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Exploiting Money Illusion in the Markets for Inflation Protected Securities

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ABSTRACT:

Money illusion is a psychological phenomenon which leads to biased market participants evaluating monetary values in nominal terms instead of real terms. Hence, neglecting the consequences of inflation. Prior research has found indications of money illusion in various asset classes, such as stocks and real estate. Moreover, money illusion has been found to prevail in the real prices of bonds. Due to the underlying mechanics of inflation protected securities, their price can theoretically be determined as real, leading to the assumption that their market is also prone to money illusion. The purpose of this thesis is to investigate whether the market for inflation protected securities, represented by Treasury Inflation Protected Securities (TIPS), is affected by money illusion and whether other events indicating investor irrationality are perceivable. Break-even inflation has been utilized by prior research to measure the inflation expectations of the TIPS market. However, if TIPS yields incorporate attributes of money illusion, this may cause inflation expectations, denoted by break-even inflation, to continuously deviate from realized inflation. Therefore, by utilizing ex-poste data of a recently matured TIPS, nominal market yields and inflation, this thesis simultaneously tests whether inflation expectations are realized in the TIPS market and whether money illusion can be perceived in TIPS yields. Furthermore, it tests the magnitude of the potential irrationality prevailing in the TIPS market. The results indicate that inflation expectations continuously fail to realize and that attributes of money illusion are perceivable in TIPS yields, leading to the conclusion that TIPS may be undervalued in periods of higher inflation, as suggested by prior research on money illusion. However, even though inflation expectations are biased, TIPS yields develop in accordance with them during periods of less uncertainty. Hence, providing unbiased investors an opportunity to exploit when the market faces uncertainty.

KEYWORDS: Money illusion, inflation, expected inflation, inflation protection, Treasury Inflation Protected Securities, TIPS.

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TIIVISTELMÄ:

Rahailluusio on psykologinen ilmiö, jonka johdosta puolueelliset markkinaosapuolet arvioivat rahamääräisiä arvoja nimellisesti, reaalisen sijaan. Näin toimiessaan he laiminlyövät inflaation seuraukset. Aikaisemmat tutkimukset ovat löytäneet merkkejä rahailluusiosta monissa omaisuusluokissa, kuten osakkeissa ja kiinteistöomaisuudessa. Tämän lisäksi rahailluusion on havaittu vallitsevan myös joukkovelkakirjojen reaalisissa hinnoissa. Inflaatiosuojattujen arvopapereiden toimintaperiaatteen ansiosta niiden hinta voidaan myös määritellä reaaliseksi. Tämä johtaa oletukseen, että myös niiden hinta on altis rahailluusiolle. Tämän tutkielman tarkoituksena on tutkia rahailluusion vaikutusta inflaatiosuojattujen arvopapereiden markkinaan ja lisäksi sitä, että onko niiden markkinoilla havaittavissa sijoittajien irrationaalisuutta. Break-even-inflaatiota on käytetty aikaisemmissa tutkimuksissa inflaatio-odotusten mittaamiseen inflaatiosuojattujen arvopapereiden markkinoilla. Jos rahailluusiota kuitenkin vallitsee niiden hinnassa, tämä voi johtaa siihen, että break-even-inflaation osoittamat inflaatio-odotukset eroavat jatkuvasti toteutuneesta inflaatiosta. Näin ollen, käyttäen historiallista dataa niin inflaatiosuojatuista arvopapereista, markkinakoroista, kuin inflaatiosta, tämä tutkielma tarkastelee samanaikaisesti inflaatio-odotusten toteutumista, sekä rahailluusion ilmenemistä inflaatiosuojattujen arvopapereiden markkinoilla. Tämän lisäksi tutkielma tarkastelee potentiaalisen irrationaalisuuden mittakaavaa. Tulokset osoittavat, että inflaatio-odotukset jäävät jatkuvasti toteutumatta ja että inflaatiosuojattujen arvopapereiden hinnoissa on merkkejä rahailluusiosta. Tämä johtaa päätelmään, että inflaatiosuojatut arvopaperit saattavat olla aliarvostettuja korkeamman inflaation ympäristöissä, kuten aikaisemmat tutkimukset rahailluusiosta ovat esittäneet. Inflaatio-odotusten puolueellisuudesta huolimatta inflaatiosuojattujen arvopapereiden hinta kehittyy niiden mukaisesti pienemmän epävarmuuden olosuhteissa. Tämä tarjoaa puolueettomille sijoittajille mahdollisuuden hyödynnettäväksi, kun markkina kohtaa epävarmuutta.

AVAINSANAT: Rahailluusio, inflaatio, inflaatio-odotukset, inflaatiosuojaus.

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1. Introduction

A dollar today is worth more than a dollar tomorrow. Maybe you have been a keen saver, maybe not. But when have you truly considered how your real purchasing power has developed over time? According to Shafir, Diamond and Tversky (1997), money illusion refers to the psychological phenomenon in which biased investors evaluate monetary values in nominal terms instead of real terms. In other words, biased investors do not consider the effect inflation has on their purchasing power. Whereas the efficient market theory of traditional financial literature states that all available information is reflected in the price of assets, money illusion is a bias in investor behavior which causes prices to shift from their theoretically correct market equilibrium.

Moreover, money illusion implies that market participants are not always rational in their decisioning, a thought which is hard for some economists to welcome. Nevertheless, even though people tend to change their minds and learn, prior studies indicate that biased judgement, money illusion, is perceivable on a regular basis. This could provide opportunities for market participants that can recognize the phenomenon, even though it is in controversy with traditionally accepted theory.

Due to the nature of money illusion as a cognitive error, accurately measuring the quantity of error is challenging. However, the existence of such a bias has been sufficiently presented by, for example, Shafir et al. (1997) who examine money illusion as a bias in their study. It consists of the results of multiple inquiries held to a diverse audience who have, and have not, received education in the field of economics.

Most respondents it their study manage to answer correctly, therefore implying knowledge towards the concept of real purchasing power. Yet a significant portion of respondents tend to base their evaluation on nominal terms, ignoring the consequence of inflation. Hence, presenting biased judgement nominated as money illusion. In addition, their paper attempts to assimilate money illusion with other distortions in decisioning, such as loss aversion, risk attitudes and fairness concerns which, on the other hand, are subjects of less dispute in the science community. In the end, no definite conclusions are made.

Prior to Shafir et al. (1997), Modigliani and Cohn (1979) suggested that the stock market suffers from money illusion and that real cash flows are discounted at nominal discount rates, leading to undervaluation. Their finding has later become known as the Modigliani-Cohn hypothesis. Since inflation deteriorates purchasing power, and if it is left unaccounted for, the valuation of equities may not represent their actual economic value. Yet such methods of biased assessment may be perceived on a continuous basis.

This suggestion is consistent with subsequent research, finding that investors in the stock market may capitalize earnings without fixing it for inflation, implying that future cash flows are discounted with nominal bond yields, not their real yields. After all, even those who are skeptic of money illusion, such as Cochrane (2011), agree that financial theories are discount rate theories. When considering other major asset classes, such as bonds, the potential effect of money illusion yet refuses to renounce. Even though the Modigliani-Cohn hypothesis suggests that nominal bond prices are not prone to money illusion, later studies have found implications of money illusion in real bond prices.

Inflation protected securities (also known as inflation-linked and inflation-indexed securities) are fixed-income instruments that offer payments linked to inflation development. Whereas common bonds are commitments to pay a fixed nominal rate of interest, their real return fluctuates according to the development of inflation, as real return equals nominal return minus inflation. By investing in inflation protected securities, investors may secure a real rate of return, regardless of the current inflationary period.

In the U.S., the main inflation protected security sold is TIPS (Treasury Inflation Protected Securities). Whereas the real returns of TIPS are fixed, their nominal return is adjusted daily, based on the development of the Consumer Price Index (CPI), the common indicator of U.S. inflation (Fabozzi, 2021). Therefore, due to the features of the instrument, we should assume that the nominal return of TIPS will always compensate for prevailing inflation. In other words, their yield and price should only represent their underlying real yield. However, motivated by prior findings on money illusion, it is likely that the TIPS market is also prone to money illusion.

In the TIPS market, break-even inflation is utilized as a general measurement of inflation expectations (D'Amico, Kim & Wei, 2018). However, if money illusion prevails in TIPS yields, which should constantly incorporate only their underlying real yield, expectations measured by break-even inflation may systematically deviate from realized inflation. Moreover, prior research has shown that inflation expectations fail to realize. Consequently, this thesis will test the accuracy of inflation expectations in the TIPS market whilst simultaneously exposing any money illusion prevailing in TIPS yields. It is likely that investor irrationality will be perceivable on a continuous basis, offering unbiased investors an opportunity to exploit.

1.1. Purpose and contribution

The purpose of this thesis is to investigate whether the market for inflation protected securities, represented by TIPS, is affected by money illusion and whether other events indicating investor irrationality are perceivable in their market. Furthermore, these events could be systematically exploited to capture excess nominal returns. Even though pursuing real returns is the essential, as they signify actual increases in investor purchasing power, the nominal return of TIPS is the item which varies according to inflation. In other words, the product of this thesis will be to provide a foundation for whether and how investors can increase their nominal returns in the market for inflation protected securities.

As stated earlier, the behavioral phenomenon of money illusion is associated with the false judgement between nominal and real quantities. The factor which separates these two is inflation. Therefore, inflation expectations are an essential topic when considering this judgement. Hence, this thesis will also evaluate the correctness of inflation interpretation and the realization of expectations whilst simultaneously considering their effect on nominal returns.

At the time of writing, inflation has yet again risen to considerable levels. Even though news reports suggest that inflation protected securities now face record-breaking demand (Financial Times, 2021), the number of studies conducted on them is relatively limited. Furthermore, prior research has primarily focused on inflation protected securities as a part of a bond portfolio, in which their usual purpose is to provide a hedge against inflation.

This thesis will contribute to the group of academic literature which examine inflation protected securities, represented by TIPS. In addition, this thesis will contribute to the field of behavioral finance by attempting to validate the findings of prior research on money illusion. Moreover, it will attempt to introduce the psychological phenomenon of money illusion as the propellent of errors in expected inflation and mispricing in the market for inflation protected securities and investigate whether this provides opportunities for unbiased investors.

1.2. Research hypotheses

The research hypotheses of this thesis consist of three interrelated hypotheses. Motivated by prior research on both money illusion and inflation expectations, it may be assumed that mistakes in interpreting inflation are perceivable in the TIPS market on a continuous basis. Therefore, the first hypothesis of this thesis is that inflation is evaluated incorrectly in the market for inflation protected securities. More precisely, inflation expectations fail to realize in the TIPS market. This is regardless of inflation protected securities being instruments which should theoretically be neutral to inflation, therefore providing a safe investment in inflationary environments. Hence, confirming the first hypothesis already implies that investor irrationality exists and that the propellant is of cognitive nature.

$$H_1\text{: } Inflation\ expectations\ fail\ to\ realize\ in\ the\ TIPS\ market$$

Assuming the first hypothesis is confirmed, the second hypothesis aims to exhibit that investor irrationality is attributable, or at least closely associated, to money illusion. As prior studies have shown that money illusion prevails in the prices of similar assets, leading to undervaluation in periods of higher inflation, it is expected that the TIPS market is also prone to money illusion.

$$H_2\text{: } TIPS\ yields\ incorporate\ factors\ attributable\ to\ money\ illusion$$

Assuming the first two hypotheses are confirmed, the third hypothesis aims to express the magnitude of inflation misinterpretation in the market for inflation protected securities. Prior literature has indicated that TIPS prices develop in accordance with inflation expectations. Hence, TIPS yields being propelled by investor irrationality if expectations continuously deviate from realized inflation.

$$H_3\text{: } Inflation\ expectations\ are\ capable\ of\ explaining\ inflation\ protected\ yields$$

Eventually, the sum of confirming these hypotheses is that inflation expectations continuously fail to realize, and that money illusion prevails in TIPS yields, yet TIPS yields still develop according to inflation expectations even though they are biased. Hence, providing unbiased investors an opportunity to exploit.

1.3. Structure of the Thesis

This thesis consists of five chapters. The first chapter introduced the underlying motivation for studying the topic and denoted the purpose, contribution, and the research hypotheses of the thesis. The second chapter seeks to provide readers an inclusive background of the key themes discussed in the thesis, such as money illusion, features of both the nominal- and inflation-linked bonds, expectations hypothesis and inflation. Further on, it will narrow the scope into examining previous studies on inflation protected securities represented by TIPS and provide insights for evaluating the practical opportunities they provide. Chapter 3 will present the hypothesis formation, data and methodology utilized in the thesis. Chapter 4 will illustrate and evaluate results after which chapter 5 will gather the main findings and provide conclusions.

2. Theoretical background

This chapter will first examine the theoretical background of money illusion as a behavioral phenomenon as well as a closely related bias prevailing in the financial markets. After this, the textbook theory of nominal bonds will be examined, including the term structure of interest rates, the expectations hypothesis, which has been rejected many times by previous research, and inflation. Finally, it will introduce the theory and distinct functionalities of inflation linked securities, including prior research.

2.1. Money illusion

Money illusion as a term was initially composed by economist Irving Fisher (1928) in the early half of the 19th century. It was later defined by Patinkin (1965) to denote any economic judgement conducted in other than real terms, in other words, decisioning that is not solely based on relative prices and real wealth. Fisher and Modigliani (1978) find that money illusion may be perceived when nominal accounting methods are utilized, causing a distortion in the real value of corporate assets, leading to biased decisioning. However, from a broader scope, the topic has a divisive nature among economists. This is caused by dominant financial theory, namely the efficient markets theory. The efficient markets theory states that asset prices constantly reflect all available information. Furthermore, according to this theory, differences in investor preferences, attitudes, expectations, and hopes do not matter in terms of asset price development. In addition, it assumes that all market participants act rationally. Money illusion as a concept is closely related to the individual's interpretation (expectations) of present (future) inflation and is therefore indifferent according to the advocates of the efficient markets theory. However, the opposing evidence is considerable.

Shaffir, Diamond and Tversky (1997) approach money illusion from a psychological perspective. They recognize that one frequent argument against the relevancy of money illusion is that contracts on the macroeconomic level are indexed for inflation, therefore inflation being sufficiently accounted for. However, Shaffir et al. (1997) argue that indexing clauses are more uncommon than implied by theory. This signifies that the cognitive recognition of inflation as a factor when evaluating monetary values is more often left for each individual agent herself. Hence, this is one potential explanation for why characteristics of money illusion are observable in highly inflationary environments. In the experimental studies they conduct, Shaffir et al. (1997) find that when evaluation is not solely based on economic terms, instead on emotion or ones' perception of happiness, evaluation may falsely emphasize nominal values.

This finding would suggest that the cognitive features of individual agents may drive the tendency to prefer nominal items. In accordance with this suggestion, traits of money illusion have also been recorded by research in the medical field. In the experiment by Weber, Rangel, Wibral & Falk (2009), participants were awarded with prizes that had the same real value, but different nominal value. It was then measured whether the prize with a higher nominal value would induce a larger reaction in the parts of the human brain which are engaged in experiencing rewards. Hence, if participants are not suscept to money illusion, no significant difference should occur. Yet the results of Weber et al. (2009) indicate otherwise, as the larger nominal reward inflicted a larger cognitive response.

Narrowing our scope, Thaler, Tversky, Kahneman and Schwartz (1997) test how inflation affects investment decisions in an experimental survey environment. Participants in the Thaler et al. (1997) experiment were students attending the University of California at Berkeley, a highly distinguished U.S. educator. The 80 attendees were asked to allocate a portfolio of 100 shares among 2 funds, which represented bond (A) and stock (B) funds. Their mean monthly return and standard deviation represent the values of corresponding real-life investments. However, the attendees were not informed of this resemblance. Whereas the experiment had numerous other implications, the effect of inflation is our question of interest. The results of interest are displayed in Table 1 below.

Table 1. Final investment allocations in Thaler et al. (1997) survey experiment.

	Fund A "Bonds"	Fund B "Stocks"
Mean return per month	0.25	1
Standard deviation	0.18	3.5
Monthy allocation - No inflation	59.1	40.9
Monthy allocation - Inflation	27.6	72.4

Participants' opportunities for changing their allocations varied among the group. Each having a distinct time period, such as daily, monthly, and yearly, meant that some participants had more opportunities to shift their allocation. However, the effect of inflation on investment decisioning is best observable when comparing the monthly periodization with and without inflation. Participants were not explicitly informed of the inflationary conditions, but were merely suggested that inflation does influence returns, meaning that it was left for participants themselves to consider. Nevertheless, it is evident from the results of Thaler et al. (1997) that recalling inflation shifted investments away from bonds towards stocks. Eventually, they purpose that this observation contains implications of money illusion, as it may provide fixed income investments a "no loss" reputation, given that some participants were not comfortable with taking risk and rather allocated to bonds at minuscule real rates. However, this may ultimately be a question of individuals' knowledge.

When considering how the individuals' learning of related concepts affects the appearance of money illusion, a further examination is provided by Fehr and Tyran (2007). According to their study, the choice of whether returns are presented in either nominal or real terms has a significant effect on the outcome of individuals' decisioning. Moreover, presenting returns in nominal terms shifts decisioning away from the pareto efficient equilibrium, inducing losses for the agent. In addition, individuals may adopt nominal returns as a proxy for evaluating real returns. These findings have significant commonalities with the findings of Shaffir et al. (1997) and, according to Fehr and Tyran (2007), is a failure of the supposed rationality of economic agents. However, according to Fehr and Tyran (2007), the key argument against the relevancy of money illusion has been that since it has negative effects on the well-being of agents, it will eventually be evened out as learning occurs. Therefore, it is critical to observe the long-term real effects of money illusion.

Fehr and Tyran (2007) hypothesize that even though learning occurs over time, reducing the effect of money illusion on the individual level, there may be long-term real effects in the strategic environment. Strategic environment as a concept refers to whether future optimal decisioning truly incorporates all necessary factors. The reference point for such optimal decisioning is called the equilibrium. Hence, Fehr and Tyran (2007) suspect that the initial abandonment of the equilibrium towards inefficient levels is not sufficiently retrieved over time, even though learning occurs. For facilitating this experiment, Fehr and Tyran (2007) first utilize a pre-programmed computer optimization game in which individual subjects are asked to repeatedly choose the economically optimal decision from nominal- and real-term alternatives.

The data obtained from the computerized phase of Fehr and Tyran's (2007) experiment indicates that even though individuals may initially suffer from money illusion and submit to biased decisioning, most subjects express learning during the experiment and eventually proceed towards the pareto efficient equilibrium. However, when the opponent is changed to a human being, the strategic perspective is introduced. In other words, the opportunity for predicting the opponents' choice is added. Eventually, decisioning yet again falls under the pareto efficient equilibrium. This finding strongly suggests that money illusion has long-term real effects, as variations in predictions may continuously distort decisioning.

Subsequently, Chytilova (2017) finds that even the economically educated may suffer from money illusion. However, one could at least suppose that education mitigates exposure to money illusion. Hence, Darriet, Guille and Vergnaud (2020) investigate on the individual level whether the possession of financial knowledge and numeracy decreases attributes of money illusion. In accordance with the findings of prior research, which show that these features are beneficial in terms of evaluating economic alternatives, Darriet et al. (2020) find that individuals with financial knowledge are less likely to demonstrate money illusion. However, they are still vulnerable. On the other hand, numeracy as a talent did not have significant effects.

2.1.1. Stock market – The Modigliani-Cohn hypothesis

The stock market has traditionally been perceived as a "safe haven" from inflation, which partially explains why the allocations in the Thaler et al. (1997) experiment shifted from bonds to stocks. However, the stock market may not be as immune as anticipated. When further on examining money illusion in the stock market, Modigliani and Cohn (1979) provide the initial insights on the topic. Their research suggests that investors have continuously misvalued the stock market, represented by the S&P 500 in their paper, by half. However, not in the direction as one could quickly anticipate in present times. Due to investors making two mistakes on a regular basis, the S&P 500 was undervalued by 50 percent in 1977. The first mistake is that stock returns are capitalized at nominal interest rates instead of real rates, that is, nominal adjusted for inflation. In practice, this means that stock returns are evaluated against nominal bond returns, instead of the real return on bonds. Furthermore, since inflation varies over time, they suggest that the expected equity premium may systematically deviate from the theoretically correct expectation.

The second mistake investors make, according to Modigliani and Cohn (1979), is that that they misinterpret the real value of corporate liabilities. Creditors of corporate debt are generally compensated for inflation-induced reductions in real value. However, their study claims that this compensation is perceived as a repayment of capital, instead of a cost of capital. Furthermore, this type of earning manages to dodge taxation due to the structure of income statements. Eventually, the operating profit which indicates taxable income has an inverse relationship with inflation meaning that, when inflation rises, taxable income decreases. In addition, inflation may cause the real profits of companies to turn into real losses, if companies are significantly levered.

The finding of Modigliani and Cohn (1979), that the stock market may suffer from money illusion as real cash flows are discounted at nominal discount rates, has later become known as the Modigliani-Cohn hypothesis. Cohen, Polk and Vuolteenaho (2004) provide additional support for this hypothesis. Whereas the hypothesis was originally confirmed to hold when comparing the pricing of the S&P 500 to Treasury bill rates, Cohen et al. (2004) further on distinguish stocks to safe and risky stocks, after which prices of all three are compared.

Cohen et al. (2004) recognize that multiple previous studies since Modigliani and Cohn (1979) have found indications of money illusion. However, they suggest that these studies have a common weakness. They do not consider the effect inflation has on investor risk preferences, which may have a significant effect on stock prices. Cohen et al. (2004) argue that money illusion has an equal effect on all stocks, both safe and risky, and by separating the two It is possible to compart investor risk preferences from money illusion. The underlying motivation for this is that variations in risk preference have a greater effect on the price of risky stocks. Their results indicate that, regardless of stock riskiness, high inflation increases stock market returns to levels that are over rational expectation, which can be explained by money illusion.

In addition, Cohen et al. (2004) propose that money illusion could be propelled by a common methodology utilized for valuating equities, known as the “Fed model”. The Fed model forms a relationship between the value of stocks and nominal bond yields. Moreover, the value of stocks is defined by a risk premium which is added on top of the yield of nominal bonds. Yet they state that the Fed model has performed relatively well in explaining historical stock prices even though it is based on the first error suggested by Modigliani and Cohn (1979).

Further on considering the alternative explanations for this type of misevaluation, Chen, Lung and Wang (2009) examine the Modigliani-Cohn hypothesis and the resale option hypothesis by Scheinkman and Xiong (2003). The resale option hypothesis of Scheinkman and Xiong (2003) states that differences in the predicted growth of dividends, combined with constraints that prevent short selling, result in stock prices that are higher than any rational valuation. Eventually, the findings of Chen et al. (2009) support prior research as they lean towards money illusion as the propellant for mispricing. For visualizing their regression results, they present figure 1 below.

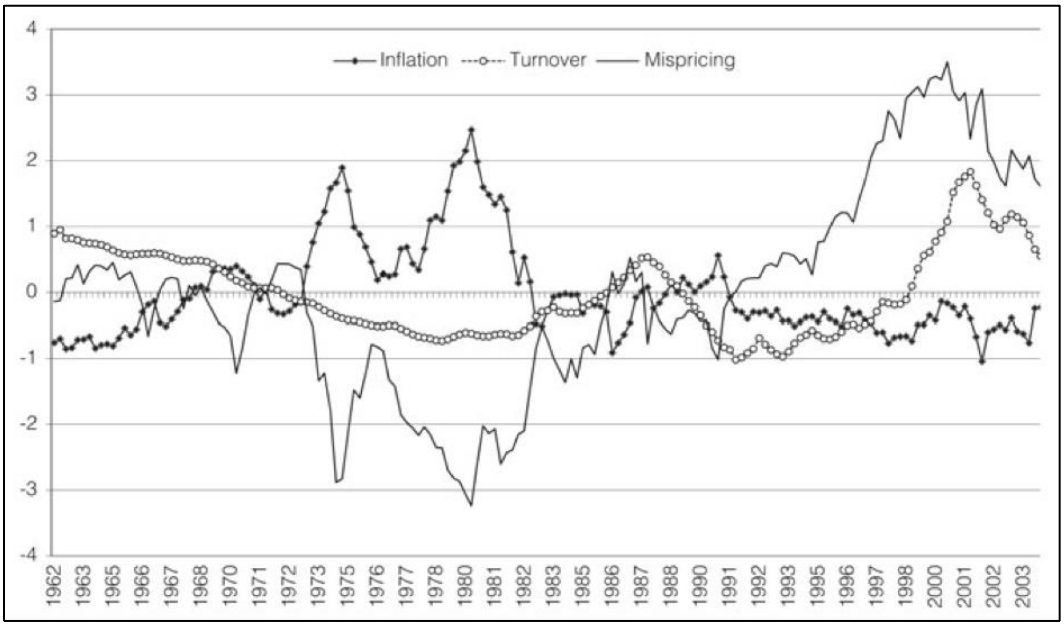

Figure 1. Relations of mispricing, turnover and inflation from Chen et al. (2009).

In the analysis of Chen et al. (2009), mispricing has been the dependent variable, whereas share turnover and inflation have been independent. Throughout the time period of 1962-2004, inflation has had an inverse relationship with mispricing. On the other hand, turnover has somewhat paralleled mispricing over this period. Nevertheless, the key takeaway from this finding, noted by Chen et al. (2009), is that the negative relationship between inflation and mispricing strongly tangents the findings of Modigliani and Cohn (1979). That is, stocks are undervalued when inflation is high, vice versa.

2.1.2. Bond market

Even though one key attribute of money illusion is that real returns are evaluated in nominal terms, the Modigliani-Cohn hypothesis does not consider the effect money illusion has on the yields of nominal bonds. Nevertheless, the value of nominal bonds, common debt market instruments, is significantly affected by changes in interest rates, which in turn fluctuate to provide compensation for credit risk and inflation. In the case of U.S treasury bonds, interest rates are determined by the Federal Reserve, more commonly known as the Fed. One could suspect that the need for indexing debt with inflation is definite. However, as stated earlier, is usually not the case. Therefore, Akerlof and Shiller (2009) rightfully question how efficiently investors will eventually consider inflation if they have passed the indexation-option in the first place.

An early revision of inflation and real interest rates in the bond market is provided by Barr and Campbell (1997). They utilize current bond prices to estimate future inflation and real interest rates. The key motivation for their paper is that fluctuations in either one will affect nominal interest rates, whereas the only real data available daily is the price of market securities. Eventually, a yield curve is formatted in accordance with the implications of present prices, from which expectations can be derived from.

The empirical part of Barr and Campbell's (1997) study pairs a nominal bond with an inflation index-linked bond, fixed for lag. Their methodology is successful in terms of being capable to divide the expected nominal interest rate into provisions attributable to either the expected real interest rate or expected inflation. A key finding following this division is that forecasts derived from these separate components are more accurate than forecasts acquired solely from nominal interest rates. In addition, they find that 80% of fluctuations in long-term nominal interest rates is caused by variation in expected inflation, which was later confirmed by Ang, Bekaert and Wei (2008). This also suggests that long-term real interest rates are relatively stable. Therefore, if one were to suffer from money illusion and base their evaluation on nominal terms, they would unnecessarily expose themselves to greater volatility.

A more recent study confirming these results is presented by Basak and Yan (2010). Whereas their paper examines whether money illusion shifts asset prices from market equilibrium, investigating multiple asset classes, they surface implications of a potential irrationality in the market. A mutual finding of both Barr and Campbell (1997) and Basak and Yan (2010) is that inflation and short-term real interest rates are negatively correlated.

When considering this finding and taking a broader macroeconomic perspective, Basak and Yan (2010) argue that if investors suffer from money illusion, their consumption decreases when inflation increases. On the other hand, the money-illusioned investor utilizes nominal interest rates for discounting which steers them to saving less than what would be deemed beneficial. This results in short-term equilibrium, assuming markets behold rational investors as well. However, the mathematical presentation of the negative correlation, as proposed by Basak and Yan (2010), would indicate that since inflation is theoretically infinite, the investor suffering from money illusion would eventually run entirely out of real wealth.

The latest remarks of money illusion in the bond market are provided by Duarte and Saporito (2019). Their findings are in line with the Modigliani-Cohn hypothesis, implying that nominal bond prices are not affected by money illusion. However, they find that money illusion does prevail in real bond prices. That is, if the component responsible for compensating inflation in nominal bond prices is removed, and bonds were to be quoted in real terms. Moreover, the real prices of bonds correlate with the amount of prevailing money illusion. In addition, they show that money illusion has a significant effect on the real term premium of short-term bonds. Therefore, they conclude that supposed increases in real purchasing power are affected by money illusion.

2.1.3. Real estate market

Another asset class in which implications of money illusion have been caught on record is the real estate market. In general, inflation can be perceived as a friend of debtors, if their liabilities are fixed in nominal terms. As inflation increases, the money owed to creditors decreases in terms of its purchasing power. However, the price of building real estate also increases. Yet Brunnermeier and Julliard (2008) find that decreases in inflation may increase housing prices due to rising demand. This is because declining inflation lowers the announced nominal terms of prospected mortgages.

A similar finding was made later by Fairchild, Ma and Wu (2015). Nevertheless, this is in contradiction to the common wisdom mentioned above, and it is supposedly propelled by money illusion. Another fundamental error in interpretation surfaces when prospected homeowners evaluate whether to rent or buy a house. Brunnermeier and Julliard (2008) find that the favorable effect of inflation on future loan payments is neglected. Therefore, the price-rent ratio of housing is not influenced by real interest rates, which account for inflation, but rather by nominal interest rates.

2.1.4. Additional experimental observation

An additional example of how money illusion occurs in diverse inflationary environments is provided by Noussair, Richter and Tyran (2012). Their study examines the effect nominal shocks have on real asset prices. In other words, these nominal shocks represent a swift increase in inflation or deflation. Motivated by previous studies conducted on the financial and real estate markets, Noussair et al. (2012) expect that inflationary shocks do have illusionary effects on real prices. However, yet again, it is mentioned that traditional financial theory would not recognize such a phenomenon. In addition, there is no theoretical reasoning that would explain why investors would react asymmetrically to these shocks. For facilitating their experiment, they introduce an illustrative asset market which they expose to either inflationary or deflationary shocks.

Their experimental asset is traded on 21 periods, of which the 7 first periods are noted as the "pre-shock" phase. The nominal, either inflationary or deflationary, shock is then introduced, leaving the remaining periods as the "postshock" phase. The nominal shock is conducted by altering the value of the experimental currency utilized to purchase the experimental asset, weakening representing inflation and strengthening representing deflation. Their findings imply that the reactions to such shocks are in fact, asymmetrical. When inflationary shocks emerge, nominal prices quickly adjust, resulting in little real effects. However, during deflationary shocks, nominal prices adjustments are delayed, causing a delay in the rebound of real prices. In addition, the real price does not fully return to pre-shock levels. According to Noussair et al. (2012), this delay is attributable to money illusion.

2.1.5. Related bias – Forward discount

Due to the nature of money illusion as a cognitive failure of interpretation, we further investigate a bias that is closely associated with investor perception and expectations. In the currency market, forward discount is known as a condition in which the expected price of a currency is under the current spot price. In other words, it is anticipated to be available for a cheaper price in the future. However, academic literature has discovered that the forward discount is biased. Froot and Frankel (1989) investigate whether such biased expectations merely exist for compensating risk in the foreign exchange market. Moreover, they investigate the composition of forward discount, and whether it originates from errors in expectations or encloses an implicit risk premium. Even though prior literature indicates a consensus on the biasedness of the forward discount, there has been disagreement on the initial source, some claiming that the bias implies a risk premium for carrying a currency.

In accordance with prior literature, Froot and Frankel (1989) reject the unbiasedness of the forward discount. Furthermore, as illustrated by Figure 2 below, they find that nearly all biasedness is attributable to expectational errors of future rates instead of a risk premium. The risk premium manages to explain the forward discount only briefly, whereas the connection is otherwise negative. Furthermore, the variance of expectational errors is significantly larger than the variance of the risk premium. The main conclusion from a practical perspective is that investors would perform better if they would decrease the weight of expected depreciation when evaluating investments. Furthermore, as currency values are closely associated with interest rates among other economic factors incorporating inflation, there may be a connection among the forward discount bias and money illusion.

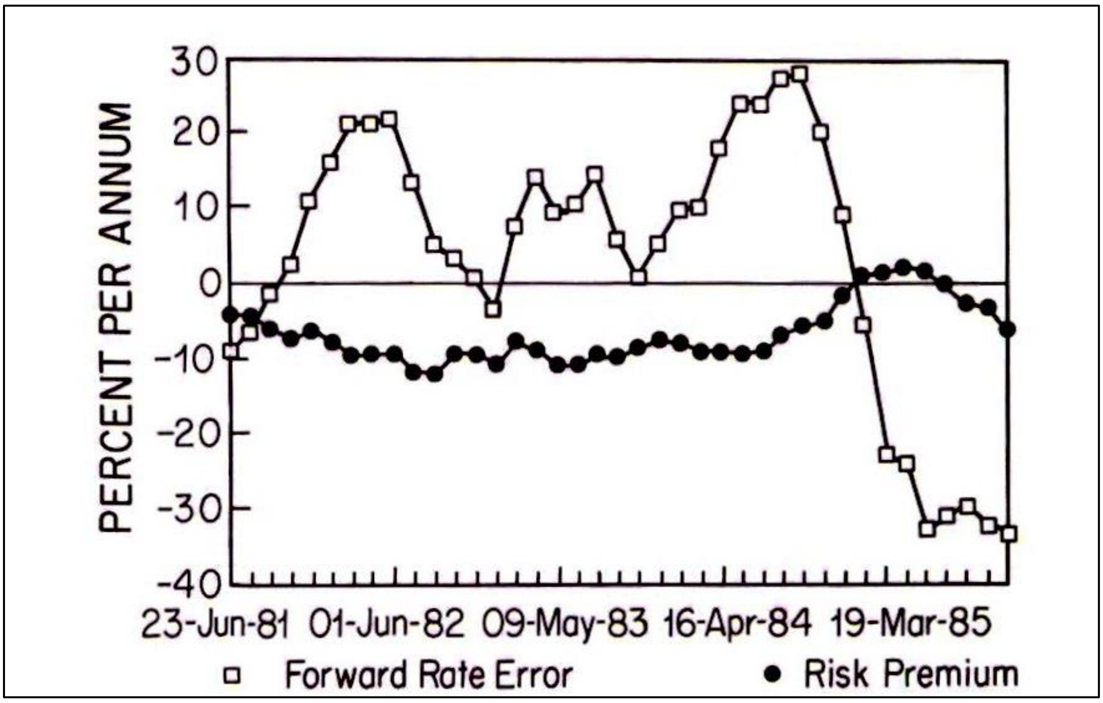

Figure 2. 3-month economist survey of forward rate errors and risk premium (Froot and Frankel, 1989).

2.2. Bonds, interest rates and Inflation

The international debt market is manifold in size when compared to the equity market. Bonds are a typical debt instrument in which the issuer of the bond promises to repay the principal amount at a predetermined time. The issuer may also offer to pay regular interest in addition to the principal amount, referred to as a coupon payment. In exchange, the issuer receives capital which can be utilized in other endeavors. Bonds may be issued by public entities, such as governments and municipalities, or by corporates. In this thesis, we will focus on the characteristics of bonds issued by the U.S. treasury. A notable feature of bonds issued by the U.S. Treasury is that their credit risk is one of the lowest, due to qualities such as the U.S governments' ability to collect taxes, and in more extreme situations, create more money.

2.2.1. Basic valuation

Bonds are valued according to the present value (*PV*) of the future cash flows they provide. These cash flows are the coupon payments, which are paid semiannually in bonds issued by the U.S. government, and the principal, which is paid to holders at maturity. The standard formula for valuating a nominal bond in annual terms is presented in equation 1 below. The price of the bond is equal to the present values of future cash flows (C) including the principal (C_T), which is paid at maturity. Since coupons of U.S. treasury bonds are paid semiannually, the stated coupon must be multiplied by two prior to utilizing equation 1. In addition, if interest rates (i) are quoted semiannually, they must also be adjusted.

$$PV = \sum_{t=1}^{T} \frac{C_1}{(1+i)} + \frac{C_2}{(1+i)^2} + \frac{C_3}{(1+i)^3} + \cdots + \frac{C_T}{(1+i)^T} \qquad (1)$$

If investors are interested in the percentual return the bond offers, they will have to calculate the yield to maturity of the bond. That is, the total return it provides if one were to hold it until maturity. In practice, one must solve for i in equation 1 above. It is correct when the present value of cash flows is equal to the price of the bond. Due to the complexity of such calculation, authors of fixed income theory suggest methods of trial and error (Brealey, Myers & Allen, 2020). The return investors require is referred to as the required yield (Fabozzi, 2021). The required yield may be discovered by comparing a bond to other bonds with matching characteristics, such as maturity and issuer riskiness.

The relationship between bond prices and their yields is inverse (Fabozzi, 2021). Hence, when the required yield of a bond rises, the price of that bond decreases, vice versa. Moreover, this relationship is not linear. As presented in figure 3 below, the relationship is concaved downwards. This characteristic is known as the convexity of bonds (Fabozzi, 2021).

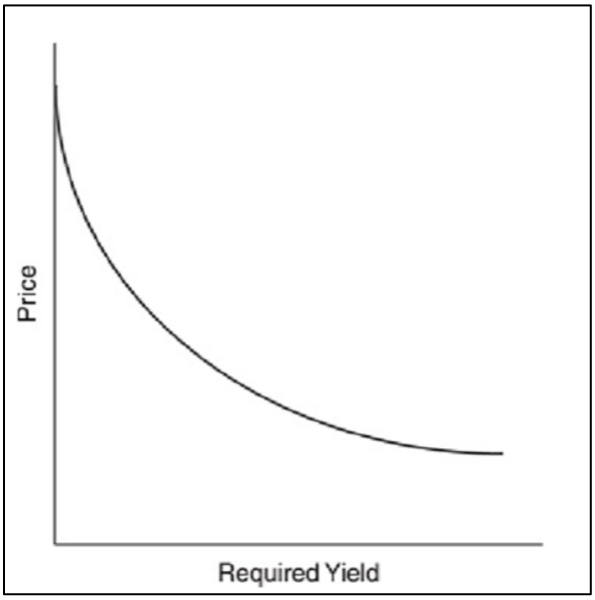

Figure 3. Convexity of bonds (Fabozzi, 2021).

The required yield is ultimately determined by current interest rates, which in the case of U.S Treasury bonds, as mentioned earlier, are quoted by the Federal Reserve, more commonly known as the Fed. Hence, we may conclude that changes in interest rate quotes cause opposite movement in bond prices. Due to the convexity of the relationship between bond prices and yield, the prices of long-term bonds are more sensitive to fluctuations in interest rates (Brealey et al., 2020). Eventually, bond holders desire falling interest rates, as this implies increasing wealth.

Since long-term bonds are more sensitive to changes in interest rates, investors may need a more precise method for comparing this sensitivity. Furthermore, even though bonds have equal maturities, the timing of their cash flows may vary. Comparison may be done by calculating the duration of a bond. Three alternative methods exist for calculating duration. These are the Macaulay duration, modified duration, and effective duration. In this section we present the most common, the Macaulay duration. Its' formula is presented in equation 2 below. It is the weighted average of the times to each cash flow until maturity (Brealey et al., 2020). The present value (*PV*) of each cash flow (C), including the principal, until time *T* is multiplied by the time at which it will be paid and divided by the present value of the entire bond. Hence, the larger the result, the more sensitive the bond is to fluctuations in interest rates.

$$Macaulay\ duration = \frac{1 \times PV(C_1)}{PV} + \frac{2 \times PV(C_2)}{PV} + \frac{3 \times PV(C_3)}{PV} + \cdots + \frac{T \times PV(C_T)}{PV} \quad (2)$$

Moreover, especially a long-term bond may be bought and sold multiple times over during its lifespan. Therefore, one may be interested in the return a bond has provided over the time it was possessed. This calculation is known as holding period return (HPR), presented in equation 3 below. The change in price after the time of holding is added to coupons received and divided by the initial price of the bond.

$$HPR = \frac{C_T + (P_T - P_{T-1})}{P_{T-1}} \quad (3)$$

2.2.2. Term structure of interest rates and inflation

The term structure of interest rates denotes the relationship between short- and long-term interest rates (Brealey et al., 2020). Since short- and long-term interest rates often differ, measuring the term structure may be necessary to facilitate more accurate discounting of future cash flows. Hence, the term structure is measured by calculating present values with the help of spot rates (Brealey et al., 2020). Moreover, the series of spot rates will also imply to which direction the term structure is sloped. If the term structure is upward-sloping, investors believe that short term-interest rates will rise.

For example, finding the total present value of receiving a dollar annually for 3 years is completed by discounting each years' dollar with the prevailing spot rate. The spot rate is represented by the interest rate of the equivalent period. In other words, each years' dollar is discounted with their corresponding 1-, 2- or 3-year interest rate. The total present value is the sum of these calculations. Hence, the total present value represents the price of our hypothetical commitment. Eventually, the price may be utilized to calculate a single discount rate for the whole period (see equation 1), the yield to maturity (Brealey et al., 2020).

The relationship between bond yields of the same credit risk but distinct maturities is traditionally illustrated by the yield curve (Fabozzi, 2021). The initial purpose of the yield curve was to serve as a benchmark for bond valuation. However, it has later been discovered that the traditional model is insufficient, as bonds with equal maturities may grasp different yields (Fabozzi, 2021). In addition, this implies that the formulas introduced earlier may not provide accurate results. This is mainly because short- and long-term interest rates are generally unequal. An illustration of a normal and inverted yield curve is provided below in figure 4. In addition, there exists a possibility of a flat yield curve.

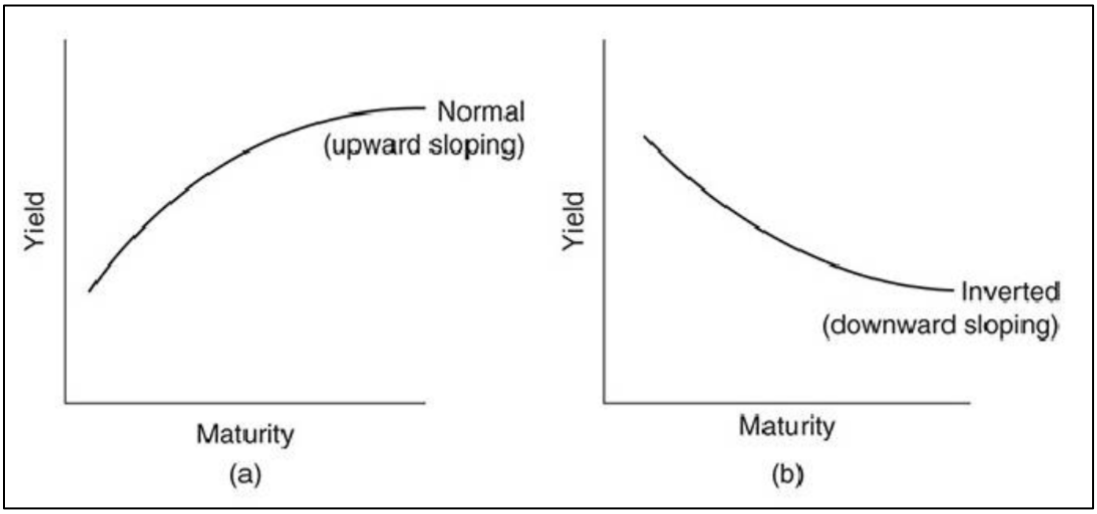

Figure 4. Normal and inverted yield curves (Fabozzi, 2021).

The upward sloping yield curve (a) is referred to as the normal yield curve (Fabozzi, 2021). The main indications of a normal yield curve are that interest rates are expected to rise, and inflation is expected to prevail. If these expectations are realized, the value of bonds decreases. In contrary, if the yield curve is downward sloping, interest rates are expected to decrease, and inflation is not a matter of concern. This event would potentially increase the value of bonds.

Since inflation diminishes purchasing power, expectations of future inflation greatly affect the willingness of investors to purchase bonds. Therefore, bond markets concerned with future inflation commonly face upward-sloping yield curves (Brealey et al., 2020). Interest rates are generally quoted in nominal terms, that is, the presented interest rate is not adjusted for inflation. Consequently, the nominal interest rate can be broken down into the real interest rate, implying the actual increase of purchasing power, and the portion attributable to expected inflation. Moreover, calculating the real rate of return can be done with equation 4 below, in which the nominal return is divided by the prevailing inflation (Brealey et al., 2020).

$$1 + r_{real} = \frac{(1+r_{nominal})}{(1+inflation\ rate)} \tag{4}$$

Unlike the nominal interest rate, the real rate of interest in an economy cannot be solely dictated by governments, treasuries or likewise institutions. The real rate of interest also depends on the supply and demand of capital (Brealey et al., 2020). In other words, the real rate of interest depends on whether economic agents are capable of saving capital, generating supply, and whether there are tangible opportunities for utilizing capital, generating demand (Brealey et al., 2020). Institutions may still indirectly affect short- and medium-term real rates through monetary policies.

However, even in inflationary environments, institutions such as central banks may deliberately keep nominal interest rates at levels which cause the real rate to fall negative (Brealey et al., 2020). There is a possibility that this phenomenon may be perceived in the U.S. bond market and investors are not sufficiently aware of it. Hence, investing in nominal bonds in such conditions implies money illusion. In contrast, nominal interest rates are usually positive, though some market areas such as Europe have experienced negative nominal interest rates for longer periods.

2.2.3. Expectations hypothesis and the Fisher equation

The expectations hypothesis of interest rates is generally regarded as a product of traditional financial theory. According to Brealey et al. (2020), it states that rolling over one short-term bond must have the same return than owning a single long-term bond for the equivalent period. In other words, short and long-term debt are perfect substitutes for one another. Otherwise, investors would prefer either, leading to the weak functioning of markets. In addition, the hypothesis states that expectations of future interest rate development are the only reason for shifts in term structure slopes. As mentioned earlier, if the term structure is upward-sloping, investors believe that short term-interest rates will rise.

However, the expectations hypothesis has been rejected by multiple earlier studies. A thorough examination of the subject is provided by Sarno, Thornton and Valente (2007), who utilize a vector autoregression (VAR) method for testing whether the expectations hypothesis holds in the US bond market. The VAR method was initially proposed by Campbell and Shiller (1987), whereas it was later reconditioned by Bekaert and Hodrick (2001) by adding the Lagrange Multiplier test. These papers provided bivariate comparisons of short- and long-term bond yields, and Sarno et al. (2007) add to them by investigating the relationship between the term structure of interest rates and their underlying macroeconomic fundamentals. In addition, they add to prior literature by simultaneously examining more than two yields and testing the expectations hypothesis on several different yields.

Their results are somewhat twofold, however eventually leaning to the full rejection of the expectations hypothesis. In accordance with prior research, tests with the generic bivariate model provide results which imply that the expectations hypothesis does not hold with bonds of short maturity. That is, maturities of under 2 years. However, this model is not capable of rejecting the hypothesis with longer maturities. Introducing the expansions of Sarno et al. (2007), the VAR accompanied with either multiple yields or macroeconomic factors, the hypothesis can be rejected to maturities of up to 10 years. An additional notable finding is that the hypothesis is extensively rejected when the longer yield has a maturity of 4 years of shorter, and when the relation between inflation, unemployment and the term structure has been considered. This underlines the importance of inflation as a macroeconomic factor when examining the term structure.

Irwing Fisher (1930), also the founding father of money illusion, proposes that changes in expected inflation have absolute effects on the nominal interest rate, and no effect on the real interest rate. More precisely, as presented in equation 5 below, the nominal interest rate is the current real interest rate times expected inflation.

$$1 + r_{nominal} = (1 + r_{real})(1 + i_{expected}) \quad (5)$$

Practitioners have argued that the real interest rate is affected by inflation, therefore implying that Fisher's equation is insufficiently accurate. More generally, long-term forecasts which are based on occurred events may suffer from systematical distortion caused by unforeseen events ultimately affecting the outcome. Moreover, variables may be interrelated. In the case of the Fisher equation, these remarks are examined by Sun and Phillips (2004). As anticipated, they find cointegration among the real interest rate and inflation, indicating that the fisher equation is insufficient for estimating long-term nominal interest rates and that this is mainly caused by shocks. However, it may hold for shorter timeframes.

For an illustrative example of expectational errors when evaluating inflation is also provided by Sun and Phillips (2004). Illustrated in figure 5 below, it may be perceived that the variance of realized inflation (ex poste) is considerably larger than expected inflation (ex ante), implying an error in forecasting. Even though the sample size in the paper of Sun and Phillips (2004) for facilitating this graph is relatively small, one could conclude that decreasing the emphasis of expectations could potentially result in more accurate forecasts, a similar notice than made by Froot and Frankel (1989).

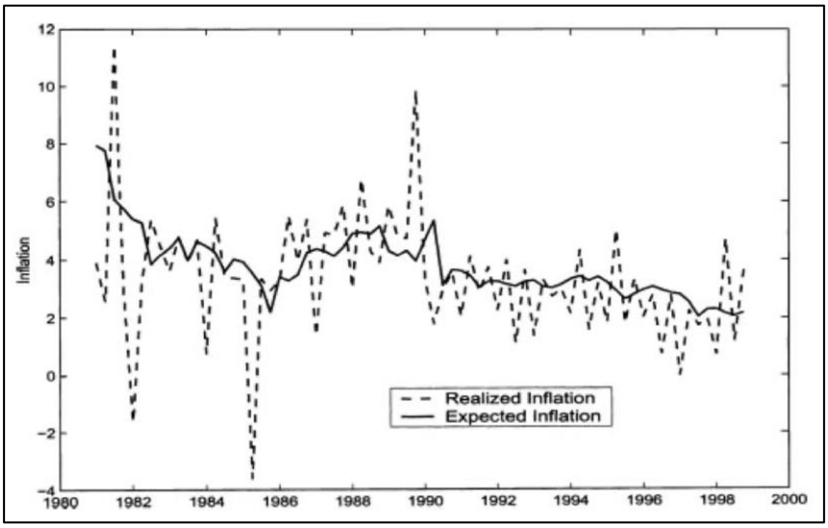

Figure 5. Expected and realized inflation 1980-1999 (Sun and Phillips, 2004).

2.2.4. The Consumer Price Index (CPI)

The main indicator of present inflation in the U.S. is the Consumer Price Index (CPI). It represents the weighted average cost of a basket containing everyday goods and services (Acemoglu, Laibson and List, 2019). The fundamental purpose of the CPI is to measure changes in the cost of living. This is carried out by monitoring and averaging the price changes of the products in the basket and comparing it to previous years. Examples of the included products and services in the basket are gasoline, vehicles, fruits and vegetables, hospital services, education, and airline fares.

The U.S. CPI is released subsequently each month by the Bureau of Labor Statistics. Multiple variations of the CPI exist, containing diverse focusses on which industries and geographic areas are included. The U.S. Treasury utilizes the CPI-U variation for measuring inflation, in which the character U stands for All Urban Customers. Hence, it emphasizes the cost of living in urban areas.

2.3. Inflation protected securities

As presented earlier, the value of nominal, one may also say traditional, bonds vary according to the prevailing nominal interest rate. Rising inflation may deteriorate the real return of such bonds, decreasing the purchasing power of investors. Therefore, inflation protected securities, also known as inflation-indexed and inflation-linked securities, were introduced as an alternative for safe investing in inflationary environments. These securities are generally considered as bond equivalents, although specific features may vary among issuers. Similar instruments are currently offered in over 15 countries, such as the U.S., U.K., Australia, France, and Germany (Fabozzi, 2021). However, this thesis will concentrate on the characteristics of inflation protected bonds issued in the U.S.

2.3.1. Treasury Inflation Protected Securities (TIPS)

Treasury Inflation Protected Securities (TIPS) were introduced by the U.S. Treasury to offer protection from inflation. The nominal yield of TIPS is adjusted according to the changes in the CPI-U. However, the adjustment does not occur immediately when the most recent CPI-U is announced, as TIPS have a 3-month lag in indexation. Yet they protect the purchasing power of investors by paying coupons, which are paid twice a year, as well as the principal in nominal amounts that correspond the development of the CPI (Fabozzi, 2021). Therefore, TIPS are best known for the hedge they offer against inflation. From a practical perspective, they offer investors an opportunity to speculate on changes in real interest rates and inflation (Fabozzi, 2021). In addition, they have a low correlation with other financial assets and moderate volatility.

More accurately, the coupon payments are calculated based on the indexed principal, which is adjusted according to the development of the CPI-U. For example, an investor holds $1000 worth of TIPS, and the coupon is 10% per annum. If the CPI-U does not increase, the investor would receive $100 worth of coupon payments for that year. However, if the CPI-U increases by 5%, the principal of $1000 will adjust upwards to $1050. Eventually, as the coupon payment is calculated from the principal, the coupon will also rise to $105.

Another feature of TIPS is that whilst the principal and coupon payments are adjusted in accordance with the development of the CPI-U, the real return of TIPS is expected to remain fixed. This means that the real return an investor captures at the end of the holding period is predetermined, regardless of the nominal payout (Fabozzi, 2021). Due to these features, the structure of TIPS cash flows classifies them to be Capital Indexed Bonds (CIBs), which are the most common inflation protected security (Deacon, Derry & Mirfendereski, 2004). Another common mechanism for determining cash flows would be to link cash flows to changes in interest rates. These are known as Interest Indexed Bonds (IIBs).

2.3.2. Distinct characteristics

Treasury inflation protected securities have some additional distinct characteristics to consider when comparing them to nominal bonds. When performing this comparison, investors may be interested to know which level of inflation evens TIPS holders with holders of nominal bonds. This level of inflation is known as the break-even inflation rate (Fabozzi, 2021). Break-even inflation may be calculated with equation 6 below. However, this equation does not account for the portion of nominal yield attributable to inflation risk, known as the inflation risk premium (Fabozzi, 2021). Furthermore, the inflation risk premium should be reduced from the result of the break-even inflation equation if investors seek risk-adjusted results.

$$Break - even\ inflation = \frac{(1+nominal\ yield)}{(1+TIPS\ yield)} - 1 \tag{6}$$

Break-even inflation is also used in the TIPS market to measure inflation expectations (Andonov et al., 2010; D'Amico et al., 2018). Recalling from the earlier chapter, TIPS mechanics should ensure that the real return for investors remains unchanged during its lifetime. Hence, if TIPS market yields successfully incorporate their underlying real yields, break-even inflation should then provide the missing components of expected inflation and inflation risk premium, eventually forming an equivalent of the nominal yield (D'Amico et al., 2018).

In chapter 2.2.1 we reviewed duration as a method for evaluating the sensitivity of nominal bonds to changes in nominal interest rates. It was also mentioned that there are three of different methods available for calculating duration. In terms of TIPS, there are two alternatives which are closely associated with the uniqueness of inflation protected securities. That is, the real yield being fixed whilst the nominal yield fluctuates according to the development of inflation. These alternatives are calculating the real duration or the effective duration of TIPS.

Real duration expresses the sensitivity of TIPS market value to changes in real interest rates (Fabozzi, 2021). The equation itself is the same as the equation utilized for calculating the duration of nominal bonds, whereas results are in real terms (Fabozzi, 2021). One could argue that changes in real interest rates are more important to TIPS holders since they would imply either increases or decreases in realized purchasing power. However, calculating the sensitivity of TIPS market value towards changes in nominal interest rates is reasonable, as real, and nominal interest rates do not experience perfect correlation (Fabozzi, 2021).

Effective duration measures the sensitivity of TIPS market value towards changes in nominal interest rates. In practice, this is deemed especially important if TIPS are included into a bond portfolio containing nominal bonds (Fabozzi, 2021). The method for calculating was initially perceived challenging, due to the significant proportion of inference incorporated among variables (Fabozzi, 2021). However, this issue was resolved later. Currently, the effective duration is estimated by practitioners with a linear regression model.

2.4. Prior research on TIPS

This thesis may be the first to investigate the role of money illusion in the market for inflation-linked securities even though money illusion has been mentioned as a plausible deterrent for investing in them (Deacon et al., 2004). Moreover, D'Amico et al. (2018) find that TIPS yields continuously exceed risk-free real yields, leading to a potential undervaluation, a common consequence of money illusion found in other asset classes. In addition, the research conducted on TIPS as investment instruments is relatively scarce when compared to other assets and instruments. Due to the nature of money illusion being an inflation-induced error in investor evaluation, a few notable topics are reviewed which examine the efficiency of the TIPS market in inflationary environments. Moreover, the following provide key insights for the empirical part of this thesis.

2.4.1. Empirical features

Roll's (2004) findings are widely cited in papers which examine the empirical behavior of TIPS and inflation. The ultimate purpose of the research of Roll (2004) is to estimate expected inflation by comparing the real yield curves of TIPS with nominal yield curves. Due to the mechanics of TIPS, there should be no explainable relationship between TIPS yields and nominal yields as TIPS yields should only react to changes in real yields and inflation. Nevertheless, Roll (2004) shows that regardless of whether they should or not, TIPS yields react to changes in the nominal yield curve. However, effective durations are higher for nominal bonds than for TIPS, indicating that they are not equally affected by variations in nominal factors.

Roll (2004) also finds that short-term TIPS provide better returns when the nominal term structure tilts upwards. In chapter 2.2.2 it was mentioned that if the term structure is upward-sloping, investors believe that short-term interest rates will rise. Moreover, inflation is expected to prevail, and compensation for inflation increases in nominal yields. However, this may also increase the demand for inflation protection, which TIPS represent. Later studies have brought up the possibility that demand related liquidity premiums also affect TIPS returns (D'Amico et al., 2018).

When deriving inflation expectations from the TIPS-implied real yield curve and nominal yield curve, Roll (2004) finds that during the period reviewed, expected inflation is considerably low. Consequently, TIPS real yields decrease as investors question the need for inflation protection. Additional remarks provided by Roll (2004) are that TIPS nominal return volatility is less than the volatility of nominal bonds of equivalent maturities and that TIPS are highly correlated with one another. Hence, the prior would indicate that investing in TIPS is less risky than investing in nominal bonds.

2.4.2. TIPS prices adjusting to inflation information

The paper by Chu, Pittman and Yu (2011) examines TIPS price movement in a form of an event study. More accurately, they investigate how TIPS prices respond to announcements in the CPI. First, Chu et al. (2011) note that TIPS prices behave differently than nominal bond prices. Nominal bond prices reflect expectations of both inflation and real interest rates, whereas TIPS prices also reflect expected real rates, TIPS prices should be based on realized inflation. Nevertheless, expected inflation, denoted by break-even inflation, remains a key measure when forecasting TIPS prices. Moreover, Chu et al. (2011) present that investors may profit by sufficiently forecasting future inflation prior to public announcement. Assuming the forecast is accurate, investors could then buy or sell in accordance.

The experiment of Chu et al. (2011) divides the availability of information into 5 discrete periods around the time of CPI announcement, separately evaluating the effect each has on TIPS pricing. The first period begins 44 business days prior to announcement, which occurs in period 4. They anticipate that TIPS prices will adjust during the first two periods. The first period incorporates information provided by market forecasters and the second period includes the publicly available information of price changes. Therefore, prices should not experience significant motion in period 3, prior to announcement occurring in period 4. If prices shift consequent to announcement, in period 5, this will imply a significant inefficiency in the TIPS market.

The results of Chu et al. (2011) indicate that the market can relatively well anticipate future CPI announcements as they have no significant effect on TIPS prices. A plausible explanation for this is the 3-month lag in indexation since the CPI announcement does not alter cash flows until 3 months later. When the indexation eventually occurs, the corresponding CPI announcement is old information. This also emphasizes that the market focusses on expected inflation as a measure of future inflation. Hence, their paper states that break-even inflation is a fair measure of markets’ expectations and capable of capturing short-term surprises. Another note to be made is that their finding is in accordance with the traditional view which suggests that the best proxy for future inflation is past inflation. However, their study period ends before the financial crisis of 2008, therefore implying that their results may not hold in uncertain conditions.

2.4.3. TIPS and inflation expectations

In the study by Andonov, Bardong and Lehnert (2010), the key measure of inflation expectations associated with TIPS, breakeven inflation, is compared to inflation forecasts over various periods. Their objective is to find opportunities, or inefficiencies in the TIPS market. This is motivated by the findings of, for example, Carlstrom and Fuerst (2004) who find that inflation forecasts implied by TIPS prices constantly underestimate expected inflation. This suggests a market inefficiency, providing a similar remark than stated earlier by Sun and Phillips (2004). Investors that forecast inflation more precisely could potentially capture excess returns. Moreover, the methodology of Andonov et al. (2010) focuses more on the quality of inflation forecasts, whereas Chu et al. (2011) concentrated on how the price of TIPS reacts to inflation announcements. Furthermore, Andonov et al. (2010) apply various trading strategies to compare the performance of their non-market implied inflation forecasts, which were publicly available during the time of their study. In the strategy of plain holding, if these forecasts presented higher inflation than the market expects, TIPS were to be bought. Otherwise, TIPS would be sold short.

In addition to the basic buy & hold strategy, Andonov et al. (2010) utilize a trading strategy which is closely associated with a distinct TIPS characteristic. Recalling that the holder of a TIPS may “break even” with a holder of a nominal bond at a certain level of inflation (Fabozzi, 2021), their strategy may capture shifts in the markets’ expected inflation. However, implementing this strategy omits the effect of changes in other factors, such as changes in real interest rates. Nevertheless, the bond portfolio for the breakeven strategy consists of a TIPS and a nominal bond of equivalent maturity. Alike with the holding strategy, TIPS were bought long if forecasted inflation surpassed the markets' expected inflation, whereas the nominal bond was sold short.

The results of Andonov et al. (2010) provide indications of potential inefficiencies in the TIPS market which can be exploited by informed investors. This is possible by utilizing alternative inflation forecasts accompanied by their breakeven strategy, whereas their buy & hold strategy did not yield notable returns. Nonetheless, their primary observation is that excess returns are available even though the information allowing for such practices is publicly released. In addition, the performance of the breakeven strategy appears to enhance during conditions of high macroeconomic uncertainty, including uncertain inflation. According to Andonov et al. (2010) this suggests that, in uncertain conditions, TIPS investors' expectations of inflation are insufficiently accurate.

2.4.4. Assigning a duration to TIPS

One important justification of paying for active portfolio management is that it should regularly beat the reference index to which investment performance is compared to. When this portfolio contains bonds, recalling our prior discussion on measuring bond interest rate sensitivity, solving the duration of bonds is critical for fulfilling this presumption. Regarding the question of which type of duration should be utilized when including TIPS into a bond portfolio, Rudolph-Shabinsky and Trainer (1999) provide early implications. They note that calculating the modified (real) duration is rather simple, however it only measures changes in the real yield. Therefore, if TIPS were to be included into a bond portfolio which otherwise contains only nominal bonds, it is critical to estimate the effective duration of these TIPS. Eventually, calculating the effective duration has become common industry practice (Rudolph-Shabinsky and Trainer (1999).

Yet their study attempts to show that the active managers would be better off using something else. Nominal interest rates change in accordance to changes in real yields and inflation expectations. Consequently, Rudolph-Shabinsky and Trainer (1999) state that their combined change is typically greater than changes in real yields alone. However, they argue that TIPS yields reflect only changes in real yields and that real yields are less volatile than nominal yields. Yet the prior argument was later shown to be false by Roll (2004). Nevertheless, according to Rudolph-Shabinsky and Trainer (1999), the price change of TIPS is a function of duration and change in real yields, as presented in equation 7 below. Hence, inflation is left out of the equation.

$$\Delta Price_{TIPS} = (-Duration_{TIPS})(\Delta Real\ yield) \tag{7}$$

Introducing TIPS with a 10% stake into a portfolio of nominal bonds, the results of Rudolph-Shabinsky and Trainer (1999) depend on the event off which the active manager plans to cash in. If the manager is seeking to profit from decreasing real yields, switching cash equivalents into TIPS is deemed beneficial. On the other hand, according to the model of Rudolph-Shabinsky and Trainer (1999), if the portfolio manager is seeking to profit from increasing inflation, she should switch TIPS for nominal bonds of equal modified duration. This suggestion is in contrary with the initial reasoning behind why TIPS as a security was constructed in the first place.

3. Hypotheses, data, and methodology

This chapter will present the hypotheses, data and methodology utilized in this thesis. First, the hypotheses will be formed in detail, justified by the findings of previous studies. Second, it will explain the collection of the data sample and provide descriptive statistics, which will also be examined in detail. Last, it will present the formation of variables and methodology.

3.1. Hypotheses formation

According to D'Amico et al. (2018), if TIPS market yields successfully incorporate their underlying real yields, break-even inflation should then provide the missing components of expected inflation and inflation risk premium, together forming an equivalent of the nominal yield. Moreover, break-even inflation is generally utilized for measuring inflation expectations in the TIPS market (Andonov et al., 2010; D'Amico et al., 2018). Hence, this means that break-even inflation alone should parallel realized inflation if expectations are accurate. However, recall the findings of Sun and Phillip (2004) and Froot and Frankel (1989). Those are, expectations continuously deviating from realized and the significance of errors in expectations. Therefore, the first hypothesis to be tested in this thesis is whether inflation expectations are realized in the TIPS market. Based on the findings of prior literature, it is expected that they are not.

$$H_1: Inflation\ expectations\ fail\ to\ realize\ in\ the\ TIPS\ market$$

Moreover, recall the findings of Carlstrom and Fuerst (2004) and D'Amico et al. (2018), which indicate that inflation forecasts implied by TIPS prices constantly underestimate expected inflation and that TIPS yields continuously exceed risk-free real yields. If money illusion prevails in the TIPS market, as suggested by research on stocks and real bond prices (Cohen et al., 2004; Duarte and Saporito, 2019), the TIPS yield utilized as the denominator could be greater than justified if it incorporates factors that are attributable to money illusion, forming our second hypothesis. Hence, the prior implies that if break-even inflation is lower than realized inflation, then TIPS are undervalued in periods of higher inflation, which is a mutual consequence of money illusion among other assets classes.

$$H_2\colon TIPS\ yields\ incorporate\ factors\ attributable\ to\ money\ illusion$$

A key feature of the strategy of Andonov et al. (2010) is that investors with more accurate inflation forecasts, accompanied with break-even inflation representing the markets' expectations of inflation, may capture excess returns. When considering the mechanics and initial purpose of TIPS, the usefulness of at least the former ability is easily comprehensible. However, there exists a possibility that the success of the break-even strategy is beneficial due to traits of money illusion, since break-even inflation is derived from both nominal and TIPS yields, and that investors may underestimate inflation, at least during periods of less uncertainty. For example, in the Thaler et al. (1997) experiment, investment allocations faced considerable shifts when participants were reminded of inflation. Consequently, even a credible doubt of whether hypotheses one and two hold could reinforce this presumption.

Moreover, Roll (2004) finds that even though TIPS are regarded as real assets and should theoretically be solely affected by changes in the real term structure, they respond to changes in the nominal term structure. This phenomenon indicates attributes of money illusion. Furthermore, expected inflation and the inflation risk premium are significant propellants of nominal yield volatility. According to both Barr and Campbell (1997) and Ang et al. (2008), up to 80% of variation in nominal yields is caused by changes in inflation related factors.

In addition, both Roll (2004) and Ang et al. (2008) find that the real yield curve is nearly flat, with only minor curvature, and that the nominal yield curve is steeper. This points out the necessity of focusing an alternative forward-looking effort on nominal interest rates as their changes are greater, even though this is in contrary with prior TIPS theory, as presented by Rudolph-Shabinsky and Trainer (1999). Nevertheless, the more recent findings together suggest that TIPS yields may be solely explainable by market-implied inflation expectations, represented by break-even inflation, and if the market is prone to money illusion, the explanatory power may be further enhanced by inflation expectations incorporated in nominal interest rates. This forms hypothesis 3.

$$H_3: Inflation\ expectations\ are\ capable\ of\ explaining\ inflation\ protected\ yields$$

The sum of confirming these hypotheses is that inflation expectations continuously fail to realize, and that money illusion prevails in TIPS yields, yet TIPS yields still develop according to inflation expectations even though they are biased. Hence, providing unbiased investors an opportunity to exploit. Hence, it is likely that the uncertainty associated with the Covid-19 crisis will appear in the sample and results. Even though a related hypothesis is not formed, this period will be discussed separately.

3.2. Data

The empirical experimentation performed in this thesis requires the historical data of three nominal market yields, a TIPS yield, and U.S. inflation. In total, 5 datasets are required, with a monthly periodization. Monthly examination was chosen as the CPI-U is announced once a month. In addition, this mitigates the effects of daily volatility, which is indifferent in terms of gross results.

The inflation protected TIPS yield will be represented by the historical yield to maturity and price of 5-year TIPS issue CUSIP 912828Q60, which matured in April 2021. Given the current market environment, a short-term TIPS was chosen due to the findings of Roll (2004), indicating that they provide better returns when the nominal term structure tilts upwards. The data is fetched from the Bloomberg portal of the University of Vaasa.

However, the last 3 quotes are excluded, as the last 3 months of TIPS lifetime are no longer indexed for inflation. Therefore, the total number of observations for each separate dataset is 57.

The nominal yields for the equivalent period will be represented by the 1-, 2- and 5-year nominal interest rates on U.S Treasury Securities with constant maturity. They are retrieved from the database of the Federal Reserve Economic Data (FRED). Hence, they represent the return for holding a traditional nominal bond, excluding coupon payments.

The last required dataset is the Consumer Price Index for All Urban Consumers (CPI-U) announced monthly by the Bureau of Labor Statistics, for the equivalent period. As mentioned earlier, the CPI-U is the measurement for U.S. inflation utilized by the U.S. Treasury. The additional U denotes the emphasizing of urban areas.

Table 2. Descriptive statistics.

	5yr TIPS yield	5yr market yield	2yr market yield	1yr market yield	CPI-U
Mean	0,27	1,72	1,45	1,37	1,81
Median	0,26	1,82	1,39	1,40	1,86
Std	0,64	0,81	0,84	0,83	0,64
Kurtosis	0,52	-0,77	-1,06	-1,34	-0,02
Skewness	0,06	-0,36	-0,05	0,06	-0,50
Min	-1,29	0,27	0,13	0,12	0,12
Max	2,00	3,00	2,86	2,70	2,95
N	57	57	57	57	57

The first observation to be made from the descriptive statistics in table 2 above is that the mean and median of the CPI-U are larger than those of the nominal market yields. As the real rate of return is calculated by reducing inflation from nominal returns, this implies that, on average, the real return captured by investors is negative. Moreover, this finding refers to the situation mentioned in chapter 2.2.2. The institution responsible for quoting nominal interest rates, in this case the U.S. Treasury, retains nominal interest rates at levels which cause the real rate of return to fall negative. Therefore, investing in securities with equivalent nominal yields to those presented in table 2 would indicate illusioned decisioning. Recalling the results of Thaler et al. (1997), it is likely that the prior decisioning occurs in the real market.

From table 2 above it may also be observed that the standard deviation of all nominal market yields is greater than the TIPS yield. This is in accordance with the findings of Roll (2004), that nominal bond volatility is greater than the volatility of TIP bonds. In addition, TIPS standard deviation is remarkably close to the standand deviation of the CPI. This may indicate that they develop in tandem to one another, which implies that the inflation protection is relatively sufficient.

3.3. Methodology

As presented earlier, break-even inflation has been utilized in multiple previous TIPS studies as a measure of the markets' inflation expectations and is also required for implementing certain trading strategies. Yet Andonov et al. (2010) suggests that break-even inflation does not consider some distinct characteristics of inflation, such as the cyclicity of inflation. However, later studies have shown that the cyclicity of inflation does not play a significant role in TIPS pricing (D'Amico et al., 2018). Nevertheless, when considering the usefulness of break-even inflation, Andonov et al. (2010) admits that whilst it has its limitations, it is an applicable measure of future inflation expectations. Hence, break-even inflation is still commonly utilized for measuring the inflation expectations of the TIPS market (D'Amico et al., 2018).

Moreover, D'Amico et al. (2018) state that break-even inflation should represent expected inflation and the inflation risk premium if TIPS market yields sufficiently incorporate their underlying real yields. Therefore, break-even inflation is simultaneously capable of offering a reasonable measurement of the correctness of TIPS market valuation. More precisely, it measures the consistency of the TIPS yield.

The formula for finding break-even inflation, as presented by Fabozzi (2021), is identical to the Fisher equation (equation 5) if one were to attempt to derive inflation by rotating the Fisher equation. Thus, for initial reasoning and testing hypotheses 1 and 2, the experiment will utilize the break-even inflation equation. However, the results will not be risk-adjusted, as the inflation risk premium will not be deducted from the result.

$$BEI = \frac{(1+US_{5yr})}{(1+TIPS_{5yr})} - 1 \quad (9)$$

where
BEI = break-even inflation
US_{5yr} = U.S. 5-year market yield
$TIPS_{5yr}$ = yield to maturity of U.S. 5-year TIPS

After inserting the variables and forming equation 9 above, the historical break-even inflation, or market yield-implied level of inflation, will be derived. The monthly break-even inflation for the whole sample will then be illustrated alongside realized inflation implied by the CPI-U and the TIPS yield for the equivalent period, fixed for the 3-month lag in inflation indexation.

Subsequently, the Pearson correlation coefficient, equation 10 below, between break-even inflation and TIPS yield as well as between realized inflation and TIPS yield and between the market yield and TIPS yield will be presented and evaluated. Due to the Covid-19 outbreak, the correlation coefficient will be presented separately for both the preceding period, denoted as the pre-shock phase, from issue in April 2016 to December 2019, and the whole sample, beginning from April 2016 and ending in December 2020.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{10}$$

Later, if break-even inflation behaves as anticipated, it will be utilized to produce an estimation of TIPS yield development. Hence, hypothesis 3 will be tested with the OLS regression model (11) below. The key feature of the model presented below is that, in contrary to earlier studies, the model omits separate inflation variables. In other words, it contains only the inflation expectations and inflation risk premiums which are incorporated in break-even inflation and nominal interest rates. However, as it is likely that the uncertainty associated with the Covid-19 outbreak has caused turmoil in the data during the year of 2020, it will be excluded from the timeframe of this experiment. Therefore, it will only represent the period of less uncertainty. Consequently, this will reduce the sample size to 45 observations.

$$TIPSY_{t+1} = B_0 + B_1(-BEI) + B_2US_{1yr} + B_3US_{2yr} + \in \tag{11}$$

where

$TIPSY_{t+1}$ = TIPS yield to maturity of subsequent month

$(-BEI)$ = negative break-even inflation

US_{1yr} = U.S. 1-year market yield

US_{2yr} = U.S. 2-year market yield

$\in$ = error term

The TIPS yield as the dependent variable is of the subsequent month to facilitate a predictive angle of TIPS yield development. Moreover, due to the convexity of bonds, break-even inflation has been reversed to facilitate the investigation of whether TIPS yields develop in accordance with expectations, whereas the additional market yield factors attempt to further on explain the development of TIPS yields. Even though this model is in contrary to earlier TIPS theory, presented by Rudolph-Shabinsky and Trainer

(1999), it is justified by Roll (2004) who find that TIPS yields react to changes in the nominal term structure.

Last, if the regression results are according to the prior assumptions and TIPS yields develop according to inflation expectations, represented by break-even inflation, it will then be tested how break-even inflation paired with an alternative forecast of inflation expectations would have performed as an investment strategy during the whole 57-month period, the indexed lifetime of the 5-year TIPS. This is primarily motivated by Andonov et al. (2010), who managed to capture excess returns by using a non-market implied inflation forecast alongside break-even inflation. Hence, if the markets' expectations are illusioned, it is plausible that this strategy can exploit them.

The alternative forecast of inflation expectations for the period is provided by the Federal Reserve Bank of Cleveland, and it is publicly available. More precisely, it is the 1-year expected inflation which is based on both market-implied and survey-based methods. To facilitate short selling, a nominal bond with similar specifications is required. Therefore, the historical prices of a nominal bond are represented by a 5-year U.S. Treasury note, which matured in March 2021. The note data is also retrieved from the Bloomberg portal of the University of Vaasa.

If the alternative 1-year expected inflation in the beginning of the 3-month holding period is lower than break-even inflation, then the nominal U.S. Treasury note would have been bought and the TIPS sold short. On the other hand, if the alternative expected inflation is higher than break-even inflation, then the TIPS would have been bought and the nominal note sold short. Excluding coupons and assuming there are no trading costs, after each 3-month holding period, the return will be calculated with equation 12 and presented.

$$HPR = \frac{(P_T - P_{T-1})}{P_{T-1}} \quad (12)$$

4. Results

For initial remarks, the historical development of the yield of 5-year TIPS CUSIP 912828Q60 from issuance in April 2016 to the last indexed month, December 2020, is illustrated in figure 6 below. It may be observed that during the whole period, the TIPS yield has paralleled realized inflation and nominal market yields. The prior is not surprising, as this implies that the inflation indexing of TIPS operates as intended. However, the difference between inflation and the TIPS yield is not constant, implying that market decisioning influences the TIPS yield to some extent. Moreover, all factors faced significant adverse movement during the spring of 2020. This is likely caused by the uncertainty associated with the outbreak of the Covid-19 virus. Later, this period will be referred to as a shock period in the market, beginning from January 2020 and ending in December 2020.

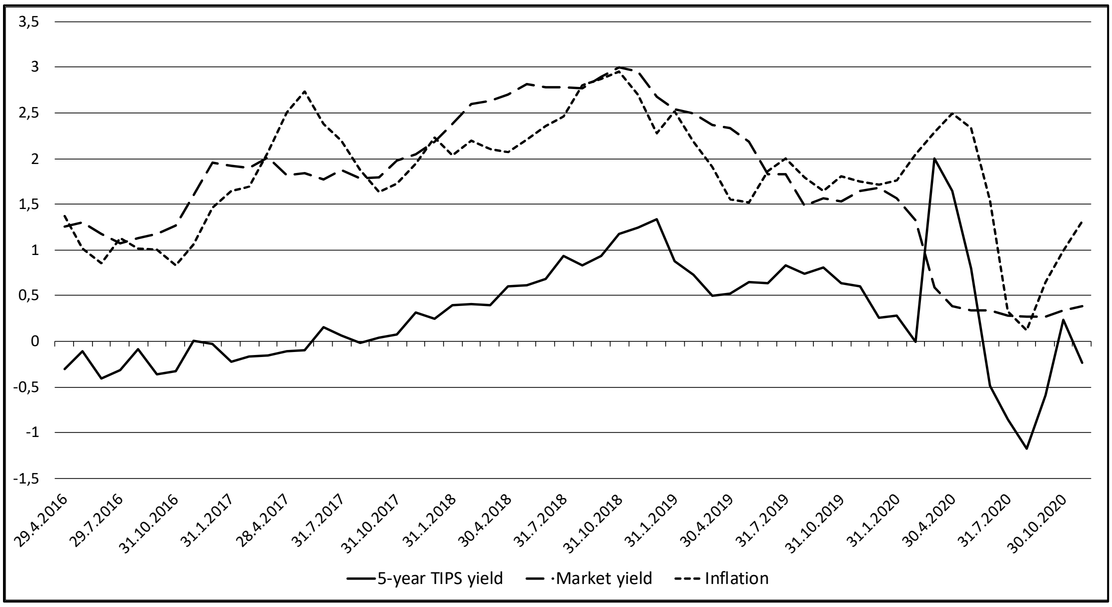

Figure 6. Developments of 5-year TIPS yield, 5-year market yield and inflation from April 2016 to December 2020.

4.1. Hypotheses 1 and 2

The monthly break-even inflation, or derived inflation, is presented alongside realized inflation and TIPS yield in figure 7 below. As mentioned earlier, break-even inflation is used in the TIPS market to measure inflation expectations (Andonov et al., 2010; D’Amico et al., 2018). Therefore, it can also be interpreted from figure 7 that expected inflation has deviated from realized inflation for nearly the whole sample period, with the average deviation being -0,6%. In addition, it is notable that this break-even inflation is not risk-adjusted, which could potentially increase the difference even more. That is, if the inflation risk premium incorporated in nominal yields were reduced from the result of equation 9.

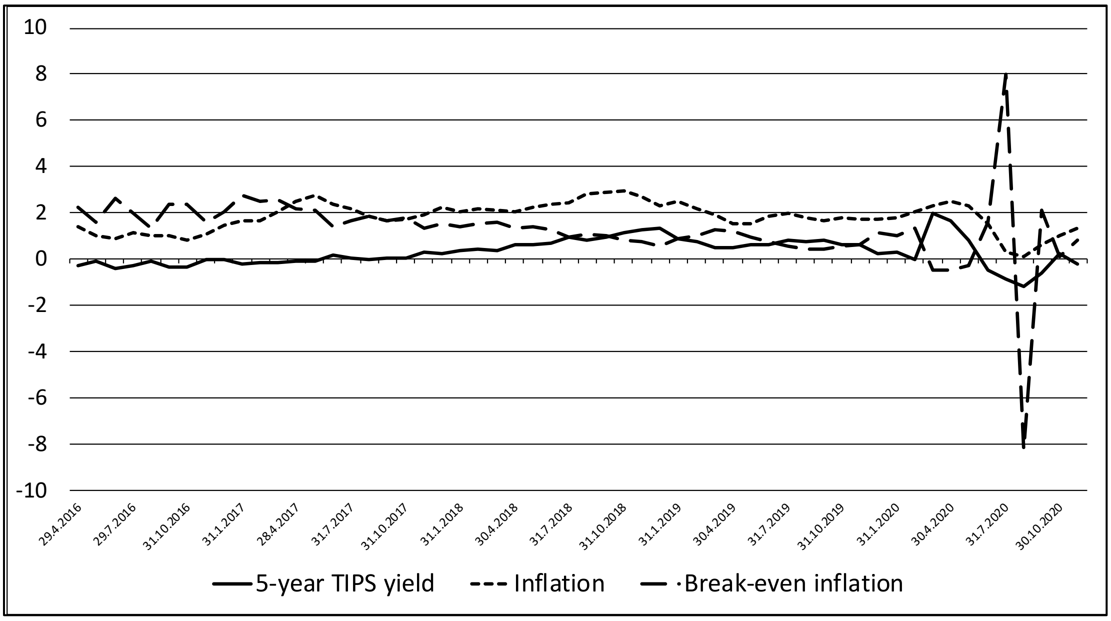

Figure 7. Developments of 5-year TIPS yield, inflation and break-even inflation from April 2016 to December 2020.

This finding is consistent with the evidence of Sun and Phillip (2004), showing that expected inflation systematically deviates from realized inflation. Hence, deviation running constantly for nearly the whole sample period implies that investors continuously fail to correct their forecasts. Moreover, expected inflation undermines realized inflation for a significant period. Therefore, hypothesis 1 is confirmed.

The viable explanation for why inflation forecasts derived from TIPS prices underestimate expected inflation, as shown by Carlstrom and Fuerst (2004), is that money illusion prevails in the TIPS market. That is, TIPS are undervalued in periods of higher inflation. As mentioned before, D'Amico et al. (2018) state that if TIPS market yields successfully incorporate their underlying real yields, break-even inflation should then provide the missing components of expected inflation and the inflation risk premium. Moreover, they also find that TIPS yields continuously exceed risk-free real yields.

Since the results indicate that break-even inflation undermines realized inflation for a significant part of the sample period, even without risk adjustment, it is plausible that the TIPS yield contains attributes of money illusion. In other words, the TIPS yield is higher than what both prevailing and expected inflation would suggest, leading to a potential inconsistency in present value. The phenomenon is best visible in figure 7 during January 2019. Consequently, due to bond convexity the TIPS price is lower than what expected inflation would imply, explaining the results of Carlstrom and Fuerst (2004).

Moreover, the plausible undervaluation of TIPS in periods of higher inflation is in accordance with the Duarte and Saporito (2019), who find that the money illusion perceivable in stock prices also exists in real bond prices. As the mechanics of TIPS should constantly ensure investors a fixed real rate of return, their price should also be considered real. Unfortunately, as mentioned earlier, this also implies that they are also prone to money illusion. Yet the results so far indicate that TIPS yields are affected by decision making that is not solely based on real terms. This meets the definition of money illusion, as set by Patinkin (1965). Therefore, hypothesis 2 is confirmed.

Whereas money illusion may prevail during the whole period in which inflation is misinterpreted, the shock period provides some additional indications. After the initial shock during the spring of 2020, expected inflation implied by break-even inflation faced extreme movement. First, there was a notable increase which was followed by a significant decrease. This shift temporarily breaks the long trend of lower-than-realized expectations. Hence, investors were reminded of inflation, and any plausible money illusion was momentarily cured. During these times, the U.S. government underwent discussions of novel fiscal policies to reduce the economic effects caused by the Covid-19 virus. It is arguable that this caused significant shifts in inflation expectations, possibly propelled by the extensive news coverage around the topic.

An additional finding is that the shock period is the only period in which break-even inflation falls negative. This phenomenon also appeared in the research of Andonov et al. (2010) during the financial crisis of 2008. They suggest that this implies investors expecting deflation. During the financial crisis, it was uncertain how the economy will eventually recover, which caused delays in investments. It is likely that the Covid-19 outbreak caused similar tensions, and investors had doubts about future growth prospects.

On the other hand, it may be observed that after a swift increase, the TIPS yield also falls negative during the shock period. This implies a considerable increase in TIPS prices. As this occurs simultaneously with the significant increase in break-even inflation, it may indicate that investors rush to the TIPS market to protect their portfolios which may eventually lead to overbidding. Recalling the results of the Thaler et al. (1997) experiment, when participants were informed of inflation, they significantly shifted their allocations towards stocks. As TIPS offer portfolio inflation protection, they may enjoy an even higher “safe haven” reputation in uncertain conditions when compared to stocks. However, this phenomenon may also be explained by demand-related liquidity premiums, as TIPS are not as liquid than traditional nominal bonds (D’Amico et al., 2018). Nevertheless, market participants may experience a sense of clarity, leading to soaring TIPS prices. Either way, investor attitudes and preferences have an impact.

Table 3. Correlation of 5-year TIPS yield among variables.

	Market yield	Inflation	Break-even inflation
Pre-shock	0.73	0.65	-0.88
Whole period	0.44	0.72	-0.21

Table 3 above presents the correlations between the yield of the 5-year TIPS, market yield, inflation, and break-even inflation. The pre-shock period was determined as April 2016 up to December 2019. The whole period includes the last 12 months beginning from April 2016 and ending in December 2020. From table 3 we may observe that during the pre-shock period, the strongest correlation is between TIPS yield and break-even inflation. This can be interpreted that during times of less uncertainty, TIPS yield development has been strongly in contrary with inflation expectations. On the other hand, due to the convexity of bonds the strong negative correlation between break-even inflation and TIPS yields would imply that there is a strong positive correlation between break-even inflation and TIPS prices during periods of less uncertainty.

In addition, TIPS yield correlation with nominal market yields has also been stronger than with inflation during the pre-shock period, a further indication of market irrationality. However, when the market is reminded of inflation, adding the shock period, the correlation between TIPS yield and inflation increases to the highest, whereas correlation with other variables decreases significantly. This is a further implication that uncertainty of future inflation enhances the functioning of the TIPS market.

4.2. Hypothesis 3

The results of the regression analysis are presented in table 4 below. The high R2 indicates that the explanatory variables manage considerably well in explaining the development of the TIPS yield during the period of less uncertainty. All three independent variables have a positive relation with the TIPS yield of the subsequent month. However, only the negative break-even inflation is statistically significant, at the 5% level.

Table 4. Results of regression analysis. (* = 5% significance level)

Regression Statistics			
Multiple R	0,94		
R Square	0,88		
Adjusted R Square	0,87		
Standard Error	0,17		
Observations	45		
	Coefficients	**Standard Error**	**t-Stat**
Intercept	-0,189	0,165	-1,141
-BEI	0,196	0,074	2,632*
1-year	0,179	0,258	0,691
2-year	0,311	0,243	1,280

Nevertheless, even though the additional nominal market yields are not significant variables in explaining TIPS yield development, hypothesis 3 can be confirmed with this model. Hence, this result indicates that, during periods of less uncertainty, TIPS yields develop in accordance with inflation expectations, represented by break-even inflation, even though these expectations continuously fail to represent realized inflation. This signifies a level of irrationality in the TIPS market. Nevertheless, it also emphasizes the importance of utilizing break-even inflation when predicting future developments of TIPS yields. Moreover, Chu et al. (2011) argued that the best proxy for future inflation is past inflation. This view may also be somewhat applicable to expected inflation.

The results so far imply that TIPS are potentially undervalued during the sample period, and their yields are propelled by biased expectations during periods of less uncertainty. This may explain both why the investment strategy of Andonov et al. (2010) managed to capture excess returns in the TIPS market, and why their strategy performed especially well when the market faced uncertainty. Hence, by utilizing break-even inflation as a benchmark and basing trades on other than market-implied inflation forecasts, Andonov et al. (2010) managed to forecast future TIPS yield deviations more accurately.

In attempt to repeat the findings of Andonov et al. (2010), table 5 below presents the results of utilizing publicly available alternative inflation expectations and break-even inflation to determine investment positions. Hence, TIPS were sold short if the markets' expected inflation surpassed forecasted expected inflation (-), whereas the near-equivalent nominal U.S. Treasury note was bought. The position was then held for a 3-month period. In contrary, if the forecasted expectation surpassed the markets' expectations (+), then TIPS were bought, and the nominal note sold short. Whereas the average return for all 19 periods was slightly negative, merely due to the period between January and March 2020, over half of the trades were profitable. Moreover, there are multiple other providers of public inflation forecasts. Therefore, definite conclusions of the strategy's' long-term success cannot be made.

Yet table 5 presents a similar finding with Andonov et al. (2010). That is, the most unprofitable period was immediately followed by the most profitable period. Both periods are influenced by the uncertainty associated with the Covid-19 outbreak. Capturing the greatest returns during uncertainty is in accordance with the suggestion of Andonov et al. (2010), that the performance of their investment strategy is enhanced in uncertain environments. However, it is the same period in which the markets' expected inflation breaks the long-term trend of under-than-realized expectations. Therefore, it can also be argued that the profitability during uncertain conditions is due to the market recognizing inflation, eventually fixing the mispricing of TIPS.

Table 5. Utilizing alternative expectations and break-even inflation in an investment strategy.

Period	1-year exp. inflation	*BEI*	+/-	3Mo *HPR*
4-6/2016	1,69	2,25	-	1,01 %
7-9/2016	1,65	2,00	-	-0,72 %
10-12/2016	1,74	2,39	-	-0,84 %
1-3/2017	2,10	2,74	-	-0,47 %
4-6/2017	1,72	2,18	-	0,99 %
7-9/2017	1,71	1,68	+	0,30 %
10-12/2017	1,95	1,78	+	0,02 %
1-3/2018	1,90	1,43	+	0,04 %
4-6/2018	1,85	1,31	+	-0,44 %
7-9/2018	2,12	0,95	+	0,16 %
10-12/2018	2,21	0,84	+	-1,43 %
1-3/2019	1,80	0,89	+	0,34 %
4-6/2019	2,04	1,20	+	-1,12 %
7-9/2019	1,75	0,55	+	-0,25 %
10-12/2019	1,72	0,54	+	0,55 %
1-3/2020	1,80	0,99	+	-3,06 %
4-6/2020	-0,05	-0,47	+	2,14 %
7-9/2020	1,57	8,01	-	0,12 %
10-12/2020	1,40	0,08	+	0,64 %
			AVG 3Mo *HPR*	-0,11 %
			Profitable trades	11/19

In conclusion, all three hypotheses were confirmed. These were, inflation expectations continuously fail to realize in the TIPS market, attributes of money illusion prevail in TIPS yields, yet in periods of less uncertainty, TIPS yields develop in accordance with the markets' inflation expectations even though they are biased. However, the functioning of the TIPS market is enhanced during periods of greater uncertainty, as investors are reminded of inflation and race to protect their portfolios, offering an opportunity to exploit.

5. Conclusions

The purpose of this thesis was to investigate whether the market for inflation protected securities, represented by TIPS, is affected by money illusion and whether other events indicating investor irrationality are perceivable in their market. As defined, money illusion occurs when individuals evaluate monetary values in nominal terms. In other words, they do not sufficiently assess the effect of inflation. As inflation diminishes purchasing power, it is possible that illusioned investors fail to increase their wealth in real terms. In the most extreme mathematical representations, money illusion may lead to loosing entire fortunes.

Prior literature has found indications of money illusion in various markets, for example in the stock and real estate market. However, one traditional theory of money illusion, the Modigliani-Cohn hypothesis, does not consider the effect money illusion has on the prices of nominal bonds. Whereas this hypothesis had later been verified, an additional discovery was announced. That is, the real prices of bonds are suscept to money illusion. This also indicated that the Treasury Inflation Protected Securities (TIPS) market may be prone to money illusion.

The mechanics of TIPS alter coupon payments and the principle in accordance with the development of the CPI, to offer investors a fixed real rate of return. However, the indexation has a 3-month lag from announcement, which emphasizes the importance of estimating future inflation by examining expected inflation. In accordance, prior literature consistently indicated that inflation expectations play a significant role in the TIPS market. Therefore, it was crucial to begin by evaluating the inflation expectations of the TIPS market.

After gathering the data sample, it managed to confirm some findings of prior studies. For example, nominal bond volatility is greater than the volatility of TIPS, as shown earlier by Roll (2004). However, the most noteworthy finding was that during the sample period, on average, the real rate of return was negative. This implied that investing in securities with equivalent nominal yields during the sample period would have been a biased decision.

For representing expected inflation, break-even inflation was utilized, as it is a common measurement of inflation expectations in the TIPS market (Andonov et al., 2010; D'Amico et al., 2018). However, if unexplainable factors prevail in TIPS yields, which should constantly incorporate only their underlying real yield, expectations measured by break-even inflation may systematically deviate from realized inflation. After measuring ex-poste inflation expectations, denoted by break-even inflation, our results confirm that inflation expectations fail to realize in the TIPS market. That is, inflation expectations continuously deviate from realized inflation.

In addition, the results imply that TIPS yields incorporate factors which are not explained by prevailing real yields, leading to the undervaluation of TIPS in environments of higher inflation. Moreover, it was noted that this error could be even greater if risk adjustment were introduced. Supported by prior studies on money illusion and TIPS, it is probable that the inconsistency in valuation is propelled by money illusion. However, the results also indicate that the uncertainty of future inflation manages to momentarily correct the markets' inflation expectations, temporarily fixing the mispricing of TIPS.

Prior findings also suggested that capturing excess returns in the TIPS market is possible by combining market-implied inflation expectations with other than market-implied inflation forecasts. As mentioned above, market-implied inflation expectations, denoted by break-even inflation, were found to be continuously biased. Hence, even though the nominal yield variables in the OLS regression model failed to provide additional explanatory power, break-even inflation had a statistically significant effect in explaining the development of TIPS yields during the period of less uncertainty, as implied by previous studies. Consequently, our results indicate that utilizing break-even inflation as a benchmark for estimating yield development, and sufficiently evaluating whether inflation will be higher or lower than the market expects, could be the key to lucrative endeavors.

After introducing an alternative forecast of expected inflation and comparing it to the markets' inflation expectations to determine investment positions, the result was slightly unprofitable. However, it provided a further indication that holding TIPS during economic uncertainty is beneficial. Whether the significant increase in TIPS price is due to the market waking up from money illusion, sufficiently assessing inflation, or demand-related liquidity premiums, as argued by D'Amico et al. (2018), it is evident that the ultimate trigger is in the human mind.

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