982	17.523	142
AE	-0.175	-0.269	0.999	146.523	153	-2.929	-2.520	0.910	27.494	142
Chevron	0.215	0.286	0.996	126.450	153	-2.945	-2.205	0.893	23.488	142
DowDupont	0.585	0.463	1.002	75.500	153	-0.464	-0.199	0.969	14.603	142
Average	0.112	0.084	0.995	109.067	-	-2.456	-1.705	0.908	20.868	-

Results of 50 CAPM regressions with 5 year holding period returns of wine and corporate bonds as risk free assets respectively, US stocks and the S&P 500 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table A5: UK CAPM regression results for government bonds and gold

Corresponds to table 23

Company	**Government bonds**					**Gold**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
BP	0.326	0.767	1.035	14.040	294	0.198	0.438	1.000	201.852	234
Barclays	2.046	2.760	1.450	11.285	294	0.945	1.151	1.007	111.890	234
Diageo	-0.860	-2.365	0.680	10.795	294	0.163	0.392	0.997	218.353	234
HSBC	1.205	2.913	1.233	17.197	294	0.588	1.288	1.004	200.661	234
Sainsbury's	-1.411	-2.775	0.716	8.119	294	-0.669	-1.230	0.993	166.516	234
Rolls Royce	1.303	2.176	1.184	11.404	294	0.472	0.758	0.993	145.541	234
RELX	-0.374	-0.698	0.793	8.544	294	0.456	0.756	1.003	151.719	234
Pearson	0.079	0.146	0.982	10.467	294	0.517	0.982	1.005	173.947	234
Morrison's	-1.466	-2.773	0.601	6.556	294	-0.280	-0.480	0.992	155.243	234
Aviva	1.019	1.953	1.280	14.145	294	-0.011	-0.019	1.000	154.642	234
BAE Systems	4.083	0.612	0.764	0.660	294	10.474	1.352	1.077	12.676	234
Barrat	2.600	2.808	1.421	8.847	294	1.314	1.265	1.005	88.262	234
BT	0.331	0.536	1.114	10.402	294	0.242	0.358	1.004	135.395	234
Ferguson	1.814	2.909	1.344	12.429	294	0.380	0.532	0.999	127.761	234
GlaxoSmithKlyne	-1.419	-3.655	0.604	8.968	294	0.478	1.078	1.006	206.649	234
Halma	0.374	0.764	0.914	10.773	294	0.268	0.496	0.995	167.783	234
Johnson Matthey	0.861	1.630	1.089	11.888	294	0.393	0.704	0.995	162.372	234
Kingfisher	-0.085	-0.114	0.918	7.100	294	1.355	1.654	1.015	113.028	234
Marks&Spencer	-1.161	-2.049	0.779	7.929	294	-0.608	-0.997	0.992	148.294	234
Persimmon	1.057	1.388	1.034	7.837	294	0.582	0.710	0.994	110.549	234
Rentokil	0.221	0.346	0.950	8.570	294	0.313	0.436	1.005	127.853	234
RBS	1.332	1.759	1.407	10.705	294	0.020	0.024	1.004	108.612	234
Sage Group	1.953	2.934	1.133	9.820	294	2.517	3.408	1.017	125.509	234
Severn Trent	-1.962	-3.997	0.460	5.408	294	0.011	0.018	0.998	155.603	234
Smiths Group	-0.142	-0.318	0.934	12.094	294	0.192	0.400	1.001	189.588	234
Average	0.469	0.306	0.993	9.839	-	0.812	0.619	1.004	146.412	-

Results of 50 CAPM regressions with government bonds and the five year holding period return of gold as risk free assets respectively, UK stocks and the FTSE100 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table A6: UK CAPM regression results for wine and corporate bonds

Corresponds to table 24

Company	**Wine**					**Corporate Bonds**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
BP	0.039	0.068	1.002	166.443	153	0.003	0.002	1.005	32.447	142
Barclays	-0.071	-0.059	0.997	78.612	153	1.778	0.762	1.057	15.854	142
Diageo	0.721	1.584	1.004	210.044	153	-1.335	-1.628	0.948	40.462	142
HSBC	-0.291	-0.601	0.997	195.839	153	-0.032	-0.035	1.007	38.504	142
Sainsbury's	-0.408	-0.706	0.997	164.051	153	-1.184	-1.093	0.971	31.353	142
Rolls Royce	0.872	1.071	0.994	116.209	153	3.138	2.175	1.056	25.615	142
RELX	0.346	0.706	1.005	194.980	153	0.161	0.171	1.005	37.362	142
Pearson	0.342	0.550	1.004	153.555	153	-0.517	-0.469	0.976	30.983	142
Morrison's	-0.292	-0.421	0.996	136.607	153	-3.388	-2.622	0.900	24.374	142
Aviva	-0.197	-0.236	0.998	113.503	153	2.911	1.859	1.083	24.213	142
BAE Systems	-0.201	-0.297	0.995	140.280	153	1.050	0.835	1.029	28.640	142
Barrat	0.926	0.633	0.994	64.711	153	5.384	1.933	1.136	14.267	142
BT	0.474	0.667	1.006	134.665	153	1.699	1.321	1.042	28.345	142
Ferguson	0.587	0.610	0.998	98.815	153	3.412	1.912	1.095	21.486	142
GlaxoSmithKlyne	-0.073	-0.134	1.003	174.689	153	-1.973	-2.065	0.942	34.516	142
Halma	1.182	1.901	1.006	153.867	153	-0.145	-0.126	0.970	29.449	142
Johnson Matthey	0.964	1.701	1.003	168.358	153	0.780	0.718	1.002	32.270	142
Kingfisher	0.831	1.007	1.010	116.411	153	-0.761	-0.548	0.968	24.360	142
Marks&Spencer	-0.195	-0.240	0.991	115.926	153	-0.391	-0.263	0.985	23.141	142
Persimmon	0.676	0.609	0.990	84.873	153	4.695	2.273	1.114	18.866	142
Rentokil	0.013	0.014	1.004	102.703	153	-1.545	-0.861	0.964	18.807	142
RBS	-1.576	-1.282	0.991	76.707	153	4.076	1.743	1.165	17.437	142
Sage Group	0.474	0.694	1.000	139.266	153	1.328	1.167	1.023	31.455	142
Severn Trent	0.273	0.378	0.999	131.610	153	-0.617	-0.445	0.971	24.492	142
Smiths Group	0.107	0.181	1.000	160.805	153	0.458	0.411	1.017	32.011	142
Average	0.221	0.336	0.999	135.741	-	0.759	0.285	1.017	27.228	-

Results of 50 CAPM regressions with the 5 year holding period returns of wine and corporate bonds as risk free assets respectively, UK stocks and the FTSE100 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table A7: EU CAPM regressions for government bonds and gold

Corresponds to table 25

Company	**Government bonds**					**Gold**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
Nestle	-0.989	-3.750	0.626	14.669	352	0.231	0.854	0.997	274.815	352
Novartis	-1.154	-3.649	0.492	8.564	289	-0.369	-0.426	0.989	93.719	289
Allianz	-2.153	-3.205	0.189	1.563	269	-0.258	-0.243	0.995	77.698	281
Siemens	1.537	2.744	1.341	13.203	270	-0.243	-0.216	0.984	73.998	270
Unilever	-0.661	-1.836	0.633	9.660	290	-0.304	-0.368	0.988	97.689	290
ASML	3.662	2.820	1.429	6.121	250	2.461	1.385	0.995	48.997	250
Airbus	2.036	3.431	1.330	11.590	212	1.762	2.596	1.009	132.829	212
Santander	0.745	1.650	1.325	15.993	232	-1.116	-0.956	0.979	75.596	232
AB INBEV	0.129	0.259	0.773	8.402	221	0.222	0.188	0.983	75.801	221
L'Oreal	-0.208	-0.584	0.688	10.526	232	0.305	0.289	0.991	84.513	232
BASF	0.848	2.259	1.107	16.062	232	-0.164	-0.155	0.984	83.813	232
BNP Paribas	1.265	2.913	1.304	17.076	307	-1.279	-1.400	0.975	85.173	307
Iberdrola	-0.291	-0.662	0.672	8.316	232	-0.497	-0.469	0.978	83.314	232
Deutsche Telekom	-0.230	-0.420	0.923	9.287	269	-0.698	-0.637	0.988	76.231	269
Adidas	0.751	1.402	0.936	9.717	251	0.299	0.267	0.986	76.909	251
ENEL	-0.656	-1.663	0.747	10.397	234	-0.469	-0.450	0.987	84.996	234
Daimler	1.317	2.915	1.489	18.137	271	-1.008	-0.936	0.982	76.813	271
UBS	0.722	1.461	1.327	14.785	285	-1.071	-1.098	0.983	83.031	285
ING	2.396	4.839	1.748	19.415	290	-0.202	-0.200	0.991	80.396	290
Philips	2.967	1.536	1.152	3.280	290	3.439	1.599	1.023	38.908	290
Intesa Sanpaolo	1.723	2.553	1.489	12.125	290	-0.422	-0.380	0.984	72.554	290
Heineken	-0.665	-1.733	0.637	9.142	290	-0.226	-0.260	0.989	92.722	290
BMW	1.039	2.190	1.231	14.307	270	-0.466	-0.436	0.985	77.722	270
Unibail	-1.068	-2.721	0.660	9.947	340	-0.809	-1.121	0.976	102.611	340
Deutsche Bank	0.894	1.642	1.493	15.120	270	-1.621	-1.453	0.978	73.953	270
Average	0.558	0.576	1.030	11.496	-	-0.100	-0.161	0.988	88.992	-

Results of 50 CAPM regressions with government bonds and the 5 year holding period return of gold as risk free assets respectively, European stocks (minus the UK) and the STOXX600 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).

Table A8: EU CAPM regressions for wine and corporate bonds

Corresponds to table 26

Company	**Wine**					**Corporate Bonds**				
	α	t-value	β	t-value	Months	α	t-value	β	t-value	Months
Nestle	0.475	0.959	1.002	192.519	153	-2.992	-3.501	0.899	37.017	142
Novartis	0.182	0.326	1.001	170.293	153	-2.124	-2.210	0.936	34.313	142
Allianz	0.127	0.105	0.995	77.814	153	-2.789	-1.530	0.904	17.464	142
Siemens	0.776	1.070	1.003	131.651	153	1.468	1.200	1.031	29.688	142
Unilever	0.611	1.131	1.007	177.183	153	-2.876	-3.026	0.907	33.609	142
ASML	1.416	1.279	1.006	86.470	153	3.154	1.656	1.062	19.634	142
Airbus	1.642	1.741	1.005	101.359	153	4.638	2.697	1.114	22.803	142
Santander	-0.161	-0.235	0.996	138.568	153	1.310	1.055	1.035	29.331	142
AB INBEV	1.325	1.744	1.004	125.683	153	-0.547	-0.387	0.952	23.738	142
L'Oreal	0.538	1.007	1.004	178.862	153	-1.895	-2.039	0.935	35.416	142
BASF	1.354	2.426	1.006	171.497	153	0.845	0.840	0.998	34.922	142
BNP Paribas	0.089	0.125	0.996	133.513	153	2.252	1.726	1.067	28.795	142
Iberdrola	-0.354	-0.506	0.990	134.719	153	-1.092	-0.844	0.958	26.065	142
Deutsche Telekom	-0.047	-0.060	1.004	122.181	153	-0.494	-0.403	0.988	28.379	142
Adidas	1.235	1.866	1.003	144.168	153	0.507	0.443	0.990	30.428	142
ENEL	-0.260	-0.461	1.000	168.822	153	-0.339	-0.323	0.996	33.368	142
Daimler	1.022	1.261	1.009	118.419	153	2.220	1.545	1.057	25.891	142
UBS	-0.865	-1.065	0.989	115.807	153	3.078	2.051	1.106	25.955	142
ING	0.150	0.142	1.001	90.087	153	5.025	2.584	1.152	20.856	142
Philips	0.098	0.142	1.000	137.541	153	1.244	1.038	1.039	30.546	142
Intesa Sanpaolo	-0.295	-0.331	0.991	105.857	153	3.439	2.210	1.099	24.876	142
Heineken	0.473	0.845	1.006	170.769	153	-2.126	-2.144	0.935	33.195	142
BMW	1.399	2.020	1.010	138.788	153	1.066	0.843	1.016	28.284	142
Unibail	0.259	0.412	0.991	150.337	153	-0.143	-0.124	0.975	29.818	142
Deutsche Bank	-0.523	-0.601	0.993	108.531	153	1.072	0.663	1.041	22.659	142
Average	0.427	0.614	1.001	135.657	-	0.556	0.161	1.008	28.282	-

Results of 50 CAPM regressions with wine and corporate bonds as risk free assets respectively, European stocks (minus the UK) and the STOXX600 as market return. Critical t-values are +/- 1.282 (90% c.i.), +/- 1.645 (95% c.i.) and +/- 2.326 (99% c.i.).