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# TIPS, Inflation Expectations and the Financial Crisis

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[+] Any views or opinions presented here are solely those of the author and do not reflect the views or opinions of Barclays Global Investors.

## Abstract

Previous research indicates that the US market for inflation-linked bonds is not efficient and that market inefficiencies can be exploited by informed traders who include survey estimations or inflation model forecasts in trades on break-even inflation. Results from this extended research over a time-period in which the TIPS market matured and increased in depth, while the volatility of real yields and inflation increased, confirm that TIPS market inefficiency was not temporary but persisted over the entire time period between 1997 and 2009. Using estimations generated by the Survey of Professional Forecasters or forecasts based on the Kothari and Shanken (2004) inflation model to construct break-even trading strategy leads to excess returns over a static buy-and-hold strategy. These excess returns remain substantial even after accounting for trading costs. Furthermore, TIPS returns still include a substantial liquidity premium, which increased during the financial crisis.

## 1. Introduction

Index-linked government bonds are bonds that pay either an inflation-adjusted coupon or principal (in the rare case of zeros) or both, depending on the increase in an inflation index relative to a base period over time. Hence, these bonds promise to eliminate not only the default risk, but also the inflation risk and thereby offer a constant real yield. Many economies, such as United Kingdom, Canada, Sweden, have issued inflation-linked bonds for a longer time period, and the U.S. Treasury started issuing them in 1997. After the Treasury Inflation Protection Securities (TIPS) were issued by the US Treasury in January 1997, the TIPS market expanded quickly. As of June 2009, a total of 33 TIPS have been traded (including four already matured TIPS), while the market has grown to over $532.3 billion or 8.05% of the marketable debt or 4.61% of the total outstanding Treasury debt by the end of June 2009 (Bureau of Public Debt, 2009).

Especially investors who desire predictable real cashflows are willing to include TIPS in their portfolios as their characteristics as inflation hedge are especially interesting retirement saving (be it individuals or pension funds). To be interesting to the broader investor community, however, the theoretical predictions regarding TIPS return performance need to be confirmed empirically. One avenue of research is to focus on the diversification properties of this asset class and to estimate the correlations with equities and bonds over different time horizons. Bearing in mind that TIPS exist for only 12 years, the term structure of the TIPS risk-return trade-off still cannot be analysed precisely. Another avenue of research is to study the efficiency of the TIPS market. The vast majority of investors include these securities in their portfolios in order to decrease the inflation risk and protect the expected real returns. Whether TIPS will fulfil investors' objectives depends on how precisely TIPS account for future inflation rates. Thus, the concept of break-even inflation, which is the implied future inflation rate, is crucial for examining the efficiency of the TIPS market. The break-even inflation could be compared with estimated inflation rates from surveys and forecasting models. TIPS market efficiency could then be tested by implementing different trading strategies exploring the relationship between the BEI and inflation forecasts. For instance, if the

estimated future inflation rate is higher than BEI, it can be interpreted as a signal of future increase in the BEI, which would lead to an increased demand for TIPS, and a long TIPS position today will be the logical trading strategy.

This research builds on previous work by Bardong and Lehnert (2004a,b and 2008), who estimated the returns on four trading strategies, long-short, break-even, carry trades and growth optimal, over the 1997-2003 time period. Their findings imply that informed investors were able to earn positive average excess returns over the first six years TIPS were in existence using the abovementioned trading strategies. The combination performing best is a break-even trades in the short to medium end of the yield curve over a holding period of nine months and based on an inflation forecast of one to two years (Bardong and Lehnert, 2004a). This results imply inefficiencies in the TIPS market.

Looking at the TIPS market again to extent the research of Bardong and Lehnert is interesting for several reasons. First, the TIPS market matured and developed during the 2003-2009 time period. Four indexed bonds series matured and new series were issued more frequently. It would be interesting to observe whether the inefficiencies documented by Bardong and Lehnert (2004a and 2008) were temporary in the early years of TIPS market or persist until today. Second, Roll (2004) estimated a severe decrease in TIPS yields at the end of 2003, which implies a dramatic change in the TIPS market environment. Third, higher inflation volatility during the last 12 months and the recent financial crisis provide an opportunity to study the efficiency of the TIPS market when market conditions change. For instance, the inflation rate in Q3 2008 was the highest since TIPS have first been issued; including this period in this study allows testing how well TIPS actually protect from inflation risk. It also allows testing how precise expectations of future inflation are in an uncertain economic environment. The financial crisis, which started in Q3 2008 and continued until Q2 2009, provides an interesting setting to test TIPS market efficiency. TIPS performance relative to nominal bonds will answer the question whether investors consider these two types of bonds similar or distinct asset classes. Due to market inefficiencies and the possibility of changes in the

real yield over time, it is possible that the inflation-indexed bonds introduce, rather than eliminate, risks to investors' portfolios.

As an alternative measures to break-even inflation, we use the Survey of Professional Forecasters for forecasting horizons up to one year. The survey is released quarterly by the Federal Reserve Bank of Philadelphia. For time horizons longer than one year the Kothari and Shanken (2004) inflation forecasting model is used. Their model explains future inflation using the following financial and economic variables: the nominal one year spot interest rate, the yield spread between the five-year zero-coupon bond and the one-year spot rate, the one-year lagged inflation rate, the sum of realized monthly returns on one-year government bonds over the preceding one-year period, the spread of the one-year forward rate over the current spot rate and the spread of the two-year forward rate over the forward rate of a zero-coupon bond in one year. Trading strategies then make use of the estimated inflation rate and the observed break-even inflation to derive their positions.

The results from the trading strategies for the time period between 1997 and 2009 indicate that TIPS market has yet to fulfil investors' expectations of being a low-risk, efficient and liquid financial instrucment, as well as the expectations of the US Treasury for lower borrowing costs. The best performing trading strategy is again the break-even strategy, which confirms the previous findings of Bardong and Lehnert (2004a and 2008). The break-even strategy is consistently profitable across different forecasting horizons and over three, six and twelve months holding periods. The excess returns are positive for almost each series of the 32 series of TIPS. Contrary to this, the evidence for the long-short strategy is mixed and this strategy cannot be considered as constantly profitable nor implementable in reality. Furthermore, the break-even trades are profitable even after accounting for trading costs, which means that they can be implemented in practice.

The paper is organised as follows. Section 2 explains the mechanism of the inflation-indexed bonds market with focus on the US experience and discusses the empirical tests for TIPS market efficiency. Section 3 describes the methodology used to calculate break-

even inflation, the characteristics of the Survey of Professional Forecasters, the Kothari and Shanken inflation forecasting model and the implementations of the different trading strategies. Section 4 presents the main results from the three trading strategies. The results are discussed for various forecasting and holding periods, with and without taking into account transaction costs. Section 5 summarizes the main findings and concludes.

## 2. Literature review

Research on indexed-linked bonds is mainly focused on deriving inflation expectations from bond prices and analyzing the diversification properties of this asset class. Due to their inflation-protective characteristic, these bonds were immediately suggested as the "perfect" retirement investment and were incorporated in the investment strategies of many life-cycle and pension funds (Viceira, 2008 and Shankar 2008). While the potential of inflation-indexed bonds to improve portfolio diversification is intuitively clear in theory, it seems that reaping diversification benefits is harder in practice. Therefore, how inflation-linked bonds behave in practice and how they interat with other asset classes has to be empirically examined over a longer time period as the effectiveness of the asset allocation policies that consider these instruments depends on the efficiency of indexed bonds' markets. For instance, the market for inflation-indexed bonds should cover a broad range of maturities and be liquid enough for the trading activity of the major institutional investors. In order to proceed with the discussion of the TIPS market, first the basic characteristics of inflation-indexed bonds in general and the recent US experience in particular will be discussed.

### *2.1 Conventional bonds vs. Inflation-indexed bonds*

Conventional bonds provide periodic fixed payments of interest and a set principal at maturity. The real value of these cashflows is not known when a nominal bond is issued because of uncertainty about future inflation. Therefore, both the issuer and the investor of nominal bonds face inflation risk, the risk of unanticipated changes in the purchasing power of the nominal payments promised by the bond (Wrase, 1997). When inflation rate

turns out to be higher than expected, bondholders suffer unanticipated losses in the real value of their investment. On the other hand, when inflation is lower than expected, bondholders receive unexpected gains of purchasing power. In these cases, the issuers of nominal debt suffer losses, because the real cost of paying off the debt rises.

With an inflation-indexed bond, the real interest rate is known in advance, because the nominal rate of return varies proportionally with the inflation rate realized over the life of the bond. Therefore, neither the issuer nor the investor face the risk that unexpected changes in inflation will change the purchasing power of bond's cashflows (Wrase, 1997).

Considering all of the above, inflation-indexed bonds are interesting instruments for those investors who desire predictable real cashflows. The value from the inflation hedge of an inflation-indexed bond is especially desirable for persons saving for retirement and annuitants for the following two reasons. First, retirement savers and annuitants are relatively more vulnerable to the steady erosion of purchasing power due to persistent inflation. Second, these persons are also vulnerable to a sudden loss of purchasing power due to inflationary spikes like those experienced in the 1970s. In the latter case, retirement savers have only a few years ahead of them to make up for this loss in purchasing power, which typically means that they have to either delay retirement or reduce consumption (Brynjolfsson and Fabozzi, 1999).

The US Treasury also expects to benefit from inflation-indexed bonds via lower borrowing costs and less volatile real interest rates. Unlike investors in nominal bonds, inflation-indexed bond investors do not demand an inflation risk premium, which lowers the total yield demanded from Treasury debt, thus lowering total borrowing costs. The real interest rate, and hence the real cost of borrowing, however, can only be determined when a new series of TIPS is issued.

It is worth mentioning that the payments from TIPS are subject to a three-month indexation lag, which implies that indexed bonds lack inflation protection for the three

months right before they mature. Of course, for a long-term TIPS, this time period is very small compared to its entire lifetime. TIPS are also subject to deflation protection. Keeping in mind that the US economy experienced deflation in 2008-2009, it would be interesting to investigate the behaviour of the TIPS market during this period.

TIPS are usually examined together with nominal bonds. The spread between the yield to maturity of TIPS and the yield on a comparable nominal bond is known as the rate of inflation compensation or break-even inflation (BEI). Hence, BEI is a measure used to derive information on market expectations of future inflation from the financial markets (Chicago Mercantile Exchange, 2004).

*2.2 US Experience*

In contrast to the predictions on the benefits of TIPS to investors and the Treasury discussed above, the US experience has been rather disappointing so far regarding the diversification properties and the expected decline in real yields. Regarding the diversification properties of this asset class, Roll (2004) finds that TIPS were negatively correlated with equities (as were nominal bonds) during the period 1997-2004 but the correlations were small in absolute magnitude. Long-term conventional bonds are positively correlated with long-term inflation-linked bonds. These correlations are mainly in the range of 0.5–0.8 (Roll, 2004). Further, shorter-term conventional bonds, with time to maturity from three months to one year, are more weakly correlated both with inflation-linked bonds and with longer-term conventional bonds.

What is more important, the yields on TIPS have been unexpectedly high relative to those on comparable nominal Treasury bonds. The spread between ten-year yields on nominal securities and TIPS has, on average, fallen about 50 basis points below the long-run inflation expectations reported in the Survey of Professional Forecasters, conducted by the Federal Reserve Bank of Philadelphia (Sack and Elsasser, 2004). This implies that the BEI (the spread) has been 50 basis points below the expected long-term inflation. Carlstrom and Fuerts (2004) also find that the expected inflation rate derived from TIPS

prices seriously underestimates the actual inflation rate. However, as a recent paper by Dudley, Roush, and Ezer (2009) argues, this disappointing benefits from lowering real borrowing cost depend on whether one analyses the benefits from TIPS ex ante or ex post. While the ex post results are not encouraging, they find that on an ex ante basis, the cost of issuing TIPS is equivalent, if not lower, than the costs of issuing nominal Treasuries.

Sack and Elsasser (2004) provide three explanations for this valuation puzzle. First, the undervaluation of TIPS has reflected investors' difficulty to adjust to this new asset. The TIPS investor community has been fairly small especially in the first years. Second, opposite trends in supply affected the relative values of nominal securities and TIPS. The dramatic increase in the supply of TIPS was not followed by proportional increase in the demand, which may have put upward pressure on the TIPS yields.

Third, the low valuation of indexed-linked securities could be a result of their lower liquidity. TIPS liquidity was especially poor during the first years of the securities' existence. Liquidity forms a restriction whenever the desired allocation to an asset class is not available in the market at realistic transaction costs (Hoevenaars et al. 2008). Liquidity has improved in recent years as participation in the market has broadened, but TIPS will likely never achieve the same liquidity as nominal Treasury debt, largely because of the different roles that the two types of securities play in financial markets (Sack and Elsasser, 2004). Namely, TIPS are held primarily by long-term investors, who tend to "buy and hold" the instruments. By contrast, nominal securities are to a large extent used as hedging and trading instruments, with primary dealers playing a very active role in the market.

The US experience with respect to the liquidity in TIPS market is in line with the experience in other countries. Markets for indexed bonds in other countries tend to be small and have relatively low trading activity, reflecting the importance of buy-and-hold investors in this market (Wrase, 1997). Hence, investors in inflation-indexed securities may require a real return premium relative to that expected from nominal bonds as a

compensation for the risk associated with lower liquidity. Thus, the spread between the yields on nominal and indexed bonds is made up of a market consensus expectation of inflation and premia for illiquidity and inflation risk.

However, even after adjusting for the impact of the abovementioned factors, Sack and Elsasser (2004) argue that the observed undervaluation of TIPS relative to nominal bonds suggests that bondholders simply had a very "benign outlook" of inflation over this period and did not demand much of an inflation risk premium for holding nominal bonds. This conclusion provides strong evidence against TIPS market efficiency and the use of BEI as a rational estimate of future inflation. However, Carlstrom and Fuerts (2004) state that if there were no liquidity risk in both the nominal and the TIPS market, than the expected inflation implied by TIPS would overstate actual inflation expectations by 95 basis points. This arises from the inflation risk premium being incorporated in nominal bond prices. Similarly, Campbell and Shiller (1996) also estimate an inflation risk premium of 50 to 100 basis points.

The differences between the BEI measure of inflation expectations and those based on the historical behaviour of inflation or surveys could lead some observers to question the usefulness of this measure. Sack (2000) states that the usefulness of the measure was improving, since the most extensive variation in the measure occurred through 1999, after which the measure has held fairly steady despite a considerable rise in the actual rate of inflation. Considering all of the above, there is no clear-cut answer regarding the relationship between the BEI and expected inflation as well as the sizes of the liquidity premium and inflation risk premium.

### *2.3 TIPS Market Efficiency*

Bardong and Lehnert (2004a,b and 2008) go one step further and focus not only on the price process of inflation-linked bonds, but also on the potential for using some of the TIPS price drivers to construct signals indicating their future prices. The inflation adjustment is the factor that most directly affects the payments from inflation-linked

bonds. If the assessment of future inflation (BEI) implied earlier by the market differs from the realized rate, the price of inflation-indexed bonds is expected to be adjusted accordingly, as its cash flow is directly related to the realized rate of inflation. Bearing in mind that BEI can be interpreted as a market consensus estimate of the future inflation rate, if some investors could estimate the future inflation rate more precisely than the market does, they should be able to forecast the price movements of inflation-linked securities and modify the portfolio allocation accordingly.

There are two different ways in which the future inflation rate can be assessed. First, inflation forecasting models can be used. For instance, Bardong and Lehnert (2004a,b, and 2008) use the McCuloch and Stec (2000) model to forecast next-period inflation for a time horizon within one year. For time horizons from one to three years, a technique derived from Kothari and Shanken (2002) is used to forecast future inflation. The other way to assess future inflation is to use inflation expectations provided by the Survey of Professional Forecasters of the Federal Reserve Bank of Philadelphia. The quarterly survey, formerly conducted by the American Statistical Association (ASA) and the National Bureau of Economic Research (NBER), began in 1968:Q4 and was taken over by the Philadelphia Fed in 1990:Q2 (Philadelphia Fed, 2008). Keeping in mind that these survey estimates are publicly available, it should not be possible to make excess returns systematically using this survey if the TIPS market is efficient in the semi-strong form.[1]

BEI represents the average market-implied inflation rate between today and the maturity of the inflation-linked bond. BEI may not always be a useful predictor of future inflation. BEI usefulness as a short-term inflation signal has several limitations. First, BEI is an estimate of the average inflation rate up to the maturity of TIPS, which does not take into account the cyclical aspects of the inflation. For instance, BEI is based on the CPI-U inflation index, which is not adjusted for seasonal changes in US price level. Second, nominal bond yields includes compensation for expected inflation as well as an inflation

[1] The semi-strong form of market efficiency implies that security prices reflect all publicly available information.

risk premium. If the inflation risk premium is significant, then BEI will overestimate the expected future inflation. Despite these caveats BEI is considered a market consensus of the future inflation rate.

Bardong and Lehnert (2004a,b and 2008) test TIPS market efficiency using BEI inflation forecasts from the Survey of Professional Forecasters and an inflation forecasting model. The difference between BEI on the one hand and the alternative inflation forecast on the other is used as a signal for four different trading strategies. The trading strategies considered are a long-short strategy, a break-even strategy, a carry trades strategy and a growth optimal strategy. Their findings imply that informed investors are able to earn positive excess returns on average, which is an argument against TIPS market efficiency. The combination performing best is a break-even trading strategy investing in the short to medium end of the yield curve over a holding period of nine months and based on an inflation forecast of one to two years (Bardong and Lehnert, 2004a). Comparing the US results with other countries, Bardong and Lehnert (2004b) find out that active trading in French OATi performs fairly well across a variety of holding periods and trading strategies. In particular, the break-even trading strategy performs best and shows the least variation in returns. However, the profitable performance in the French market could not be fully confirmed in the market for British Gilts or euro-zone inflation-indexed bonds.

The Bardong and Lehnert research has been conducted using data for the first six years (1997-2003) after TIPS have been issued. Considering the valuation puzzle discussed previously, the positive excess returns could be attributed to TIPS market incompleteness. The continuous issues of new TIPS series by the Treasury should have helped addressing this issue. In addition, investors improved their understanding of this asset class over the last few years. Hence, it is conceivable that these profit opportunities have disappeared as the TIPS market matured. However, Roll (2004) finds that TIPS yields of all maturities have decreased significantly since the beginning of 2000. Namely, yield were well over 4 percent in 2000 before they fell to less than 1 percent in 2003. Moreover, inflation volatility has increased dramatically during the last few years. Figure 1 depicts the CPI-U inflation rate trend since 1997. During the last one-year period the

inflation rate reached the 12-year high of over 5 percent, which was immediately followed by a deflationary period. These rapid swings occurred simultaneously as the financial crisis gained in strength. This highlights that there potentically could be significant profit opportunities from trading TIPS.

[Figure 1]

According to the economic theory and past experience, during crisis periods investors prefer safety and liquidity. While TIPS provide the safety of a government-backed instrument, their liquidity has been limited. Hence it would be interesting to study the impact of the recent financial crisis on the behaviour of the TIPS market and the possibility to implement profitable trading strategies. Thus, improvements in TIPS liquidity and market depth on the one hand and recent volatility of real yields and inflation on the other provide an interesting setting to extend the previous research of Bardong and Lehnert.

### *2.4 Bond Trading Strategies*

TIPS market efficiency is tested using different trading strategies that exploit the difference between BEI and inflation forecasts from sources other than financial markets. For instance, if the estimated future inflation is higher than BEI, it can be interpreted as a signal of future increase in BEI, which will lead to increased demand for TIPS, and a long position in TIPS today will be the logical trading strategy.

The trading strategy described above is a long-short strategy, which goes long if the signal indicates BEI, and thus TIPS prices, increase and takes short position when the signal indicates a drop in BEI. In case there are short-selling constrains on the market, the long-short strategy can be interpreted as an over- or under-weighting strategy.

While the long-short strategy can be implemented on various assets and was extensively used by hedge funds, there is one trading strategy which is more specific for the inflation-

linked bonds market. This is the so-called break-even trading strategy. Break-even trading strategy aims to capture the change in BEI over time exclusively, and therefore attempts to isolate the price process of a position of inflation-linked bonds from the change in other factors over time, most notably the real yield (Bardong and Lehnert, 2004a). This isolation is accomplished by taking simultaneously a position in inflation-linked bonds and an opposite position but in as many maturity-matching nominal bonds. For example, if one forecasts that inflation will increase above the current BEI, one takes a long position in index-linked bonds and short position in matching nominal bonds.

The existence of excess returns on the abovementioned trading strategies over the buy-and-hold strategy will provide an argument against the efficiency of TIPS market. The technical details regarding the implementation of the strategies are presented in the methodology section.

## 3. Methodology and Data

### *3.1 Calculation of the BEI*

BEI is calculated daily for each series of inflation-linked bonds using the Fisher equation. The Fisher equation states that the nominal yield is composed of real yield and inflation compensation:

$$\left(1+y^{n}\right)=\left(1+y^{r}\right)\left(1+E\left[i\right]\right), \tag{1}$$

where $y^n$, $y_r$, and $E[i]$ represent the nominal yield, the real yield, and the inflation compensation, respectively. Nominal interest rates are taken from the maturity-matching nominal bond. The comparable nominal bond was determined in earlier studies based on the duration criteria. Sack (2000) finds that, expressed in real terms, the cashflows on the inflation-linked securities are fixed, while those of the conventional securities decline over their maturity as inflation erodes the value of their nominal payments. The nominal securities therefore have a shorter duration with respect to real interest rate changes than

the indexed security. In addition, the duration methodology was designed to take into account the differences in interest rate risk. However, the indexed and nominal bonds face different classes of interest rate risk. Namely, while the inflation-indexed bonds face real interest rate risk, nominal bonds face nominal interest rate risk (Spiegel 1998). Bootle (1991) also argued that these two forms of interest rate risk differ due to the relative fluctuations in inflation risk premium and real rates over time.

Due to these methodological problems of comparing the duration of nominal and index-lined bonds, it became standard practice to match inflation-linked and nominal bonds based on their maturity. Therefore, we match each TIPS with STRIPS having the closest maturity date.[2] Matching of all 32 series of TIPS and STRIPS is presented in Table 1. The typical maturity mis-match between TIPS and its closes maturity-matching nominal bond across our 32 series is one month. The daily prices for each series have been retrieved from DataStream. The time period used for this study starts when the first TIPS is issued (January 30$^{th}$, 1997) until the end of the sample period (June 26$^{th}$, 2009).

[Table 1]

Out of 32 series of TIPS, three bonds have already matured. One observation that can be made from the data is that the returns on TIPS are less volatile than the returns on the matching nominal bonds. Nominal yields are much more volatile than real yields, because changes in nominal yields incorporate shocks to expected inflation (Roll, 2004). Kothari and Shanken (2002) develop this point further and find that the real returns on TIPS are less volatile than their nominal returns, which is opposite to what one observes for nominal bonds. However, the lower return volatility of TIPS only applies to the series

[2] STRIPS is the acronym for Separate Trading of Registered Interest and Principal of Securities and they let investors hold and trade the individual interest and principal components of eligible Treasury notes and bonds as separate securities. When a Treasury fixed-principal note or bond or a Treasury inflation-protected security (TIPS) is stripped through the commercial book-entry system each interest payment and the principal payment becomes a separate zero-coupon security. Each component has its own identifying number and can be held or traded separately.

that have not yet matured. The four TIPS series that have already matured have a higher return standard deviation. This can be explained by the fact that TIPS do not provide inflation protection for the last 3 months of their life, due to the inflation indexation lag. This feature increases return volatility and therefore lead some researchers (Gurkaynak et al., 2008) exclude TIPS with maturity of less than 2 years from their empirical analysis. As this paper looks at the profitability of the trading strategies over the entire life of the bond we considered the inclusion of these bonds important, however.

Once the matching of the TIPS with equivalent nominal bonds is completed, BEI can be calculated from observed yields. The nominal and real yields are decomposed as shown in Figure 2 below:

[Figure 2]

Figure 2 demonstrates that BEI consists of the expected inflation, an inflation risk premium, and potentially other risk premia. In practice, changes in the inflation risk premium are hard to distinguish from changes in expected inflation (Spiegel, 1998). Hence, most researchers usually assume that the inflation risk premium is equal to zero (Arak and Kreicher 1985, Woodward 1990, Barr and Campbell 1997). This assumption is typically justified by the small size of the empirical estimates of the inflation risk premium (e.g., Cogley, 1995).

Using the daily values of real and nominal yields, daily BEI can be calculated for each pair of bonds. These daily BEI rates are then compared to the forecasts from the Survey of Professional Forecasters (see section 3.2) or from the inflation forecasting model presented in section 3.3.

### *3.2 Survey of Professional Forecasters*

The Survey of Professional Forecasters (henceforth referred to as the Survey) was started by the American Statistical Association and National Bureau of Economic Research in

1968. The number of forecasters at the beginning was around 60, but later it decreased in two major steps in the 1970s and 1980s to 14 forecasters. The Federal Reserve Bank of Philadelphia took over the survey in 1990 and the number of forecasters since then stabilized at 30. The one-year-ahead expectations are annual averages, in annualized percentage points, over the four quarters, beginning with the quarter following the survey date (Philadelphia Fed, 2008). The survey closing and publication dates are available on the Philadelphia Fed website. The inflation forecasts are released at 10 a.m. in the morning, which implies that they are price relevant for that particular day (Bardong and Lehnert, 2008). Changes in the CPI index are forecasted since 1991:Q4. All data are available on the Philadelphia Fed website.

Regarding the quality of the survey, there is no guarantee that forecasters in the survey provide the best possible (in a statistical sense) estimations. They may give biased answers due to, for example, strategic considerations (Giordani and Soderlind, 2003). The risk that forecasters provide nonsensical inflation forecasts can be considered low, as the Federal Reserve Bank of Philadelphia appoints the indificual forecasters, which ensures that the vast majority of the answers accurately reflect the respondents' opinion. In addition, the strength of the Survey of Professional Forecasters is that the forecasters are close to important economic decision-makers, which implies that the survey reflects beliefs that affect important investment and pricing decisions. The weakness of the survey is that it reflects the beliefs of a small fraction of market participants, which may not represent overall market expectations. Nevertheless, as the Survey is publicly available, it should be reflected in TIPS prices if the TIPS market is semi-strong efficient.

The Survey can be used for up to one year ahead estimates of the inflation rate. For longer period ahead forecasts, a forecasting model has to be used, which is going to be discussed next.

### *3.3 Kothari and Shanken inflation forecasting model*

Kothari and Shanken (2004) create a model to forecast inflation from one up to three years into the future. Their regression approach makes use of several financial and economic variables to model future inflation. Thereby, the current inflation rate is first regressed on past state variables. These coefficients are then to estimate future inflation using current realizations of these state variables. One critical assumption underlying this forecasting technique is that the coefficients change slowly over time as this forecasting model uses in sample estimates of the relationship between current inflation and past observed state variables (Kothari and Shanken 2004).

The current inflation rate observed at time *t*, $Inf_t$, is related to the following past state variables, observed at time *t-1*:

- The nominal one year spot interest rate, *1YrSpot*
- The yield spread between a five year zero-coupon bond and the one year spot rate, *5-1Spread*
- The one year lagged inflation rate, $Inf_{t-1}$
- The sum of realized monthly returns on one-month T-bills over the preceding one year period observed in the previous period, $RR_{t-1}$

The inclusion of the one-year spot rate is motivated by the work of Fama (1975) and the argument that interest rates account for expectations of future inflation. As real interest rates are likely to change over time, additional variables are needed to improve the explanatory power of the model.

The yield spread between the five-year zero coupon bond and the one-year spot rate is considered a proxy for general business conditions (Fama and French, 1989) and should therefore be correlated with expected real interest rates. One year lagged inflation is included due research of Nelson and Schwert (1977), who find that past inflation has incremental explanatory power beyond the spot interest rate for forecasting near-term inflation. Finally, the sum of real T-bill returns represents a direct, though admittedly noisy, proxy for realized real interest rates. Assuming that the real rate changes only

slowly over time, this variable could provide additional explanatory power to the model. Therefore, the following regression model is estimated:

$$Inf_t = \beta_0 + \beta_1 1\text{YrSpot}_{t-1} + \beta_2 5\text{-}1\text{Spread}_{t-1} + \beta_3 Inf_{t-1} + \beta_4 RR_{t-1} + \varepsilon_t, \qquad (2)$$

The coefficients from this regression are then used to forecast inflation at time *t+1* using the realization of the right-hand side variables at time *t*. The one-year spot rate and the five year nominal yield on zero-coupon bonds (both from the constant maturity curve) are sourced from DataStream. Therefore, first two variables are available on a daily frequency. Inflation, however, is reported on a monthly frequency and therefore needs to be transformed to daily frequency. Thus, monthly inflation index level data are converted into weekly index numbers by linearly interpolating between the monthly index numbers, thereby assuming that a given inflation rate is realized homogeneously throughout the month. If a week falls in between two months, weekly inflation is calculated as the weighted average of the weekly inflation index level of these two months. The weekly inflation rate is then calculated as the log difference of two index numbers 52 weeks apart from each other (Bardong and Lehnert, 2004a). Finally, the daily inflation is defined as one fifth of the assumed weekly inflation numbers.

The sum of the realized monthly returns on government securities over a one-year period, $RR_{t-1}$, are calculated as follows:

$$RR_t = YTM_{t-12} + \sum_{i=1}^{12} \left[ \left( \frac{1+YTM_i}{1+YTM_{i+1}} \right)^{1/12} - 1 \right] \qquad (3)$$

where $YTM_{t-12}$ is the annualized yield to maturity observed in the previous year, $YTM_i$ refers to the annualized yield to maturity observed at the beginning of month *i*. This expression is calculated using daily values of one-year constant maturity zero yield curves from DataStream (Bardong and Lehnert, 2004a).

In a next step, the change in the rate of inflation relative to last year, $\Delta Inf_t$, is related to a set of explanatory variables observed at time *t-2*. Similar to the previous regression, which was used to construct a one-year ahead forecast, we use the resulting regression coefficients and observations of the explanatory variables observed at time *t*, to forecast the change in inflation between time *t+1* and *t+2*. The forecasted level of the inflation rate for year *t*+2, $Inf_{t+2}$, then equals the forecast of the one-year ahead inflation, $Inf_{t+1}$, which is calculated using the estimated regression coefficients from equation (2), plus the forecasted change in inflation calculated from the estimated coefficients in equation (4). For that purpose, the one-year spot rate in Equation (2) is replaced by the spread of the one-year forward rate for a one-year deposit over the current spot rate *1,2FwdSpread*, and the spread of the 5-year rate over the 1-year rate is dropped. This results in the following regression model:

$$\Delta Inf_t = \delta_0 + \delta_1 1,2\text{FwdSpread}_{t-2} + \delta_2 Inf_{t-2} + \delta_3 RR_{t-2} + \xi_t, \qquad (4)$$

This change in regression set-up is motivated by the expectations hypothesis, where the forward rates reflect the expectations of the future nominal spot rate. Therefore, the forward rates should also incorporate expectations of the future inflation rate (Kothari and Shanken, 2004). Thus, the spread of the forward rate over the spot rate, *1,2FwdSpread*, should capture the expected change in inflation rates between year *t+1* and year *t+2*.

Similarly, we relate the change in inflation to the observation of our explanatory variables three years earlier. This regression model is analogous to equation (4), except that the explanatory variables are lagged by another year:

$$\Delta Inf_t = \gamma_0 + \gamma_1 2,3\text{FwdSpread}_{t-3} + \gamma_2 Inf_{t-3} + \gamma_3 RR_{t-3} + \varsigma_t, \qquad (5)$$

where *2,3FwdSpread* refers to the spread of the two-year forward rate for a one-year deposit over the spot rate. This spread is also calculated using the constant maturity zero yield curves retrieved from DataStream. We then calculate the expected three-year ahead

inflation rate, $Inf_{t+3}$, as the sum of the forecasted two-year ahead inflation rate, $Inf_{t+2}$, and the estimated change in inflation between year t+2 and t+3, using the coefficients estimated in equation (5) above and the realizations of the associated right-hand side variables at time *t*. The results from estimating these regressions are presented in Table 2.

[Table 2]

As theory predicts, the one-year spot interest rate is positively related to next year's inflation (Panel A). The real return is negatively related to one-year-ahead inflation; the logic behind the negative coefficient is that with the spot rate being constant, a higher expected real interest rate implies lower expected inflation rate. Forward rates appear to contain important incremental information about the future inflation rate, as they are positively related to changes in the inflation rate two and three years ahead (Panels B and C). The negative coefficients of lagged inflation in all three models suggest a degree of mean reversion in expected inflation, which is in line with previous findings by Kothari and Shanken (2004). This means that a high inflation print implies a decrease in the inflation rate in the following years. Overall, the models explain between 23 and 43 percent of the variation in the next year's inflation for the 1990-2009 time period, which is comparable with the findings of Kothari and Shanken(2004) for 1953-2000 time period.

### *3.4 Implementing the trading strategies*

In the literature review section two TIPS trading strategies were described – long-short and break-even strategy. These strategies are implemented with various forecasting horizons and holding periods. Inflation forecasts within one year are retrieved from the Survey, The news release dates are available on the Philadelphia Fed website. Forecast for one, two or three years ahead are obtained from the Kothari and Shanken (2004) model.

All these forecasting horizons are combined with several holding periods for each trading strategy separately. The holding periods considered in this study are 3, 6 and 12 months. At the end of each holding period the positions are cleared and the returns are compared with an adequate benchmark. The long-short and carry trade strategy are compared with the returns on a buy-and-hold strategy over the same holding period. The break-even trading strategy has a different risk profile and is therefore compared with a long position in TIPS and short position in maturity-matching STRIPS.

All the trading strategies described above are first implemented without taking into account trading costs. To improve the relevance of our study to practitioners, we also look at post trading costs returns. Trading costs are assumed to be in the range of 9 to 13 basis points of the transaction value. We take the mid-point as transaction cost estimate.

## 4. Results

The profitability of our trading strategies is analyzed using five inflation forecasting horizons: The current quarter ($Q_0$), the next quarter ($Q_1$), the next year ($Y_1$), two years ahead ($Y_2$), and three years ahead ($Y_3$). In addition, we consider three different holding periods (abbreviated by HP in what follows): 3 months, 6 months, and 12 months. Finally, each combination of forecast horizon and holding period is presented pre and post transaction costs.

Table 3 presents the results for the long-short strategy using inflation forecasts from the Survey for the current quarter.

[Table 3]

The long-short strategy has positive excess returns on the first series of TIPS for a three-month holding period. This trading strategy was profitable for all TIPS series that have already matured. As one moves further to the series with longer maturities and less data history, the negative performance of long-short strategy becomes more pronounced.

Hence, this strategy was profitable in the early years of TIPS market, but this performance is not sustainable and turns into negative excess returns in the later period. The same conclusions can be derived for holding periods of six and twelve months. Although there is not much variation in the performance across the different holding periods, the losses from long-short strategy are lowest in the case of a 6-month holding period. Using the $Q_1$ forecasting horizon does not dramatically change the results.

[Table 4]

The long short strategy is profitable again only for the first series of TIPS and negative returns persist across the other series. Hence, implementing the long-short trading strategy based on Survey inflation forecasts for $Q_0$ and $Q_1$ does not lead to positive excess returns. The long-short strategy performs better using the Kothari and Shanken (2004) inflation forecasting model. For instance, when one-year ahead inflation is forecasted, positive excess returns are achieved with all three holding periods. The most promising performance is with the shortest holding period, three months. However, once trading costs are accounted for, the positive returns disappear. The excess returns based on two and three years ahead inflation forecast are similar to the ones with one-year ahead forecast, but with much lower trading activity, which leads to performance undistinguishable from zero. Table 5 presents the results for long-short strategy based on the Kothari and Shanken (2004) model.

[Table 5]

The first important observation from the comparison of the results based on Survey data with results based on the forecasting model is that the long-short strategy is profitable only on the short end of the TIPS yield curve, and for TIPS that have already matured. Using the Kothari and Shanken (2004) forecasting model in conjunction with the long-short trading strategy shows excess returns for the middle part of the TIPS yield curve. Regardless of the source of the inflation forecasts, however, long-short trading strategy leads to negative returns when it is implemented on TIPS series with longest maturity.

Table 6 present the results for break-even trading strategy based on Survey forecasts for $Q_0$.

[Table 6]

Break-even trades with holding period of 3 months provide positive excess returns across all series of TIPS. The exceptions are the newest TIPS series with less than 6 months of data history. The positive excess returns can be achieved also with six and twelve months holding periods. While the three months holding period leads to highest number of profitable TIPS series, the twelve months holding period leads to highest excess returns per series. These findings are in line with the results from Bardong and Lehnert (2008), where the break-even strategy was the best performing one. Excess returns with $Q_1$ forecasting horizon are similar to the ones with a $Q_0$ forecasting horizon.

[Table 7]

One can see that excess returns based on $Q_1$ increase in magnitude, but at the same time more TIPS series have negative returns. Based on the results presented in Tables 6 and 7, the break-even trading strategy implemented on survey data is profitable over the entire maturity spectrum of the TIPS market. Implementing this strategy leads to excess returns of approximately 3.5 percent per annum post transaction costs. Empirical tests also support the profitability of the break even strategy when it is implemented using the Kothari-Shanken one-year ahead inflation forecasts.

[Table 8]

However, the positive out-performance of the Kothari-Shanken based forecasting model is not as pronounced as the out-performance generated by using inflation forecasts from the Survey. Break-even trades on $Y_1$ forecasts result in negative returns for five series of TIPS, while negative returns occurred for only two series of TIPS when using the $Q_0$

forecasting horizon. Further, the average return for $Y_1$, $Y_2$, and $Y_3$, forecasts is approximately 1.5 percent, which is less than the out-performance resulting from the use of Survey forecasts.

Thus, the break-even strategy performs better than the long-short strategy using inflation forecasts from the Survey and the Kothari and Shanken (2004) model. Within the break-even trades strategy, excess returns are higher when inflation forecasts from the Survey are used. $Q_0$ and $Q_1$ break-even trades outperform the $Y_1$ trades for short and medium term TIPS but under-perform for long term TIPS. The best performing strategy uses $Q_0$ forecasts with a 12-month holding period, $Q_1$ forecasts with a 6-month holding period, and $Y_1$ forecasts with a 12-month holding period.

The following paragraphs focus on the performance of our trading strategies during 2008. This year was not only the one with the highest inflation rate since TIPS have been issued (see Figure 1). This year was also the year with significant financial market turmoil, unprecedented in the TIPS markets. It would therefore be interesting to study the performance of the break-even strategy in this period. The highest inflation since the beginning of the TIPS market was achieved in the last quarter of 2007 and in the first three quarters of 2008. During this one-year period, break even trades result in positive excess returns across all series of TIPS. The positive returns are highest in the third quarter of 2008, when the inflation rate in July and August was above 5%. The break even strategy produces positive returns in Q3 2008 for all 32 series of TIPS. The main reason for these results is that TIPS become more attractive as the uncertainty regarding future increases in the inflation rate. However, TIPS market participants' predictions of the future inflation rate in these unstable economic conditions seem to be generally weak. Using our inflation forecasts seem to improve the precision of the expectations of future inflation. Hence, the usage of inflation forecasts seems to be most beneficial to the TIPS investor during periods of economic uncertainty.

Further, looking at the TIPS market performance in this period compared to the performance of the nominal Treasury bond market is also an interesting case study for

some of the major drivers of the TIPS market. Both, nominal and real Treasury bonds are virtually default free and therefore should provide investors with the most secure returns in crisis times. Surprisingly, however, we can observe significant negative returns for long BEI trades during this period, especially using TIPS with short maturity. In addition, BEI is negative during that time, as the nominal Treasury rates (e.g., the yields on STRIPS) are lower than the yields on the maturity-matching TIPS. Negative BEI implies that investors expect deflation over the remaining life of the respective TIPS, which is not a normal economic condition and therefore unlikely to be realistically observed over a multi-year horizon. Knowing that TIPS have deflation protection, this negative BEI is even more puzzling.

Therefore, negative BEI is likely the result of a dramatic increase in the liquidity premium. Apparently, TIPS are not considered equivalent and as liquid as their matching nominal bonds. The severe financial crisis resulted in flight to liquidity among individual and institutional investors.

In contrast to the TIPS-implied inflation rates, we find from our inflation forecasts positive expected one-year ahead inflation. With respect to the trading strategies, this implies that the forecasted inflation rate was constantly higher than BEI during the last quarter of 2008 and the first two quarters of 2009. Hence, the break-even strategy for between the last quarter of 2008, and the second quarter of 2009 resulted in the same positions as the comparable long-only strategy. This means that for all TIPS series at the short and middle end of the TIPS yield curve did not earn excess returns over the respective return benchmark during these three quarters. Holdings only begin to differ from the benchmark strategy for the TIPS series with longer time to maturity at the end of May and June 2009.

To sum up, during the 2008 financial crisis, the break-even strategy was equivalent to a long-only strategy, because the dramatically increased liquidity premium depressed the BEI below zero, much below a realistic inflation forecast. This implies that TIPS are still not considered equivalent to nominal government securities. Investors ignored their

security and inflation protection in crisis times and apparently prefer the highest level of liquidity. The conclusion by Sack and Elsasser (2004) that TIPS will likely never achieve the same liquidity as nominal Treasury debt, largely because of the different roles that the two types of securities play in financial markets, is therefore still valid. Probably the liquidity premium required by the investors for holding TIPS also varies over time, depending on the economic conditions and financial market stability.

Another important observation during the crisis period is that the break-even strategy has negative excess returns for TIPS series starting in 2009, which can be seen in Tables 6, 7 and 8 (TIPS series with maturity date 15.01.2019 and 15.01.2029). This implies that the strategy did not perform well in the economic downturn.

## 5. Summary and Conclusions

The continuous existence of positive excess returns provides evidence of persistent TIPS market inefficiency which can be exploited by active traders. We found that the Survey of Professional Forecasters provides valuable information which can be exploited through break-even trades using three, six and twelve months holding periods. Further, long-term forecasting models seem to provide valuable information on a one-year ahead period, which can be also exploited through a break-even trading strategy with different holding periods. Generating positive excess returns from trading long-short TIPS using our simple inflation forecasts appear to be more challenging, which confirms the previous findings of Bardong and Lehnert (2004a,b and 2008). Our results can be interpreted as evidence against the efficiency of the inflation-linked bonds market in the US.

Bearing in mind that the Survey of Professional Forecasters is publicly available, realized excess returns based on its estimations of future inflation are a strong argument against semi-strong form of TIPS market efficiency. More significantly, the break-even strategy leads to excess return of approximately 3.5 percent per annum after accounting for transaction costs. Break-even trades that use inflation forecasts appear to be profitable at the short, middle and long end of the TIPS maturity spectrum.

More detailed analysis of the excess returns suggests that the break even strategy performed well in period of high economic uncertainty between the last quarter of 2007 and the third quarter of 2008). We observe positive returns across all series of TIPS in the quarter with the highest realized inflation rate. The main reason for these results is that TIPS become more attractive as the uncertainty regarding the future inflation rate increases. This also implies that in general, TIPS market participants' predictions of the future inflation rate during periods of economic uncertainty are generally weak. Hence, using an inflation forecasting model during ttimes of economic uncertainty appears to lead to significant excess returns for break-even trades.

With respect to the financial crisis period between the last quarter of 2008 and the second quarter of 2009, our observations further point to inefficiencies in the TIPS market. The most striking evidence from the results is that BEI in this period is negative for many series of TIPS, especially for series with shorter time to maturity. BEI is negative because the nominal rates are lower than the rates of TIPS. This implies that TIPS are not considered equivalent to government bonds, leading to a significant liquidity premium required for holding TIPS. Sack and Elsasser (2004) argue that TIPS will likely never achieve the same liquidity as nominal Treasury debt, largely because of the different roles that the two types of securities play in financial markets. Their conclusion is not only valid and but it further seems that the liquidity premium required by TIPS investors varies significantly over time depending on the perceived financial market stability.

To conclude, there are two important reasons to suggest TIPS market inefficiency. First, profitable trading strategies can be implemented using inflation forecasting models. Excess returns are even higher in periods with increased economic uncertainty. Second, TIPS seem to be still not considered substitutes for nominal bonds, because investors require a substantial liquidity during periods of financial crises. This implies that TIPS are a different asset class from the nominal bonds and could explain why they are held primarily by buy–and-hold investors. TIPS market inefficiency seems to persist over the entire maturity spectrum of the market. This also implies that break even inflation is not

necessarily a market estimate of future inflation. Informed investors are therefore likely to be able to exploit this inefficiency, as we find, even after taking into account the transaction costs. We also find, however, that the liquidity premium for investing in TIPS can vary substantially over time.

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**Figure 1: Annual Inflation Rate**

This figure presents the year-on-year inflation rate calculated based on the monthly values of CPI-U index for the period 1997-2009. The monthly values of CPI-U are retrieved from DataStream.

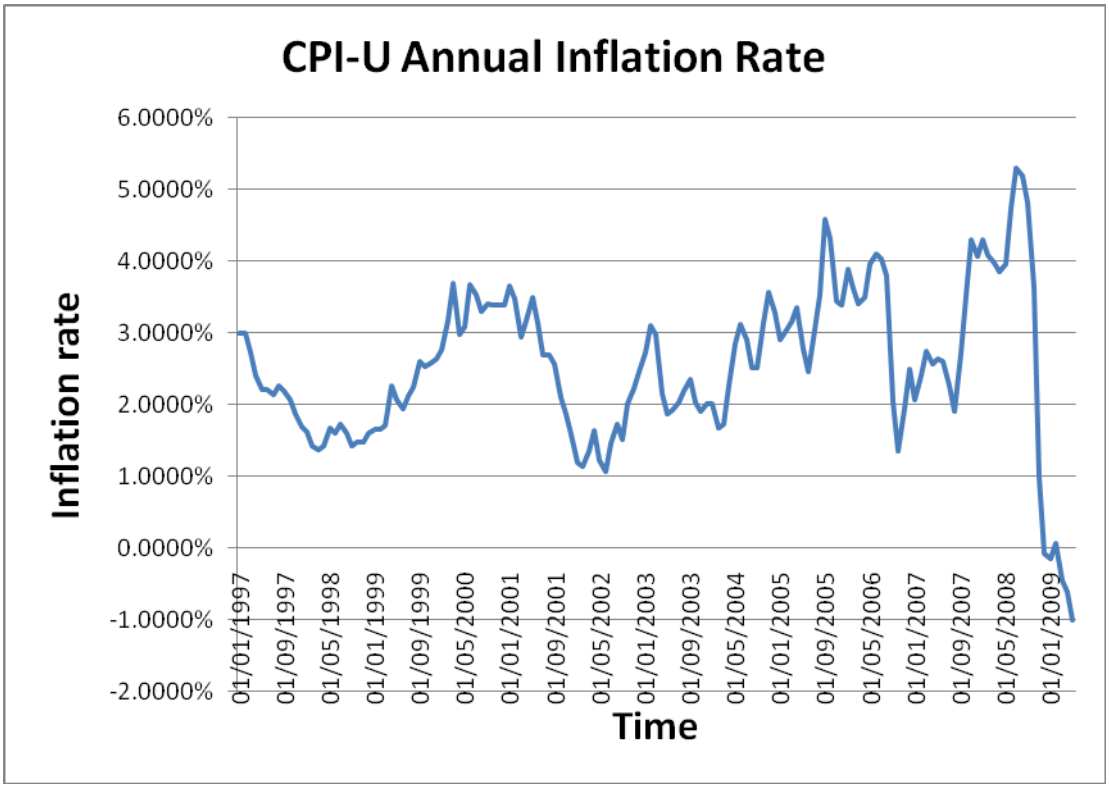

**Figure 2: Decomposition of nominal and real rates**

This figure presents a conceptual representation of nominal and real rates.

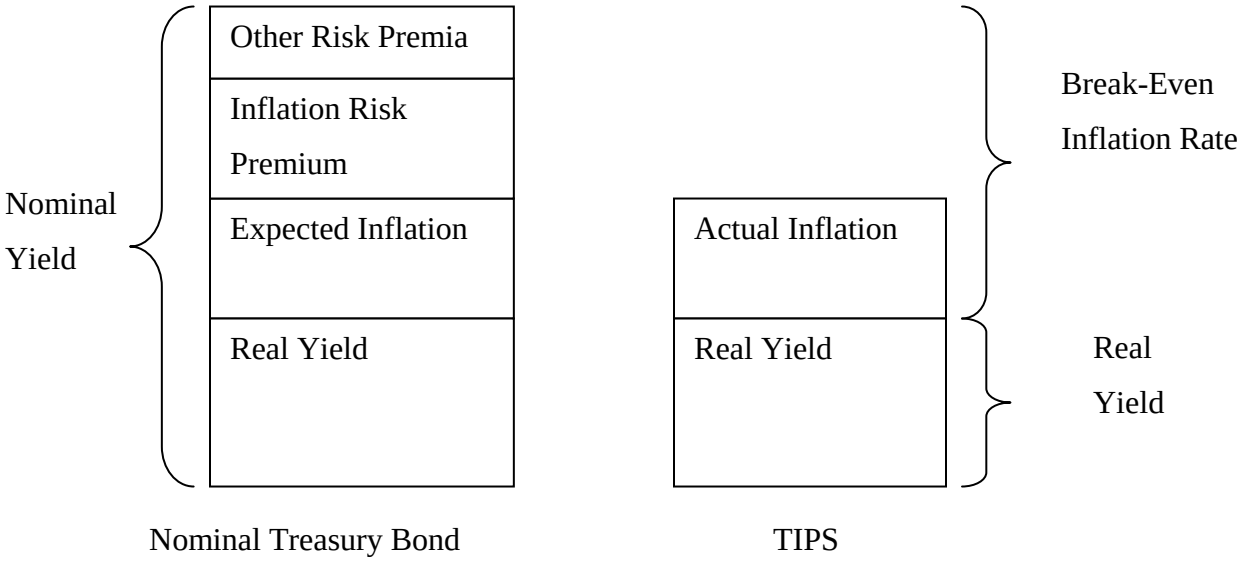

**Table 1: Matching of TIPS with nominal bonds with comparable maturity**

This table shows TIPS and their nominal counterparts, matched by maturity dates, and some summary statistics. The column *Name* shows the coupon paid semi-annually on TIPS series. The columns *Start of time series* and *Maturity date* refer to the dates when the series were issued and the maturity dates of TIPS. The columns *Average real returns* and *Standard deviation* present the average return and standard deviation of the return on each TIPS series separately. The nominal bonds series, STRIPS, start usually before the TIPS and therefore only the maturity date is reported for them. The columns *Average nominal return* and *Standard deviation* present the average nominal return and standard deviation on this return for each bond series.

| TIPS | | | | | Nominal Bonds | | | |
|---|---|---|---|---|---|---|---|---|
| Name | Start of time-series | Maturity date | Average Real Return | Standard Deviation | Name | Maturity Date | Average Nominal Return | Standard Deviation |
| TIPS - 3 3/8% | 30-1-1997 | 15-1-2007 | 2.70% | 1.73% | STRIPS | 15-2-2007 | 4.62% | 1.41% |
| TIPS - 3 5/8% | 12-1-1998 | 15-1-2008 | 2.56% | 1.27% | STRIPS | 15-2-2008 | 4.56% | 1.16% |
| TIPS - 3 7/8% | 7-1-1999 | 15-1-2009 | 2.64% | 2.71% | STRIPS | 15-2-2009 | 4.29% | 1.42% |
| TIPS - 4 1/4% | 18-1-2000 | 15-1-2010 | 2.22% | 1.27% | STRIPS | 15-2-2010 | 4.05% | 1.45% |
| TIPS - 7/8% | 27-10-2004 | 15-4-2010 | 1.88% | 1.24% | STRIPS | 15-5-2010 | 3.39% | 1.47% |
| TIPS - 3 1/2% | 16-1-2001 | 15-1-2011 | 2.04% | 0.98% | STRIPS | 15-2-2011 | 3.98% | 1.20% |
| TIPS - 2 3/8% | 26-4-2006 | 15-4-2011 | 1.88% | 1.07% | STRIPS | 15-5-2011 | 3.07% | 1.49% |
| TIPS - 3 3/8% | 10-1-2002 | 15-1-2012 | 1.93% | 0.77% | STRIPS | 15-2-2012 | 4.00% | 1.03% |
| TIPS - 2% | 25-4-2007 | 15-4-2012 | 1.59% | 0.93% | STRIPS | 15-5-2012 | 2.74% | 1.09% |
| TIPS - 3% | 11-7-2002 | 15-7-2012 | 1.86% | 0.66% | STRIPS | 15-8-2012 | 3.97% | 0.93% |
| TIPS - 5/8% | 23-4-2008 | 15-4-2013 | 1.32% | 0.57% | STRIPS | 15-5-2013 | 2.47% | 0.71% |
| TIPS - 1 7/8% | 10-7-2003 | 15-7-2013 | 1.88% | 0.59% | STRIPS | 15-8-2013 | 4.05% | 0.93% |
| TIPS - 2% | 9-1-2004 | 15-1-2014 | 1.92% | 0.59% | STRIPS | 15-2-2014 | 4.10% | 0.87% |
| TIPS - 1 1/4% | 24-4-2009 | 15-4-2014 | 1.11% | 0.11% | STRIPS | 15-5-2014 | 2.67% | 0.31% |
| TIPS - 2% | 9-7-2004 | 15-7-2014 | 1.94% | 0.58% | STRIPS | 15-8-2014 | 4.11% | 0.84% |
| TIPS - 1 5/8% | 14-1-2005 | 15-1-2015 | 2.01% | 0.58% | STRIPS | 15-2-2015 | 4.17% | 0.79% |
| TIPS - 1 7/8% | 15-7-2005 | 15-7-2015 | 2.05% | 0.58% | STRIPS | 15-8-2015 | 4.18% | 0.79% |
| TIPS - 2% | 13-1-2006 | 15-1-2016 | 2.10% | 0.58% | STRIPS | 15-2-2016 | 4.23% | 0.75% |
| TIPS - 2 1/2% | 18-7-2006 | 15-7-2016 | 2.06% | 0.59% | STRIPS | 15-8-2016 | 4.19% | 0.66% |
| TIPS - 2 3/8% | 12-1-2007 | 15-1-2017 | 2.02% | 0.59% | STRIPS | 15-2-2017 | 4.15% | 0.62% |
| TIPS - 2 5/8% | 13-7-2007 | 15-7-2017 | 1.90% | 0.56% | STRIPS | 15-8-2017 | 4.05% | 0.56% |
| TIPS - 1 5/8% | 11-1-2008 | 15-1-2018 | 1.82% | 0.53% | STRIPS | 15-2-2018 | 3.90% | 0.47% |
| TIPS - 1 3/8% | 11-7-2008 | 15-7-2018 | 3.01% | 0.46% | STRIPS | 15-8-2018 | 3.84% | 0.49% |
| TIPS - 2 1/8% | 7-1-2009 | 15-1-2019 | 1.72% | 0.19% | STRIPS | 15-2-2019 | 3.63% | 0.33% |
| TIPS - 2 3/8% | 28-7-2004 | 15-1-2025 | 2.23% | 0.30% | STRIPS | 15-2-2025 | 4.84% | 0.43% |
| TIPS - 2% | 25-1-2006 | 15-1-2026 | 2.32% | 0.29% | STRIPS | 15-2-2026 | 4.80% | 0.47% |
| TIPS - 2 3/8% | 24-1-2007 | 15-1-2027 | 2.30% | 0.31% | STRIPS | 15-2-2027 | 4.69% | 0.48% |
| TIPS - 1 3/4% | 25-1-2008 | 15-1-2028 | 2.25% | 0.33% | STRIPS | 15-2-2028 | 4.47% | 0.47% |
| TIPS - 3 5/8% | 14-4-1998 | 15-4-2028 | 2.86% | 0.74% | STRIPS | 15-5-2028 | 5.06% | 0.51% |
| TIPS - 2 1/2% | 27-1-2009 | 15-1-2029 | 2.31% | 0.15% | STRIPS | 15-5-2029 | 4.32% | 0.32% |
| TIPS - 3 7/8% | 8-4-1999 | 15-4-2029 | 2.77% | 0.73% | STRIPS | 15-5-2029 | 5.17% | 0.53% |
| TIPS - 3 3/8% | 11-10-2001 | 15-4-2032 | 2.33% | 0.45% | STRIPS | 15-2-2031 | 5.03% | 0.52% |

**Table 2: Inflation regressions: September 1990 to July 2009**

This table shows the performance of the Kothari and Shanken (2004) inflation model. Panel A refers to the relationship between current inflation and the explanatory variables observed one year earlier. The rows 1YrSpot, 5-1Spread, $Inf_t$ and $RR_t$ refer to the one-year spot rate, the yield spread between the five year zero-coupon bond and the one-year spot rate, the one-year lagged inflation rate and the sum of realized monthly returns on one-year zero-coupon bonds over the preceding one year period, respectively. Panel B presents the forecast of the change in two-tear-ahead inflation over one-year-ahead inflation rate. The row 1,2FwdSpread refers to the spread of a forward rate of a zero-coupon bond in one year over the current spot rate. Panel C presents the forecast of change in three-years-ahead inflation over the two-years-ahead inflation rate. The row 2,3FwdSpread denotes the spread of a forward rate of a one-year zero-coupon bond in two years over the forward rate of a zero-coupon bond in one year

**A. One-year-ahead inflation**

$$Inf_t = \beta_0 + \beta_1 1\text{YrSpot}_{t-1} + \beta_2 5\text{-}1\text{Spread}_{t-1} + \beta_3 Inf_{t-1} + \beta_4 RR_{t-1} + \varepsilon_t$$

| Variable | Coefficient | Std error | t-stat |
|---|---|---|---|
| Intercept | 0.038 | 0.001 | 49.05 |
| $1\text{YrSpot}_{t-1}$ | 0.264 | 0.012 | 21.57 |
| $5\text{-}1\text{Spread}_{t-1}$ | 0.099 | 0.023 | 4.27 |
| $Inf_{t-1}$ | -0.436 | 0.018 | -23.84 |
| $RR_{t-1}$ | -0.268 | 0.009 | -28.70 |
| Adjusted $R^2$ | 23.0% | | |

**B. Changes in two-years-ahead inflation**

$$\Delta Inf_t = \delta_0 + \delta_1 1,2\text{FwdSpread}_{t-2} + \delta_2 Inf_{t-2} + \delta_3 RR_{t-2} + \xi_t,$$

| | | | |
|---|---|---|---|
| Intercept | 0.073 | 0.099 | 0.73 |
| $1,2\text{FwdSpread}_{t-2}$ | 208.58 | 4.190 | 49.78 |
| $Inf_{t-2}$ | -38.469 | 2.788 | -13.80 |
| $RR_{t-2}$ | -4.322 | 1.070 | -4.04 |
| Adjusted $R^2$ | 43.2% | | |

**C. Change in three-years-ahead inflation**

$$\Delta Inf_t = \gamma_0 + \gamma_1 2,3\text{FwdSpread}_{t-3} + \gamma_2 Inf_{t-3} + \gamma_3 RR_{t-3} + \varsigma_t,$$

| | | | |
|---|---|---|---|
| Intercept | -2.515 | 0.110 | -22.808 |
| $2,3\text{FwdSpread}_{t-3}$ | 270.143 | 5.815 | 46.460 |
| $Inf_{t-3}$ | -0.299 | 3.024 | -0.099 |
| $RR_{t-3}$ | 25.332 | 1.120 | 22.418 |
| Adjusted $R^2$ | 38.3% | | |

**Table 3: Performance of Long-Short Strategy with $Q_0$ Forecasting Horizon**

This table presents the excess returns (ER) from the long-short trading strategy based on the $Q_0$ forecasting horizon and different holding periods. Columns *Name* and *Maturity date* provide the coupon and maturity date of each TIPS series. Excess returns for each holding period (HP) are presented with and without taking into account transaction costs. Columns *without TC* show the annual excess returns in percent without subtracting the trading costs. Columns *with TC* show the annual excess returns in percent after accounting for transaction costs.

| Long-Short Trading Strategy with Q0 Forecasting Horizon | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Maturity date | ER with HP 3months | | ER with HP 6months | | ER with HP 12 months | |
| | | without TC | with TC | without TC | with TC | without TC | with TC |
| TIPS - 3 3/8% | 15-1-2007 | 2.02% | 1.60% | 2.01% | 1.58% | 3.08% | 2.65% |
| TIPS - 3 5/8% | 15-1-2008 | 1.51% | 1.00% | 1.22% | 0.70% | 1.89% | 1.38% |
| TIPS - 3 7/8% | 15-1-2009 | 2.23% | 1.54% | 2.52% | 1.82% | 2.33% | 1.62% |
| TIPS - 4 1/4% | 15-1-2010 | 1.42% | 0.91% | 1.50% | 0.99% | 1.46% | 0.95% |
| TIPS - 7/8% | 15-4-2010 | 2.30% | 1.71% | 2.63% | 2.00% | 2.39% | 1.71% |
| TIPS - 3 1/2% | 15-1-2011 | 1.09% | 0.58% | 1.25% | 0.73% | 1.75% | 1.23% |
| TIPS - 2 3/8% | 15-4-2011 | -0.68% | -1.12% | 0.38% | -0.13% | 0.38% | -0.13% |
| TIPS - 3 3/8% | 15-1-2012 | -0.18% | -0.79% | 0.07% | -0.52% | -0.19% | -0.82% |
| TIPS - 2% | 15-4-2012 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 3% | 15-7-2012 | 1.30% | 0.60% | -0.10% | -0.81% | 1.64% | 0.93% |
| TIPS - 5/8% | 15-4-2013 | -1.26% | -2.19% | -1.59% | -2.51% | -4.60% | -5.52% |
| TIPS - 1 7/8% | 15-7-2013 | -0.42% | -0.96% | -0.05% | -0.59% | 0.01% | -0.52% |
| TIPS - 2% | 15-1-2014 | -0.80% | -1.19% | 0.02% | -0.36% | -0.45% | -0.83% |
| TIPS - 1 1/4% | 15-4-2014 | 9.57% | 7.31% | 9.57% | 7.31% | 9.57% | 7.31% |
| TIPS - 2% | 15-7-2014 | -1.68% | -2.28% | -1.27% | -1.89% | -1.19% | -1.84% |
| TIPS - 1 5/8% | 15-1-2015 | -0.83% | -1.69% | 0.11% | -0.76% | 0.60% | -0.32% |
| TIPS - 1 7/8% | 15-7-2015 | -0.28% | -1.28% | 0.55% | -0.48% | 0.55% | -0.51% |
| TIPS - 2% | 15-1-2016 | -0.64% | -1.79% | -0.06% | -1.24% | 0.22% | -1.02% |
| TIPS - 2 1/2% | 15-7-2016 | -5.56% | -6.68% | -4.42% | -5.54% | -5.00% | -6.12% |
| TIPS - 2 3/8% | 15-1-2017 | -5.39% | -6.61% | -4.60% | -5.82% | -4.63% | -5.84% |
| TIPS - 2 5/8% | 15-7-2017 | -5.93% | -6.95% | -4.97% | -5.99% | -4.97% | -5.99% |
| TIPS - 1 5/8% | 15-1-2018 | 4.35% | 3.44% | 5.35% | 4.44% | 5.35% | 4.44% |
| TIPS - 1 3/8% | 15-7-2018 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 2 1/8% | 15-1-2019 | -0.75% | -1.49% | -3.25% | -3.99% | -3.25% | -3.99% |
| TIPS - 2 3/8% | 15-1-2025 | -6.36% | -6.71% | -5.73% | -6.09% | -5.69% | -6.05% |
| TIPS - 2% | 15-1-2026 | -5.27% | -5.84% | -5.19% | -5.76% | -5.12% | -5.64% |
| TIPS - 2 3/8% | 15-1-2027 | -7.07% | -7.39% | -7.14% | -7.46% | -7.14% | -7.46% |
| TIPS - 1 3/4% | 15-1-2028 | 3.01% | 2.10% | 3.62% | 2.71% | 3.57% | 2.65% |
| TIPS - 3 5/8% | 15-4-2028 | -3.84% | -4.16% | -4.25% | -4.77% | -5.39% | -5.94% |
| TIPS - 2 1/2% | 15-1-2029 | -19.66% | -20.90% | -18.07% | -19.30% | -18.07% | -19.30% |
| TIPS - 3 7/8% | 15-4-2029 | -3.70% | -3.99% | -4.09% | -4.49% | -4.51% | -4.92% |
| TIPS - 3 3/8% | 15-4-2032 | -4.31% | -4.65% | -4.40% | -4.72% | -5.66% | -6.01% |

**Table 4: Performance of Long-Short Strategy with $Q_1$ Forecasting Horizon**

This table presents the excess returns (ER) from the long-short trading strategy based on the $Q_1$ forecasting horizon and different holding periods. Columns *Name* and *Maturity date* provide the coupon and maturity date of each TIPS series. Excess returns for each holding period (HP) are presented with and without taking into account transaction costs. Columns *without TC* show the annual excess returns in percent without subtracting trading costs. Columns *with TC* show the annual excess returns in percent after accounting for transaction costs.

| Long-Short Trading Strategy with Q1 Forecasting Horizon | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Maturity date | ER with HP 3months | | ER with HP 6months | | ER with HP 12 months | |
| | | without TC | with TC | without TC | with TC | without TC | with TC |
| TIPS - 3 3/8% | 15-1-2007 | 2.21% | 1.91% | 2.20% | 1.88% | 3.26% | 2.95% |
| TIPS - 3 5/8% | 15-1-2008 | 1.93% | 1.38% | 2.05% | 1.48% | 1.96% | 1.39% |
| TIPS - 3 7/8% | 15-1-2009 | 2.50% | 1.76% | 2.27% | 1.50% | 2.57% | 1.80% |
| TIPS - 4 1/4% | 15-1-2010 | 1.30% | 0.80% | 1.36% | 0.86% | 1.32% | 0.80% |
| TIPS - 7/8% | 15-4-2010 | 2.65% | 1.97% | 3.20% | 2.47% | 2.92% | 2.14% |
| TIPS - 3 1/2% | 15-1-2011 | 0.84% | 0.36% | 0.99% | 0.49% | 1.44% | 0.95% |
| TIPS - 2 3/8% | 15-4-2011 | -0.30% | -0.75% | -0.35% | -0.84% | -0.87% | -1.36% |
| TIPS - 3 3/8% | 15-1-2012 | -0.38% | -0.84% | -0.53% | -0.99% | -0.29% | -0.76% |
| TIPS - 2% | 15-4-2012 | -0.48% | -0.63% | -0.42% | -0.57% | -0.35% | -0.50% |
| TIPS - 3% | 15-7-2012 | 0.14% | -0.60% | 0.41% | -0.33% | 0.48% | -0.26% |
| TIPS - 5/8% | 15-4-2013 | -0.17% | -0.91% | -0.50% | -1.24% | -3.18% | -3.91% |
| TIPS - 1 7/8% | 15-7-2013 | -1.13% | -1.74% | -0.76% | -1.37% | -0.77% | -1.38% |
| TIPS - 2% | 15-1-2014 | -1.29% | -1.79% | -0.82% | -1.33% | -0.67% | -1.17% |
| TIPS - 1 1/4% | 15-4-2014 | 12.82% | 12.25% | 12.82% | 12.25% | 12.82% | 12.25% |
| TIPS - 2% | 15-7-2014 | -1.22% | -2.04% | -0.81% | -1.66% | -0.70% | -1.57% |
| TIPS - 1 5/8% | 15-1-2015 | -1.01% | -1.73% | -0.12% | -0.86% | 0.46% | -0.34% |
| TIPS - 1 7/8% | 15-7-2015 | -1.92% | -2.62% | -1.48% | -2.21% | -1.04% | -1.82% |
| TIPS - 2% | 15-1-2016 | 0.00% | -0.60% | 3.42% | 2.78% | 0.81% | 0.17% |
| TIPS - 2 1/2% | 15-7-2016 | -4.85% | -5.70% | -4.28% | -5.26% | -4.28% | -5.26% |
| TIPS - 2 3/8% | 15-1-2017 | -3.28% | -4.22% | -2.66% | -3.69% | -2.68% | -3.72% |
| TIPS - 2 5/8% | 15-7-2017 | -4.16% | -4.95% | -3.19% | -3.99% | -3.19% | -3.99% |
| TIPS - 1 5/8% | 15-1-2018 | 3.82% | 3.22% | 5.42% | 4.81% | 5.42% | 4.81% |
| TIPS - 1 3/8% | 15-7-2018 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 2 1/8% | 15-1-2019 | 3.41% | 2.17% | 3.41% | 1.67% | 3.41% | 1.67% |
| TIPS - 2 3/8% | 15-1-2025 | -3.05% | -3.27% | -2.42% | -2.64% | -2.38% | -2.60% |
| TIPS - 2% | 15-1-2026 | -1.29% | -1.48% | -0.74% | -1.00% | -0.68% | -0.93% |
| TIPS - 2 3/8% | 15-1-2027 | -3.26% | -3.53% | -3.33% | -3.65% | -3.46% | -3.77% |
| TIPS - 1 3/4% | 15-1-2028 | 6.99% | 6.23% | 7.60% | 6.84% | 7.54% | 6.78% |
| TIPS - 3 5/8% | 15-4-2028 | -1.72% | -1.85% | -2.06% | -2.19% | -3.20% | -3.36% |
| TIPS - 2 1/2% | 15-1-2029 | -24.42% | -25.65% | -29.20% | -30.43% | -29.20% | -30.43% |
| TIPS - 3 7/8% | 15-4-2029 | -1.24% | -1.55% | -1.48% | -1.81% | -2.08% | -2.42% |
| TIPS - 3 3/8% | 15-4-2032 | -3.77% | -4.07% | -4.28% | -4.58% | -5.54% | -5.87% |

**Table 5: Performance of Long-Short Strategy with $Y_1$ Forecasting Horizon**

This table presents the excess returns (ER) from long-short trading strategy based on the $Y_1$ forecasting horizon and different holding periods. Columns *Name* and *Maturity date* provide the coupon and maturity date of each TIPS series. Excess returns for each holding period (HP) are presented with and without taking into account transaction costs. Columns *without TC* show the annual excess returns in percent without subtracting trading costs. Columns with TC show the annual excess returns in percent after accounting for transaction costs.

| Long-Short Trading Strategy with Y1 Forecasting Horizon | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Maturity date | ER with HP 3months | | ER with HP 6months | | ER with HP 12 months | |
| | | without TC | with TC | without TC | with TC | without TC | with TC |
| TIPS - 3 3/8% | 15-1-2007 | 0.66% | 0.24% | 0.46% | 0.03% | 2.12% | 1.69% |
| TIPS - 3 5/8% | 15-1-2008 | 0.23% | -0.21% | 0.17% | -0.27% | 0.59% | 0.15% |
| TIPS - 3 7/8% | 15-1-2009 | 0.79% | 0.39% | 0.78% | 0.39% | 0.78% | 0.39% |
| TIPS - 4 1/4% | 15-1-2010 | -0.38% | -0.81% | -0.96% | -1.40% | -1.08% | -1.53% |
| TIPS - 7/8% | 15-4-2010 | 0.08% | -0.15% | 0.00% | -0.23% | 0.10% | -0.13% |
| TIPS - 3 1/2% | 15-1-2011 | -1.15% | -1.89% | -1.67% | -2.41% | -3.45% | -4.19% |
| TIPS - 2 3/8% | 15-4-2011 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 3 3/8% | 15-1-2012 | -3.61% | -4.25% | -3.60% | -4.24% | -3.77% | -4.40% |
| TIPS - 2% | 15-4-2012 | -0.38% | -0.49% | -0.38% | -0.49% | -0.38% | -0.49% |
| TIPS - 3% | 15-7-2012 | -1.72% | -2.29% | 0.52% | -0.05% | 0.52% | -0.05% |
| TIPS - 5/8% | 15-4-2013 | -0.10% | -0.75% | -0.43% | -1.07% | -2.74% | -3.38% |
| TIPS - 1 7/8% | 15-7-2013 | 1.25% | 0.72% | 1.28% | 0.75% | 1.28% | 0.75% |
| TIPS - 2% | 15-1-2014 | 0.76% | 0.11% | 0.79% | 0.14% | 0.51% | -0.13% |
| TIPS - 1 1/4% | 15-4-2014 | 13.45% | 11.76% | 13.45% | 11.76% | 13.45% | 11.76% |
| TIPS - 2% | 15-7-2014 | 0.03% | -0.46% | 0.03% | -0.46% | 0.03% | -0.46% |
| TIPS - 1 5/8% | 15-1-2015 | -1.45% | -1.89% | -1.42% | -1.89% | -1.47% | -1.94% |
| TIPS - 1 7/8% | 15-7-2015 | -0.66% | -1.44% | -0.14% | -0.95% | -0.63% | -1.44% |
| TIPS - 2% | 15-1-2016 | -2.56% | -3.68% | -2.46% | -3.58% | -2.52% | -3.64% |
| TIPS - 2 1/2% | 15-7-2016 | 0.27% | -1.19% | 0.83% | -0.66% | 0.83% | -0.66% |
| TIPS - 2 3/8% | 15-1-2017 | 2.01% | 0.79% | 2.80% | 1.58% | 2.50% | 1.29% |
| TIPS - 2 5/8% | 15-7-2017 | 0.55% | -0.35% | 1.22% | 0.32% | 1.22% | 0.32% |
| TIPS - 1 5/8% | 15-1-2018 | 1.95% | 0.96% | 2.95% | 1.96% | 2.95% | 1.96% |
| TIPS - 1 3/8% | 15-7-2018 | 2.53% | 2.41% | 2.53% | 2.41% | 2.53% | 2.41% |
| TIPS - 2 1/8% | 15-1-2019 | 4.45% | 3.71% | 1.95% | 1.21% | 1.95% | 1.21% |
| TIPS - 2 3/8% | 15-1-2025 | 0.55% | -0.23% | 0.83% | 0.05% | 3.44% | 2.64% |
| TIPS - 2% | 15-1-2026 | 3.06% | 2.29% | -1.02% | -1.78% | 3.12% | 2.36% |
| TIPS - 2 3/8% | 15-1-2027 | 6.58% | 5.68% | 6.87% | 5.97% | 6.75% | 5.85% |
| TIPS - 1 3/4% | 15-1-2028 | 1.74% | 0.14% | 2.35% | 0.75% | 2.29% | 0.69% |
| TIPS - 3 5/8% | 15-4-2028 | -6.92% | -7.88% | -7.79% | -8.75% | -7.83% | -8.97% |
| TIPS - 2 1/2% | 15-1-2029 | -4.60% | -4.60% | -9.38% | -9.38% | -9.38% | -9.38% |
| TIPS - 3 7/8% | 15-4-2029 | -3.63% | -4.50% | -4.55% | -5.36% | -4.54% | -5.35% |
| TIPS - 3 3/8% | 15-4-2032 | -2.41% | -3.29% | -2.80% | -3.68% | -4.20% | -5.08% |

**Table 6: Performance of Break-even Strategy with $Q_0$ Forecasting Horizon**

This table presents the excess returns (ER) from the break-even trading strategy based on the $Q_0$ forecasting horizon and different holding periods. Columns *Name* and *Maturity date* provide the coupon and maturity date of each TIPS series. Excess returns for each holding period (HP) are presented with and without taking into account transaction costs. Columns *without TC* show the annual excess returns in percent without subtracting trading costs. Columns *with TC* show the annual excess returns in percent after accounting for the transaction costs.

| Break-even Trading Strategy with Q0 Forecasting Horizon | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Maturity date | ER with HP 3months | | ER with HP 6months | | ER with HP 12 months | |
| | | without TC | with TC | without TC | with TC | without TC | with TC |
| TIPS - 3 3/8% | 15-1-2007 | 4.33% | 3.91% | 4.32% | 3.89% | 4.34% | 3.91% |
| TIPS - 3 5/8% | 15-1-2008 | 3.56% | 3.04% | 3.60% | 3.09% | 3.64% | 3.10% |
| TIPS - 3 7/8% | 15-1-2009 | 5.48% | 4.79% | 5.10% | 4.39% | 5.30% | 4.59% |
| TIPS - 4 1/4% | 15-1-2010 | 4.39% | 3.88% | 4.35% | 3.84% | 4.39% | 3.88% |
| TIPS - 7/8% | 15-4-2010 | 2.88% | 2.29% | 2.98% | 2.35% | 2.97% | 2.34% |
| TIPS - 3 1/2% | 15-1-2011 | 4.26% | 3.75% | 4.19% | 3.67% | 5.59% | 5.07% |
| TIPS - 2 3/8% | 15-4-2011 | 0.91% | 0.49% | 1.65% | 1.17% | 3.25% | 2.77% |
| TIPS - 3 3/8% | 15-1-2012 | 4.85% | 4.25% | 4.81% | 4.20% | 4.80% | 4.18% |
| TIPS - 2% | 15-4-2012 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 3% | 15-7-2012 | 4.94% | 4.24% | 4.86% | 4.15% | 5.01% | 4.30% |
| TIPS - 5/8% | 15-4-2013 | 2.05% | 1.13% | 1.82% | 0.90% | 0.52% | -0.40% |
| TIPS - 1 7/8% | 15-7-2013 | 4.28% | 3.75% | 4.22% | 3.68% | 4.29% | 3.75% |
| TIPS - 2% | 15-1-2014 | 5.44% | 5.03% | 5.36% | 4.98% | 5.25% | 4.86% |
| TIPS - 1 1/4% | 15-4-2014 | 12.44% | 10.17% | 12.44% | 10.17% | 12.44% | 10.17% |
| TIPS - 2% | 15-7-2014 | 5.67% | 5.07% | 5.68% | 5.06% | 5.80% | 5.15% |
| TIPS - 1 5/8% | 15-1-2015 | 5.03% | 4.17% | 5.12% | 4.23% | 5.17% | 4.23% |
| TIPS - 1 7/8% | 15-7-2015 | 3.98% | 2.97% | 2.97% | 1.94% | 4.03% | 2.98% |
| TIPS - 2% | 15-1-2016 | 4.04% | 2.89% | 4.14% | 2.96% | 4.21% | 2.97% |
| TIPS - 2 1/2% | 15-7-2016 | 5.55% | 4.43% | 5.70% | 4.58% | 5.70% | 4.58% |
| TIPS - 2 3/8% | 15-1-2017 | 5.35% | 4.14% | 5.54% | 4.32% | 5.39% | 4.17% |
| TIPS - 2 5/8% | 15-7-2017 | 6.63% | 5.61% | 6.87% | 5.86% | 6.87% | 5.86% |
| TIPS - 1 5/8% | 15-1-2018 | 4.69% | 3.78% | 4.33% | 3.41% | 4.21% | 3.30% |
| TIPS - 1 3/8% | 15-7-2018 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 2 1/8% | 15-1-2019 | 0.45% | -0.29% | -0.53% | -1.27% | -0.53% | -1.27% |
| TIPS - 2 3/8% | 15-1-2025 | 11.80% | 11.44% | 12.08% | 11.72% | 12.21% | 11.85% |
| TIPS - 2% | 15-1-2026 | 2.73% | 2.15% | 3.18% | 2.61% | 3.07% | 2.49% |
| TIPS - 2 3/8% | 15-1-2027 | 1.30% | 0.98% | 1.45% | 1.14% | 1.25% | 0.93% |
| TIPS - 1 3/4% | 15-1-2028 | 8.44% | 7.53% | 8.45% | 7.54% | 8.15% | 7.24% |
| TIPS - 3 5/8% | 15-4-2028 | 9.00% | 8.68% | 9.00% | 8.67% | 9.72% | 9.39% |
| TIPS - 2 1/2% | 15-1-2029 | -15.20% | -16.44% | -13.62% | -14.85% | -13.62% | -14.85% |
| TIPS - 3 7/8% | 15-4-2029 | 5.95% | 5.66% | 5.75% | 5.46% | 5.82% | 5.53% |
| TIPS - 3 3/8% | 15-4-2032 | 5.87% | 5.54% | 5.58% | 5.24% | 6.08% | 5.75% |

**Table 7: Performance of Break-even Strategy with $Q_1$ Forecasting Horizon**

This table presents the excess returns (ER) from break-even trading strategy based on $Q_1$ forecasting horizon and different holding periods. Columns *Name* and *Maturity date* provide the coupon and maturity date of each TIPS series. Excess returns for each holding period (HP) are presented with and without taking into account transaction costs. Columns *without TC* show the annual excess returns in percent without subtracting trading costs. Columns *with TC* show the annual excess returns in percent after accounting for transaction costs.

| Break-even Trading Strategy with Q1 Forecasting Horizon | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Maturity date | ER with HP 3months | | ER with HP 6months | | ER with HP 12 months | |
| | | without TC | with TC | without TC | with TC | without TC | with TC |
| TIPS - 3 3/8% | 15-1-2007 | 4.03% | 3.74% | 4.02% | 3.70% | 4.04% | 3.72% |
| TIPS - 3 5/8% | 15-1-2008 | 3.68% | 3.11% | 3.65% | 3.07% | 3.60% | 3.02% |
| TIPS - 3 7/8% | 15-1-2009 | 5.92% | 5.18% | 6.29% | 5.52% | 5.83% | 5.06% |
| TIPS - 4 1/4% | 15-1-2010 | 4.70% | 4.20% | 4.64% | 4.13% | 4.69% | 4.18% |
| TIPS - 7/8% | 15-4-2010 | 3.03% | 2.35% | 3.43% | 2.71% | 3.58% | 2.81% |
| TIPS - 3 1/2% | 15-1-2011 | 4.46% | 3.97% | 4.38% | 3.89% | 5.79% | 5.29% |
| TIPS - 2 3/8% | 15-4-2011 | 0.92% | 0.48% | 0.84% | 0.36% | 3.03% | 2.54% |
| TIPS - 3 3/8% | 15-1-2012 | 5.07% | 4.61% | 5.03% | 4.57% | 5.02% | 4.55% |
| TIPS - 2% | 15-4-2012 | -0.48% | -0.63% | -0.48% | -0.63% | -0.48% | -0.63% |
| TIPS - 3% | 15-7-2012 | 5.33% | 4.58% | 4.85% | 4.10% | 5.40% | 4.66% |
| TIPS - 5/8% | 15-4-2013 | 0.83% | 0.09% | 0.60% | -0.14% | 1.26% | 0.53% |
| TIPS - 1 7/8% | 15-7-2013 | 5.08% | 4.47% | 5.02% | 4.41% | 5.11% | 4.50% |
| TIPS - 2% | 15-1-2014 | 6.22% | 5.72% | 5.97% | 5.47% | 5.85% | 5.34% |
| TIPS - 1 1/4% | 15-4-2014 | 12.94% | 12.38% | 12.94% | 12.38% | 12.94% | 12.38% |
| TIPS - 2% | 15-7-2014 | 7.32% | 6.49% | 7.33% | 6.48% | 7.71% | 6.84% |
| TIPS - 1 5/8% | 15-1-2015 | 6.10% | 5.39% | 6.19% | 5.44% | 6.25% | 5.45% |
| TIPS - 1 7/8% | 15-7-2015 | 4.71% | 4.01% | 4.99% | 4.26% | 4.70% | 3.92% |
| TIPS - 2% | 15-1-2016 | 4.75% | 4.14% | 4.70% | 4.06% | 4.69% | 4.05% |
| TIPS - 2 1/2% | 15-7-2016 | 6.61% | 5.75% | 6.58% | 5.61% | 6.58% | 5.61% |
| TIPS - 2 3/8% | 15-1-2017 | 3.92% | 2.98% | 3.68% | 2.64% | 3.53% | 2.49% |
| TIPS - 2 5/8% | 15-7-2017 | 4.72% | 3.93% | 4.97% | 4.18% | 4.97% | 4.18% |
| TIPS - 1 5/8% | 15-1-2018 | 3.10% | 2.49% | 3.10% | 2.49% | 2.98% | 2.38% |
| TIPS - 1 3/8% | 15-7-2018 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 2 1/8% | 15-1-2019 | 4.60% | 3.36% | 4.60% | 2.87% | 4.60% | 2.87% |
| TIPS - 2 3/8% | 15-1-2025 | 10.62% | 10.40% | 10.90% | 10.68% | 11.03% | 10.81% |
| TIPS - 2% | 15-1-2026 | 0.71% | 0.51% | 1.00% | 0.75% | 0.89% | 0.63% |
| TIPS - 2 3/8% | 15-1-2027 | 0.18% | -0.09% | 0.34% | 0.02% | 0.13% | -0.18% |
| TIPS - 1 3/4% | 15-1-2028 | 1.29% | 0.53% | 1.31% | 0.55% | 1.00% | 0.24% |
| TIPS - 3 5/8% | 15-4-2028 | 7.72% | 7.60% | 7.66% | 7.54% | 8.55% | 8.40% |
| TIPS - 2 1/2% | 15-1-2029 | -17.10% | -18.33% | -15.51% | -16.75% | -15.51% | -16.75% |
| TIPS - 3 7/8% | 15-4-2029 | 8.96% | 8.65% | 8.03% | 7.70% | 6.16% | 5.82% |
| TIPS - 3 3/8% | 15-4-2032 | 7.51% | 7.19% | 6.69% | 6.38% | 7.27% | 6.94% |

**Table 8: Performance of Break-even Strategy with $Y_1$ Forecasting Horizon**

This table presents the excess returns (ER) from break-even trading strategy based on $Y_1$ forecasting horizon and different holding periods. Columns *Name* and *Maturity date* provide the coupon and maturity date of each TIPS series. Excess returns for each holding period (HP) are presented with and without taking into account transaction costs. Columns *without TC* show the annual excess returns in percent without subtracting trading costs. Columns *with TC* show the annual excess returns in percent after accounting for transaction costs.

| Break-even Trading Strategy with Y1 Forecasting Horizon | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Maturity date | ER with HP 3months | | ER with HP 6months | | ER with HP 12 months | |
| | | without TC | with TC | without TC | with TC | without TC | with TC |
| TIPS - 3 3/8% | 15-1-2007 | 4.48% | 4.06% | 4.47% | 4.04% | 5.46% | 5.03% |
| TIPS - 3 5/8% | 15-1-2008 | 2.14% | 1.70% | 1.87% | 1.43% | 2.22% | 1.78% |
| TIPS - 3 7/8% | 15-1-2009 | 2.46% | 2.07% | 2.10% | 1.71% | 3.07% | 2.68% |
| TIPS - 4 1/4% | 15-1-2010 | 2.13% | 1.70% | 1.50% | 1.05% | 3.14% | 2.70% |
| TIPS - 7/8% | 15-4-2010 | 0.28% | 0.05% | 0.69% | 0.46% | 1.26% | 1.02% |
| TIPS - 3 1/2% | 15-1-2011 | 3.64% | 2.91% | 3.11% | 2.37% | 5.15% | 4.41% |
| TIPS - 2 3/8% | 15-4-2011 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| TIPS - 3 3/8% | 15-1-2012 | 3.77% | 3.12% | 3.66% | 3.04% | 4.79% | 4.16% |
| TIPS - 2% | 15-4-2012 | -0.38% | -0.49% | -0.38% | -0.49% | -0.38% | -0.49% |
| TIPS - 3% | 15-7-2012 | 2.41% | 1.84% | 1.18% | 0.61% | 1.18% | 0.61% |
| TIPS - 5/8% | 15-4-2013 | 3.54% | 2.90% | 3.31% | 2.67% | 1.15% | 0.51% |
| TIPS - 1 7/8% | 15-7-2013 | 2.76% | 2.74% | 4.21% | 3.67% | 5.67% | 5.13% |
| TIPS - 2% | 15-1-2014 | 2.96% | 2.31% | 2.82% | 2.17% | 2.74% | 3.38% |
| TIPS - 1 1/4% | 15-4-2014 | -1.99% | -3.68% | -1.99% | -3.68% | -1.99% | -3.68% |
| TIPS - 2% | 15-7-2014 | 2.85% | 2.36% | 2.85% | 2.36% | 2.85% | 2.36% |
| TIPS - 1 5/8% | 15-1-2015 | 2.24% | 1.79% | 2.35% | 1.88% | 2.33% | 1.86% |
| TIPS - 1 7/8% | 15-7-2015 | 3.67% | 2.89% | 3.73% | 2.92% | 3.37% | 2.56% |
| TIPS - 2% | 15-1-2016 | 4.21% | 3.09% | 5.07% | 3.95% | 4.96% | 3.85% |
| TIPS - 2 1/2% | 15-7-2016 | 6.31% | 4.82% | 6.51% | 5.01% | 6.51% | 5.01% |
| TIPS - 2 3/8% | 15-1-2017 | 2.53% | 1.31% | 2.30% | 1.08% | 8.56% | 7.34% |
| TIPS - 2 5/8% | 15-7-2017 | 2.88% | 1.98% | 2.90% | 2.00% | 2.90% | 2.00% |
| TIPS - 1 5/8% | 15-1-2018 | -0.63% | -1.62% | -0.99% | -1.98% | -1.11% | -2.10% |
| TIPS - 1 3/8% | 15-7-2018 | 3.50% | 3.39% | 3.50% | 3.39% | 3.50% | 3.39% |
| TIPS - 2 1/8% | 15-1-2019 | -22.41% | -23.15% | -23.39% | -24.13% | -23.39% | -24.13% |
| TIPS - 2 3/8% | 15-1-2025 | 10.04% | 9.26% | 10.22% | 9.45% | 10.30% | 11.10% |
| TIPS - 2% | 15-1-2026 | 8.20% | 7.43% | 10.12% | 9.35% | 14.30% | 13.53% |
| TIPS - 2 3/8% | 15-1-2027 | 11.39% | 10.49% | 11.42% | 10.52% | 11.22% | 10.32% |
| TIPS - 1 3/4% | 15-1-2028 | 25.62% | 24.03% | 25.64% | 24.04% | 25.34% | 23.74% |
| TIPS - 3 5/8% | 15-4-2028 | 12.05% | 11.09% | 11.99% | 11.03% | 12.33% | 11.37% |
| TIPS - 2 1/2% | 15-1-2029 | -70.49% | -70.49% | -68.90% | -68.90% | -68.90% | -68.90% |
| TIPS - 3 7/8% | 15-4-2029 | 5.74% | 4.93% | 6.04% | 5.23% | 6.40% | 5.60% |
| TIPS - 3 3/8% | 15-4-2032 | 10.98% | 10.10% | 11.59% | 10.71% | 12.22% | 11.35% |