Riding the Yield Curve: Diversification of Strategies*

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Abstract

Riding the yield curve, the fixed-income strategy of purchasing a longer-dated security and selling before maturity, has long been a popular means to achieve excess returns compared to buying-and-holding, despite its implicit violations of market efficiency and the pure expectations hypothesis of the term structure. This paper looks at the historic excess returns of different strategies across three countries and proposes several statistical and macro-based trading rules which seem to enhance returns even more. While riding based on the Taylor Rule works well even for longer investment horizons, our empirical results indicate that, using expectations implied by Fed funds futures, excess returns can only be increased over short horizons. Furthermore, we demonstrate that duration-neutral strategies are superior to standard riding on a risk-adjusted basis. Overall, our evidence stands in contrast to the pure expectations hypothesis and points to the existence of risk premia which may be exploited consistently.

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In its most simple form, the rational expectations hypothesis of the term structure of interest rates (REHTS) posits that in a world with risk-neutral investors, the n-period long rate is a weighted average of the future spot rates and thus any one-period forward rate is an unbiased predictor of the corresponding future one-period spot rate. Consequently, the expectations hypothesis implies that, with the possible exception of a term premium, the holding period returns (HPRs) of a class of fixed-income instruments are identical, independent of the instruments' original maturity.[1] Under this assumption, for example, the returns from purchasing a 3-month government security and holding it until maturity and the returns from purchasing a 12-month government security and holding it for 3 months are identical. The strategy of purchasing a longer-dated security and selling it before maturity is referred to as *riding the yield curve.*

If the REHTS holds, then, for any given holding period, riding strategies should not yield excess returns compared to holding a short-dated security until maturity. Any evidence of persisting excess returns from such trading strategies would indicate the existence of risk premia associated with the term structure. The body of literature on different tests of the expectations hypothesis is very large and overall the results remain inconclusive.[2]

While the majority of tests of the expectations hypothesis are hinged on testing for the predictive power of forward rates in terms of future sport rates, there is a small strand of literature that examines the persistence of excess returns from riding strategies across different holding horizons with different maturity instruments. In their seminal paper, Dyl and Joehnk (1981) examine different riding strategies for U.S. T-Bill issues from 1970 to 1975 and find that there are significant, albeit small, excess HPRs to be made from riding the yield curve. They use a simple filter rule based of break-even yield changes in order to quantify the ex-ante riskiness from riding the yield curve. Based on this filter, their results indicate that the returns increase both with the holding horizon and the maturity of the instrument.

Grieves (1992) is able to replicate similar results by looking at a much longer time series of monthly zero coupon T-Bill rates from 1949 to 1988. He applies the same filter rule as Dyl and Joehnk to identify, ex-ante, under what type of yield curve environment excess returns from rolling can be anticipated. While his results confirm that longer-maturity rides outperform the simple buy-and-hold strategy of the short-term instrument, he concludes that, on a risk-adjusted basis, longer rides perform slightly worse because of increased interest rate risk. Overall, he finds evidence against the pure form of the expectations hypothesis since it appears that profitable trading strategies have gone unexploited. Using daily closing prices for regular U.S. T-Bill issues from 1987 to 1997, Grieves et al. (1999) are able to confirm their earlier findings and they also find that their results are relatively stable over time. In contrast to Dyl and Joehnk, they conclude that conditioning the ride on the steepness of the yield curve does not seem to improve the performance significantly. The existing literature of studies on excess returns from riding the yield curve is exclusively limited to examining the money market sector of the yield curve, i.e. maturities below 12 months and has thus far only studied the U.S. Treasury market.

In this paper, we aim to add to this strand of literature by looking at riding strategies for maturities beyond one year, looking at different currencies (euro and sterling) and also comparing rides between risk-free government securities and instruments that contain some level of credit risk, namely LIBOR-based deposits and swaps. In addition, we propose and test some forward looking strategies based on either simple statistical measures or on economic models that incorporate the main drivers of the yield curve. The main purpose of such rules is to provide market practitioners with a simple tool set that not only allows them to identify potentially profitable riding strategies, but also enables an ex-ante ranking of individual strategies.

The remainder of this paper is structured as follows. Section II discusses the mathematics involved with different riding horizons and different instruments and the methodology implemented to calculate the returns. Section III discusses the data whereas in section IV we propose some simple filter rules that help to take advantage of profitable rides. Section V looks at the empirical results from riding the yield curve. Section VI reviews our main results and provides some hands-on advice for market practitioners.

I Riding the Yield Curve

Riding the yield curve refers to the purchase of a longer-dated security and selling it before maturity.[3] The purpose of riding the yield curve is to benefit from certain interest rate environments. In particular, if a fixed-income manager has the choice between investing in a one-month deposit or a 12-month money market instrument and selling after one month, there are certain rules of thumb as to which strategy might yield a higher return. For instance, when the yield curve is relatively steep and interest rates are relatively stable, the manager will benefit by riding the curve versus a buy-and-hold of the short-maturity instrument.

However, there are risks to riding the yield curve, most obviously the greater *interest rate risk* associated with the riding strategy (as reflected by its higher duration). Thus, if one is riding and yields rise substantially, the investor will incur a capital loss on the riding position. Had the investor purchased the instrument that matched her investment horizon, she would have still ended up with a positive return.

A REHTS and Riding the Yield Curve

One implication of the REHTS is that, with the exception of time-varying term premia, the return on a longer period bond is identical to the return from rolling over a sequence of short-term bonds. As a consequence, longer term rates y_t^n are a weighted average of short-term rates y_t^m plus the term premia. This can be expressed as follows:

$$y_t^n = \frac{1}{k}\sum_{h=0}^{k-1} E_t y_{t+h}^m + \sigma^{n,m}, \tag{1}$$

where y_{t+h}^m is the m period zero coupon yield at time $t+h$, E_t is the conditional time expectations operator at time t and $\sigma^{n,m}$ is the risk premium between n and m period zero coupon bond (with $n > m$). In equation (1), $k = \frac{n}{m}$ is restricted to be an integer.

In the absence of any risk premia, by taking expectations and subtracting y_t^m from both sides we can re-write equation (1) as

$$y_t^n - y_t^m = \frac{1}{k}\sum_{h=1}^{k-1} y_{t+h}^m - y_t^m. \tag{2}$$

Thus, under the REHTS, the future differentials on the short rate are related to the current yield spread between the long-term and short-term zero coupon rates. Equation (2) forms the basis for most empirical test of the REHTS, by running the regression

$$\frac{1}{k}\sum_{h=1}^{k-1} y_{t+h}^m - y_t^m = \alpha + \beta\left(y_t^n - y_t^m\right) + \epsilon_t \tag{3}$$

and testing if $\beta = 1$. In practice, however, most empirical studies report coefficients which are significantly different from one, which is almost exclusively taken as evidence for the existence of (time-varying) risk premia.[4]

Rather than postulating a linear relationship between the future differentials on the short rate and the current slope of the term structure as expressed in equation (2), we calculate the ex-post excess HPRs from riding the yield curve. Thus, if the REHTS holds and there are no risk premia, these returns should be zero.

Therefore, according to the REHTS, if all agents are risk neutral and concerned only with the expected return, the expected one-period HPR on all bonds, independent of their maturity, should be identical and would be equal to the return on a one-period asset:

$$E_t H_{t+1}^n = y_t^m, \tag{4}$$

where H_{t+1}^n denotes the HPR of an n-period instrument between time t and $t+1$. This result can now be used to derive the zero excess holding period return (XHPR) condition of the REHTS by restating equation (4) as

$$XH_{t+1}^n = H_{t+1}^n - y_t^m = 0. \tag{5}$$

Hence, if the REHTS holds, we should not be able to find any evidence that fixed-income managers are able to obtain any significant non-zero XHPRs by riding the yield curve.

B Mathematics of Riding

In this section, we derive the main mathematical formulae for riding the yield curve relative to a buy-and-hold strategy. Because we evaluate different riding strategies for maturities beyond one year, we need to distinguish between riding a money-market instrument and riding a bond-market instruments.

Furthermore, we are not only interested in evaluating riding returns for different maturities, but we also consider the case where we use different instruments to ride the yield curve. In particular, we consider the case of comparing a ride using a (risk-free) government bond against riding down the credit curve with a LIBOR/swap-based instrument. Because investors expect to be rewarded for taking on non-diversifiable credit risk, two securities which are identical except for the level of credit risk must have different yields. Thus, comparing the returns from two strategies that involve fixed-income instruments with different credit risk would normally necessitate the specification of a framework that deals appropriately with credit risk.

However, drawing on results from the literature on the determinants of swap spreads,[5] we can assume that the yield differential between government securities and swaps is not primarily a consequence of their idiosyncratic credit risk. This strand of literature argues that, even in the absence of any credit or default risk, swap spreads would be non-zero,[6] since they predominantly depend on other factors such as

- the yield differential between LIBOR rates and the repo rate for General Collateral,
- the slope of the term structure of risk-free interest rates,
- and the relative supply of government corporate debt.

There are also other non-default factors, such as liquidity and yield spread volatility, that may play an important role in determining yield spreads.[7]

In line with the pioneering work by Dyl and Joehnk (1981), we also derive a formula for quantifying the risk associated with a given riding strategy. This measure is traditionally referred to as the 'margin of safety' or *Cushion* and can be used as a conditioning moment or filter for different rides. By calculating the cushion of a given riding strategy, the investor has an *ex-ante* indication of how much, ceteris paribus, interest rates would have to have risen at the end of the holding period such that any excess returns from riding would be eliminated. The cushion is therefore also referred to as the break-even yield change. We will also derive an approximate formula that may appeal to the market practitioner because of its simplicity and intuitive form.

B.1 Riding the Money Market Curve

For the analysis of riding the money market curve, we assume that our rates are money market or CD equivalent yields. We can postulate that the price of an m-maturity money-market instrument at time t is given by:

$$P^M_{m,t} = \frac{100}{(1 + y_{m,t}\frac{m}{z})}, \tag{6}$$

where $y_{m,t}$ represents the current CD equivalent yield[8] of the instrument at time t, m is the number of days to the instrument's maturity, and z is the instrument and currency-specific day count basis.[9] We can also denote the price of this same maturity instrument after a holding period of h days as:

$$P^M_{m-h,t+h} = \frac{100}{\left(1 + y_{m-h,t+h}\frac{(m-h)}{z}\right)}, \tag{7}$$

where $y_{m-h,t+h}$ represents the interest rate valid for the instrument which has now $m-h$ days left until final redemption. Thus, the HPR of the ride of an m-maturity instrument between time t and time $t+h$ is given by:

$$H^M_{[m,h]} = \frac{P^M_{m-h,t+h}}{P^M_{m,t}} - 1 = \frac{(1 + y_{m,t}\frac{m}{z})}{\left(1 + y_{m-h,t+h}\frac{m-h}{z}\right)} - 1. \tag{8}$$

The excess holding period returns (XHPR) of this strategy of riding over the choice of holding an instrument with the maturity equal to the investment horizon h can be expressed as:

$$XH^M_{[m,h]} = \left[\frac{(1 + y_{m,t}\frac{m}{z})}{\left(1 + y_{m-h,t+h}\frac{m-h}{z}\right)} - 1\right] - \left(y_{h,t}\frac{h}{z}\right). \tag{9}$$

It follows from equation (9) that riding the yield curve is more profitable, ceteris paribus, (a) the steeper the yield curve at the beginning of the ride (i.e. large values for $y_{m,t} - y_{h,t}$) and (b) the lower the expected rate at the end of the holding period (i.e. $y_{m-h,t+h}$ is low).

B.2 Riding the Bond Curve

In line with the assumptions for computing the returns for money market instruments, we can calculate the zero coupon prices for maturities beyond one year, where our rates are zero coupon yields. We can postulate that the price an m-maturity zero coupon bond time t is given by:

$$P^B_{m,t} = \frac{100}{(1 + y_{m,t})^{\frac{m}{z}}}, \tag{10}$$

where $y_{m,t}$ represents the current zero coupon yield of the instrument at time t, m is the instrument's final maturity, and z is the appropriate day count basis. In line with equation (7), we can denote the price of this same instrument after holding it for h days as:

$$P^B_{m-h,t+h} = \frac{100}{(1 + y_{m-h,t+h})^{\frac{m-h}{z}}}, \tag{11}$$

where $y_{m-h,t+h}$ represents the interest rate valid for the zero coupon bond which is now an $m - h$ maturity instrument that was purchased h days ago. Following equation (8), we can write the HPR from riding the zero coupon bond curve as:

$$H^B_{[m,h]} = \frac{(1 + y_{m,t})^{\frac{m}{z}}}{(1 + y_{m-h,t+h})^{\frac{m-h}{z}}} - 1. \tag{12}$$

Similarly, the excess holding returns from rolling down the bond curve for h days are:

$$XH^B_{[m,h]} = \begin{cases} \left[\frac{(1+y_{m,t})^{\frac{m}{z}}}{(1+y_{m-h,t+h})^{\frac{m-h}{z}}} - 1\right] - \left(y_{h,t}\frac{h}{z}\right) & \text{if } h < 1 \text{ year,} \\ \left[\frac{(1+y_{m,t})^{\frac{m}{z}}}{(1+y_{m-h,t+h})^{\frac{m-h}{z}}} - 1\right] - \left[(1 + y_{h,t})^{\frac{h}{z}} - 1\right] & \text{if } h > 1 \text{ year.} \end{cases} \tag{13}$$

It is important to reiterate at this point, that equations (10) to (13) are expressed in terms of zero coupon rates, hence there are no coupon payments to be considered. This does not mean, however, that our simple framework cannot be transposed to the (more realistic) world of coupon-paying bonds. Using the approximation $\frac{P_{t+h}}{P_t} - 1 \approx y_{m,t}\frac{h}{z} - \Delta y_t D_{t+h}$, we can restate equation (13) in a more applicable way[10]

$$XH^{B'}_{[m,h]} \approx \begin{cases} \left[y_{m,t}\frac{h}{z} - \Delta y_t D_{m-h,t+h}\right] - \left(y_{h,t}\frac{h}{z}\right) & \text{if } h < 1 \text{ year,} \\ \left[y_{m,t}\frac{h}{z} - \Delta y_t D_{m-h,t+h}\right] - \left[(1+y_{h,t})^{\frac{h}{z}} - 1\right] & \text{if } h > 1 \text{ year,} \end{cases} \tag{14}$$

where $\Delta y_t = y_{m-h,t+h} - y_{m,t}$ and $D_{m-h,t+h}$ is the modified duration of the bond[11] at the end of the holding horizon. By virtue of this approximation, the subsequent parts of our analysis also apply to coupon-paying bonds.

B.3 Break-Even Rates and The Cushion

Given a certain yield curve, the investor needs to decide whether to engage in a riding strategy or not before making an informed decision about selecting the appropriate instrument for the ride. The easiest way to make this decision is to use the *Cushion* or break-even rate change as an indication of how much rates would have to have increased at the end of the holding period h, in order to equate the riding returns equal to the returns from buying an h-maturity instrument and holding to maturity.

For example, if the yield curve is upward sloping, longer-term bonds offer a yield pick-up over the one-period short term bonds. In order to equate the HPRs across all bonds, the longer maturity instruments would have to incur a capital loss to offset their initial yield advantage. Break-even rates show exactly by how much long-term rates have to increase over the holding period to cause such capital losses. In other words, the break-even rate is the implied end-horizon rate, $y^*_{m-h,t}$, such that there are no excess returns from riding (i.e. $XH_{t+h} = 0$). By setting $XH^M_{[m,h]} = 0$ and $XH^B_{[m,h]} = 0$ in equations (9) and (13) respectively, we can derive the break-even rates for both cases:

Money Markets Ride

$$y^*_{m-h,t} = \left[\frac{y_{m,t}\frac{m}{z} - y_{h,t}\frac{h}{z}}{1 + y_{h,t}\frac{h}{z}}\right] \times \frac{z}{m-h}. \tag{15}$$

Bond Market Ride

$$y^*_{m-h,t} = \begin{cases} \left[\frac{(1+y_{m,t})^{\frac{m}{z}}}{\left(1+y_{h,t}\frac{h}{z}\right)}\right]^{\frac{z}{m-h}} - 1 & \text{if } h < 1 \text{ year,} \\ \\ \left[\frac{(1+y_{m,t})^{\frac{m}{z}}}{\left(1+y_{h,t}\right)^{\frac{h}{z}}}\right]^{\frac{z}{m-h}} - 1 & \text{if } h > 1 \text{ year.} \end{cases} \tag{16}$$

Recalling section A, we see that under the REHTS without any term premia, the break-even rate for a riding strategy using an m-maturity instrument from time t to $t+h$ is equivalent to the $m-h$ period forward rate implied by the term structure at time t (i.e. $y^*_{m-h,t} = f_{m-h,m}$). The Cushion can now be written as:

$$C_{[m,h]} = y^*_{m-h,t} - y_{m-h,t}. \tag{17}$$

Figure 1 provides a schematic illustration of a ride on the yield curve from point A to point B. The cushion is then defined as the vertical distance between points B and C, i.e. the amount by which interest rates have to rise in order to offset any capital gains from riding the yield curve.

[INSERT FIGURE 1 ABOUT HERE]

Thus, the concept of the cushion can now be used to define some simple filter rules for determining whether to ride or not. For example, one such filter rule is based on the assumption that interest rates display mean-reverting properties and sends a *positive riding signal* whenever the Cushion moves outside a pre-specified standard deviation band around its historic moving average. The success rate of a number of similar such rules are discussed in section V.

B.4 Selecting the Best Instrument For the Ride

With a simple decision making strategy such as described above, the investor now needs to address the choice of the appropriate instrument for the ride.[12] In order to choose between two instruments, we need to compare the excess returns for a given riding strategy using either instrument. More formally, the excess riding returns from using a government instead of a credit instrument are given by:

Money Market Ride

$$\begin{aligned} XH_{[m,h]}^{M,ride} &= \left(\frac{(1 + y_{m,t} \frac{m}{z})}{\left(1 + y_{m-h,t+h} \frac{m-h}{z}\right)} - 1 \right) \\ &- \left(\frac{(1 + \hat{y}_{m,t} \frac{m}{z})}{\left(1 + \hat{y}_{m-h,t+h} \frac{m-h}{z}\right)} - 1 \right), \end{aligned} \tag{18}$$

Bond Market Ride

$$\begin{aligned} XH_{[m,h]}^{B,ride} &= \left(\frac{(1 + y_{m,t})^{\frac{m}{z}}}{(1 + y_{m-h,t+h})^{\frac{m-h}{z}}} - 1 \right) \\ &- \left(\frac{(1 + \hat{y}_{m,t})^{\frac{m}{z}}}{(1 + \hat{y}_{m-h,t+h})^{\frac{m-h}{z}}} - 1 \right), \end{aligned} \tag{19}$$

where the hats over the variables indicate the corresponding rates for the credit instrument at the respective times. Defining $\hat{y}_{m,t} = y_{m,t} + \epsilon$, $\hat{y}_{m-h,t+h} = \hat{y}_{m,t} - \eta$, and $y_{m-h,t+h} = y_{m,t} - \psi$, we can substitute these conditions into equations (18) and (19) to derive an approximate, yet very tractable expression for the excess riding return from using the two instruments:[13]

Money Market Ride

$$XH_{[m,h]}^{M,ride} \approx \frac{1}{z} \left[\underbrace{-h\epsilon}_{\text{initial spread}} + \underbrace{(\psi - \eta)(m - h)}_{\text{slope effect}} \right], \tag{20}$$

Bond Market Ride

$$XH^{B,ride}_{[m,h]} \approx \frac{1}{z}\left[\underbrace{-h\epsilon}_{\text{initial spread}} + \underbrace{(\psi - \eta)\,(D_{m-h,t+h}z)}_{\text{slope effect}}\right]. \tag{21}$$

Equations (20) and (21) highlight the two main factors that determine which instrument yields a higher profit from riding. The first factor is the difference in rates, or yield pick-up between the two instruments for any given maturity, whereas the second factor is a slope term.[14] Therefore, the bigger the initial yield differential between the government bond and the credit instrument, the less attractive is a riding strategy using the former. The second factor indicates that the steeper the slope of the government yield curve compared to the slope of the credit yield curve, the higher the relative excess returns from riding with government bonds. Furthermore, the second factor also reveals that the slope differential gains in importance as the mismatch between the holding horizon and the instrument's maturity increases.

II Data and Methodology

The data used in this study was either obtained via the Monetary and Economics Department Time Series Database (MEDTS) of the Bank for International Settlement (BIS) or directly from the relevant central bank. As such, the choice of estimation methodology for the yield curves is determined by the BIS or the respective central bank.

A Data

We are estimating returns for different rolling strategies using monthly U.S., U.K. and German interest rates for both government and corporate liabilities. In the case of the government liabilities, these rates are zero-coupon, or spot interest rates estimated from the prices of coupon-paying government bonds. In the case of corporate liabilities, the zero-coupon rates were estimated from LIBOR deposit and swap rates.

A.1 Government Zero Coupon Curves

The government zero-coupon time series for the three countries begin on different dates, span different maturity intervals and are estimated using different methodologies. The data for Germany spans a period of over 30 years from January 1973 to December 2003. The series for the United Kingdom starts from January 1979 and data for the Unites States is only available from April 1982.

Figure 2 plots the evolution of the 3-month, 2-year and 10-year government zero coupon rates, whereas figure 3 shows how the slope of different sectors of the government yield curves have changed over the sample period.

[INSERT FIGURE 2 ABOUT HERE]

[INSERT FIGURE 3 ABOUT HERE]

The zero coupon rates for the three countries also vary with respect to the maturity spectrum for which they are available. While the data is available for all countries at three-month intervals for maturities from 1 to 10 years, reliable data for the money market sector, i.e. maturities below one year, is only available for the United States. This is mainly because, unlike its European counterparts, the U.S. Treasury through its regular auction schedule of Treasury and Cash Management Bills has actively contributed to making this part of the yield curve very liquid. Since the yields on T-Bills are de facto zero-coupon rates, we use 3- and 6-month constant maturity rates published by the Federal Reserve to extend the maturity spectrum for the U.S. data.[15]

The majority of the central banks that report their zero-coupon yield estimates to the BIS MEDTS, including Germany's Bundesbank, have adopted the so-called Nelson-Siegel approach (1987) or the Svensson (1994) extension thereof. Notable exceptions are the United States and the United Kingdom, both of whom are using spline-base methods to estimate zero-coupon rates.[16]

A.2 LIBOR/Swap Zero Coupon Curves

The commercial bank liability zero-coupon rates are estimated from LIBOR deposit and swap rates. Unlike the government data, the series are computed using the same methodology and span the same maturity spectrum, namely 3-months to 10-years at 3-monthly intervals. However, the starting dates of the series also vary by country. The data for the United States is available from July 1987 to December 2003, from August 1988 for Germany, and from January 1990 for the United Kingdom.[17]

[INSERT FIGURE 4 ABOUT HERE]

The second column of figure 2 shows the evolution of selected LIBOR/swap rates, and the changes in the slope of different sectors of the yield curve are displayed in figure 3. Figure 4 plots the development of the TED- and swap spreads for the different currencies. The zero-coupon swap curves for each currency are estimated by the cubic B-splines method using LIBOR rates up to one year and swap rates from 2 to 10 years.

B Methodology

Zero-coupon curves are generally estimated from observed bond prices in order to obtain an undistorted estimate of a specific term structure. The approach commonly used to fit the term structure can broadly be separated into two categories. On the one hand, *parametric curves* are derived from interest rate models such as the Vasicek term structure model and, on the other hand, *non-parametric curves* are curve-fitting models such as spline-based and Nelson-Siegel type models.[18] The two types of non-parametric estimation techniques (Svensson and spline-based method) relevant for the data set used in this paper are described in more detail in appendix B.

III Practical Implementation

Most empirical studies on the term structure of interest rates find that the data generally offers little support for the REHTS. Our results are in line with these findings and suggest that market participants may be able to exploit violations of the REHTS. While there is some evidence that riding the yield curve per se may produce excess returns compared to buying and holding, we suggest that using a variety of decision making rules could significantly increase the risk-adjusted adjusted returns of various riding strategies. The relative merits of these decision making rules are evaluated by reporting the ex-post excess returns from riding down the yield curve, conditional on the rule sending a positive signal. Risk-adjusted excess returns are expressed as Sharpe Ratios in order to compare and rank different riding strategies.

Before describing the individual decision making rules in more detail, we present a brief overview of literature describing the main factors that affect the yield curve.

A Determinants of the Term Structure of Interest Rates

For many years, researchers in both macroeconomics and finance have extensively studied the term structure of interest rates. Yet despite this common interest, the two disciplines remain remarkably far removed in their analysis of what makes the yield curve move. The building blocks of the dynamic asset-pricing approach in finance are affine models of latent (unobservable) factors with a no arbitrage restriction. These models are purely statistical and provide very little in the way of explaining the nature and determination of these latent factors.[19] The factors are commonly referred to as "level", "slope" and "curvature" (Litterman and Scheinkman (1991)) and a wide range of empirical studies agree that almost all movements in the term structure of default-free interest rates are captured by these three factors. In contrast, as was argued at the beginning of this paper, the macroeconomic literature still relies on the expectations hypothesis of the term structure, in spite of overwhelming evidence of variable term premia.

A handful of recent studies have started to connect these two approaches by exploring the macroeconomic determinants of the latent factors identified by empirical studies. In their pioneering work, Ang and Piazzesi (2003) develop a no-arbitrage model of the term structure that incorporates measures of inflation and macroeconomic activity in addition to the traditional latent factors - level, slope and curvature. They find that including the two macroeconomic factors improves the model's ability to forecast dynamics of yield curve. Compared to traditional latent factor models, the level factor remains almost unchanged when macro factors are incorporated, but a significant proportion of the slope and curvature factors are attributed to the macro factors. However, the effects are limited as the macro factors primarily explain movements at the short end of the curve (in particular inflation), whereas the latent factors continue to account for most of the movement for medium to long maturities.[20]

Evans and Marshall (2002) analyse the same problem using a different, VAR-based approach. They formulate several VARs and examine the impulses of the latent factors to a broad range of macroeconomic shocks. While they confirm Ang and Piazzesi's results that most of the variability of short- and medium-term yields is driven by macro factors, they also find that such observable factors explain much of the movement in long-term yields and that they have a substantial and persistent impact on the level of the term structure.

Wu (2001; 2003) examines the empirical relationship between the slope factor of the term structure and exogenous monetary policy shocks in the U.S. after 1982 in a VAR setting. He finds that there is a strong correlation between the slope factor and monetary policy shocks. In particular, his results indicate that such shocks explain 80 – 90% of the variability of the slope factor. Although the influence is short-lived, this provides strong evidence in support of the conjecture by Knez, Litterman and Scheinkman (1994) on the relation between the slope factor and Federal Reserve Policy.[21]

Most recently, Rudebusch and Wu (2003) extend this research of the macroeconomic determinants of the yield curve by incorporating a latent factor affine term structure model into an estimated structural New Keynesian model of inflation, the output gap and the federal funds rate. They find that the level factor is highly correlated with long-run inflation expectations, and the slope factor is closely associated with changes of the federal funds rate.

Changes in the yield curve ultimately determine the relative success of riding the yield curve vis-à-vis buying and holding. Any filter rule which aims to improve the performance of riding strategies must therefore be somehow be conditioned on various (ex-ante) measures of changes of the term structure of interest rates. In this context, we are examining the performance of two broad categories of decision making rules, namely *statistical* and *macro-based* rules. A given rule is said to send a positive signal, if the observable variable(s), the behaviour of which is modelled by the rule, has reached a certain trigger point.

B Statistical Filter Rules

Statistical filters are a well-established relative value tool amongst market practitioners. The main motivation for using this type of rule is the belief that many financial variables have mean-reverting properties, at least in the short to medium term. In addition, such rules owe much of their current popularity to the fact that they are easy to implement and with increasing access to real-time data are often already implemented in many standard software packages. We consider the following three simple rules:

B.1 Positive Slope

In the simplest of all cases, assuming relatively stable interest rates over the holding horizon, a positive slope is a sufficient condition for riding the yield curve. We define the slope of the term structure as the yield differential between 10-year and 2-year rates and implement a riding strategy whenever this slope is non-zero.

B.2 Positive Cushion

The Cushion, or break-even rate change, is a slightly more sophisticated measure of the relative riskiness of a given riding strategy. As discussed in section B.3, the Cushion indicates by how much interest rates have to change over the holding horizon before the riding trade begins to be unprofitable. A positive Cushion indicates that interest rates have scope to increase without the trade incurring a negative excess return. With this filter rule, we implement a riding strategy whenever the Cushion is positive.

B.3 75%ile Cushion

In most instances, the absolute basis-point size of the Cushion will have an influence on the profitability of the riding strategy, since for a given level of interest rate volatility, a small positive Cushion may not offer sufficient protection compared to a large one. Assuming the Cushion itself is normally distributed around a zero mean, we compute the realized distribution of the Cushion over a 2-year interval prior to the date on which a riding trade is put on. A riding strategy is implemented whenever the Cushion lies outside its 2-year moving 75%ile.

C Macro-based Rules: Monetary Policy and Riding

In order to translate the link between the steepness of the yield curve and monetary policy into potentially profitable riding strategies, we need to formulate a tractable model of the interest rate policy followed by the central bank, such as the Taylor Rule.

The approach of a simple model of the Federal Reserve's behaviour was first suggested by Mankiw and Miron (1986), who found that the REHTS was more consistent with data prior to the founding of the Federal Reserve in 1913. This strand of literature argues that there is a link between the Federal Reserve's use of a fund rate target instrument and the apparent failure of the REHTS.[22] Rather than developing an elaborate model of term premia coupled with Federal Reserve behaviour, our approach takes the well-established Taylor Rule (1993) as a model for central bank behaviour and tests for its predictive power for excess returns by indicating changes in the slope of the yield curve. In a second approach, we do not model the Federal Reserve's behaviour explicitly, but extract the market's expectations of future policy action from the federal funds futures market. Before looking at these more elaborate macro rules, we define a simple rule that is based on a straight forward measure of economic activity.

C.1 The Slope of the Yield Curve and Recessions

Recessions are often associated with a comparatively steep term structure. As inflationary pressures are limited during such periods of reduced economic activity, central banks are generally lowering their policy rates in order to stimulate the economy.

We define a riding strategy that engages in trades whenever we have entered into a recessionary period. We use different definitions for recessions, depending on the country in question. For the United States, recessions are defined according to the NBER's Business Cycle Dating Committee methodology whereby "[...] a recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales".[23] For the U.K. and Germany, recessions are defined in terms of at least two consecutive quarters, during which real (seasonally adjusted) GDP is declining.

Using recessions as a trigger to ride the yield curve - while theoretically very appealing - suffers from a practical drawback: agents do not know in real time when a recession begins and ends due to the reporting lag of macroeconomic data. This problem may be addressed by conditioning the riding strategies on lagged 'real-time' recessions rather than 'look-ahead' recessions.[24]

C.2 The Slope of the Yield Curve and the Taylor Rule

In this section, we examine how we can effectively employ a simple Taylor rule to predict future changes in the term structure of interest rates from changes in the federal funds rate. As a first step, we verify that there is a significant link between changes in the slope of the yield curve, i.e. the degree by which the yield curve changes its slope over time, and changes in the short-term interest rates, as is suggested in section A.

A first visual inspection of slope changes and target rate changes displayed in panel 3 of figure 6 appears to support such a linkage. By regressing changes in the fed funds target on changes of the slope of the yield curve, we are able to confirm that there exists a significant negative relationship between the two variables (see table XII for the results). Indeed, our results indicate that for every 100 basis points increase in the fed funds rate, there is a corresponding 25 basis points flattening of the term structure as measured by the 10–2 year yield differential.

[INSERT TABLE XII ABOUT HERE]

We now link central bank behaviour with changes in the slope of the yield curve by following Taylor's original specification which relates the federal funds target rate to the inflation rate and the output gap as follows:

$$i_t^{TR} = \pi_t + r^* + 0.5\left(\pi_t - \pi_t^*\right) + 0.5 y_t, \tag{22}$$

where

i_t^{TR} = federal funds rate recommended by the Taylor Rule,
r^* = equilibrium real federal funds rate,
π = average inflation rate over current and prior three quarters (GDP deflator),

π^* = target inflation rate,
y = output gap (100 $\times$ (real GDP - potential GDP)$\div$ potential GDP).

One of the main criticisms of the this specification is that Taylor did not econometrically estimate this equation, but assumed that the Fed attached fixed weights of 0.5 to both deviations of inflation and output.[25] An additional problem with Taylor's original work is that the output gap is estimated in-sample. This shortcoming can be addressed by estimating the Taylor Rule out-of-sample with no look-ahead bias (see panel 1 of figure 5).[26]

As a response to the critique that the weights on inflation and the output gap in equation 22 are not estimated, we also consider a *dynamic version* of the Taylor Rule, following the work of Judd and Rudebusch (1998). In this specification, equation 22 is restated as an error correction mechanism that allows for the possibility that the federal funds rate adjusts gradually to achieve the rate recommended by the rule. In particular, by adding a lagged output gap term along with the contemporaneous gap, equation 22 is replaced with:

$$i_t^{TR} = \pi_t + r^* + \lambda_1 (\pi_t - \pi_t^*) + \lambda_2 y_t + \lambda_3 y_{t-1}. \tag{23}$$

The dynamics of adjustment of the actual level of the federal funds rate to the recommended rate, i_t^{TR}, are given by:

$$\Delta i_t = \gamma \left(i_t^{TR} - i_{t-1} \right) + \rho \Delta i_{t-1}. \tag{24}$$

This means that the change in the funds rate at time t partially corrects the difference between last period and the current target level as well as displaying some dependency on the funds rate change at time $t-1$. By substituting equation 23 into 24, we obtain the full ECM to be estimated:

$$\Delta i_t = \gamma\alpha - \gamma i_{t-1} + \gamma (1 + \lambda_1) \pi_t + \gamma\lambda_2 y_t + \gamma\lambda_3 y_{t-1} + \rho \Delta i_{t-1}, \tag{25}$$

where $\alpha = r^* - \lambda_1 \pi^*$. This equation provides estimates of policy weights on inflation and output and on the speed of adjustment to the rule. Judging by the plot of our Judd-Rudebusch estimates of the Taylor Rule alone (see panel 3 of figure 5), it is difficult to conclude if we are able to obtain an improved forecast of the federal funds rate, compared to the two static methods.

[INSERT FIGURE 5 ABOUT HERE]

In order to determine whether the Taylor Rule is a useful means to devising different riding strategies, we need to see if the Taylor Rule at time $t-1$ can predict changes in the federal funds rate at time t. If this is indeed the case, we can use the Taylor Rule for a signal to determine when to ride the yield curve, since we already have established that the target rate can predict slope changes.

Rather than determining the *equilibrium level* of the target rate, we are interested in predicting target *rate changes* by employing the Taylor Rule. For this purpose, we regress the actual changes in the federal funds target $\Delta FFTR_t$ on changes of the target rate as recommended by the Taylor Rule $\Delta Taylor_t$ as opposed to the difference between the target rate estimate and the actual rate.[27] In order to see if the Taylor signal is particularly predictive prior to an interest rate decision, we add a dummy variable $FOMC_t$ which only has a value in the month prior to an FOMC meeting.

The results of these regressions are summarized in table XIII. For both version of the Taylor Rule, the out-of-sample estimation of the original specification and the dynamically estimated Judd-Rudebusch version, there is strong significance on the predictive power of the Taylor Rule with regards to target rate changes over the entire sample period (1988 – 2003).[28] In addition, the responsiveness of rate changes with respect to the Taylor rule increases by almost 20% before FOMC meetings. This is indicated by the increase in the parameter estimates of regression 2 and 4 in table XIII. Nonetheless, the estimates for ϕ are significantly smaller than unity, suggesting that the recommended rate needs to change between 120 and 150 basis points to signal a full quarter percent change in the actual target rate.[29]

[INSERT TABLE XIII ABOUT HERE]

Having established a relatively firm link between the Taylor Rule and changes in the slope of the term structure, we can devise a simple signal whether to ride or not and compare it to alternative strategies. At every month end, we estimate i_t^{TR} by re-estimating y_t and π_t for every month-end. The change in the 'equilibrium' federal funds target rate suggested by the Taylor Rule Δi_t^{TR} is then used as the basis for our simple decision rule:

- if $\Delta i_t^{TR} > 0$, then riding the yield curve is less favourable as there is a strong likelihood that short rates will increase.
- if $\Delta i_t^{TR} < 0$ then riding the yield curve is more favourable as there is a strong likelihood that short rates will decrease.

In order to translate this decision making into a signal that indicates whether to ride the yield curve or not, we construct the variable $TaylorSignal_t$ that takes a value of 1 (or -1) whenever the relevant specification of the Taylor Rule indicates a rate rise (cut) and is 0 otherwise. We engage in a riding strategy whenever the signal is different from 1 and therefore does not indicate an impending increase in the target rate.

C.3 The Slope of the Yield Curve and Expectations from Fed Fund Futures

In theory, federal fund futures should reflect market expectations of near-term movements in the (effective) fed funds rate and thus the target rate. A growing strand of literature has demonstrated the usefulness of fed funds futures contracts in predicting monetary policy moves one to three months ahead. In particular, using daily data Söderström (2001) shows that futures-based proxies for market expectations are a successful predictor of the target rate around target changes and FOMC meetings. In line with this literature, this section investigates the relationship between market expectations from federal funds futures and changes in the slope of the yield curve as triggered by changes in the target rate. As with the Taylor Rule in the previous section, we want to see if the federal fund futures at time $t-1$ are a reliable predictor of movements in the yield curve (via implied target rate changes) at time t. Should this indeed be the case, we would be able to construct an additional decision making rule for riding the yield curve. Thus if market expectations implied by the futures contracts can be used to forecast the changes in the federal funds target, we can construct an additional decision rule for riding the yield curve. As before, we compare the equilibrium rate implied by the futures contracts i_t^{Exp} to the observed rate i_t^{Actual}. This forms then the basis for a simple decision rule along the following lines:

- if $i_t^{Exp} > i_t^{Actual}$, then riding the yield curve is less favourable as there is a strong likelihood that short rates will increase.
- if $i_t^{Exp} < i_t^{Actual}$ then riding the yield curve is more favourable as there is a strong likelihood that short rates will decrease.

A first visual inspection of plotting the target rate against the rate implied by the nearest futures contract (see panel 1 in figure 6) strongly suggests that market participants indeed do 'get it right'. In order to gauge the predictive power of futures-based expectations, we test whether target rate changes can be forecast given the implied probability of a rate change has passed a certain threshold (i.e. 50%).

[INSERT FIGURE 6 ABOUT HERE]

In order to translate this hypothesis in to a trading signal, we start by computing the implied probabilities of a change in the federal funds target rate. Futures-based expectations before an FOMC meeting can only be interpreted as a meaningful measure of the target rate expected to prevail after the meeting, if the target rate is not changed between meetings and never twice in the same month. Although federal funds futures were first introduced at the Chicago Board of Trade in October 1988, was not until 1994 that the FOMC began announcing changes in its policy stance and abandoned inter-meeting rate changes (see CBOT (2003)). For this reason, we do not consider any observations prior to that date and define the rate implied by the fed funds futures contract[30] as a time-weighted average of average of a pre-meeting and expected post-meeting target rate. This can be expressed as

$$i_t^f = i_t^{pre}\frac{d_1}{B} + \left[p i_t^{post} + (1-p)\, i_t^{pre}\right]\frac{d_2}{B}, \tag{26}$$

where

i^f	= futures rate implied by relevant contract,[31]
i^{pre}	= target rate prevailing before the FOMC meeting,
i^{post}	= target rate expected to prevail after the FOMC meeting,
p	= probability of a target rate change,
d_1	= number of days between previous month end and FOMC meeting,
d_2	= number of days between FOMC meeting and current month end,
B	= number of days in month.

Solving equation 26 for p, the probability of a change in the target rate can thus be expressed as

$$p = \frac{i_t^f - i_t^{pre}\left(\frac{d_1}{B} - \frac{d_2}{B}\right)}{\left(i_t^{post} - i_t^{pre}\right)\frac{d_2}{B}}. \tag{27}$$

In addition to the no inter-meeting changes, this specification also assumes that the Fed has only got two policy options: either shift the target rate by a pre-specified amount or leave it unchanged. For ease of computation, we can reasonably assume that this amount is (multiples of) 25 basis points, since Fed has not changed rates by any other amount since August 1989.

If market expectations indeed provide useful information with regards to riding the yield curve, we need to test if market expectations are a good indicator of future changes in the federal funds target rate. For this purpose, we construct the variable $MarketSignal_t$ which has a non-zero value whenever the implied probabilities of a rate rise (cut) is greater than 50%.[32] In line with the previous section, we employ the dummy variable $FOMC_t$ to assess if the predictive power of federal funds futures is particularly high prior to an FOMC meeting.

Our results of the informative content of futures with regards to target rate indicate that fed fund futures are indeed a useful means to predict target rate changes, both using daily and end-of-the-month monthly data. This is broadly in line with the existing literature (e.g. Rudebusch (1995) or Söderström (2001)). Regressing daily and monthly changes in the target rate on the market signal indicates that, whenever the market thinks that there is at least a 50% chance of a 25 basis point *cut* (rise), the target rate indeed *decreases* (increases) subsequently. As regressions 2 and 3 in table XIV indicate, this signal is particularly strong in the period immediately prior to an FOMC meeting.

[**INSERT TABLE XIV ABOUT HERE**]

Thus using futures closing prices before an FOMC meeting, we are able to reliably anticipate the FOMC decision. The robustness of this result can also be seen visually by plotting the changes in the target rate against the signal from market expectations in panel 2 of figure 6.

IV Empirical Results

This section reports our empirical findings for the various riding strategies across instruments and currencies and reviews the effectiveness of the different conditioning rules presented in the previous section. In addition, we present a simple framework which allows investors who are bound by more conservative investment guidelines to exploit the concept of 'riding the yield curve' without incurring a substantial amount of additional interest rate risk.

A Government Securities

With a few exceptions, the riding strategies using government securities display superior performance compared to buying and holding across all holding horizons and all currencies. In contrast to previous empirical evidence, our results provide surprisingly strong evidence for the existence of exploitable risk premia in these markets.

In general, our results indicate that the excess returns from riding increase with the maturity of the riding instrument. This is very much in line with the results of other studies such as Dyl and Joehnk (1981) and Grieves (1999) and is a direct consequence of the increased risk-return trade-off for longer maturity instruments. While riding with longer-dated instruments increases excess returns, these strategies tend to do slightly worse on a risk-adjusted basis because of the increased interest rate risk across all currencies.

[INSERT TABLES I, II and III ABOUT HERE]

For U.S. Treasuries, excess riding returns are the highest across all instruments for the shortest, 3-month holding horizon. Riding the yield curve with a 10-year Treasury for three months produces an annualized average return of 12.0%, which is 6.2% in excess of the corresponding buy-and-hold strategy. Riding for six months with a twelve month instrument yields the lowest excess mean return of only 44 basis points. This contrasts with the findings by Dyl and Joehnk, however, who observe that the riding returns increase uniformly with the holding horizon. With the exception of riding six month T-Bills for three months, the most efficient rides are consistently performed with 2-year instruments, independent of the holding horizon. This corresponds to the well-documented fact that this sector of the U.S. Treasury yield curve offers the highest risk premia because it historically shows the biggest yield volatility. According to Fleming and Remolona (1999*a*; 1999*b*), U.S. Treasury securities in the 2-year sector of the yield curve show the strongest responses to macroeconomic announcements, changes in the federal fund target rate as well as Treasury auctions.

For U.K. Gilts, the riding returns increase both with the maturity of the riding instrument and the length of the holding horizon. The mean riding returns are approximately at the same levels than those for the dollar market, whereas mean excess returns are on average only about half those achieved with U.S. Treasuries. The highest and simultaneously least volatile excess returns of 3.7% arise from riding the longest-dated Gilts for the 18-month holding horizon. However, at the other end of the scale, riding the yield curve with U.K. T-Bills for short horizons does worse than holding to maturity. This may indeed be related to the fact that the money-market sector of the Gilt curve is sparsely populated and T-Bills tend to be relatively illiquid instruments.

The results for German government paper are broadly in line with those for U.S. Treasuries, where returns increase with the maturity of the riding instruments but decrease with the holding horizon. Similarly, riding the 2-year Federal Treasury notes (referred to as "Schätze") is the most effective strategy on a risk adjusted basis across holding periods. The mean riding returns are lower than both for Treasuries and Gilts and the maximum mean excess returns of 3.7% are obtained from riding 10-year paper, the so-called Bunds, for 12 and 18 months. Because there is no continuous spectrum of on-the-run German T-Bills, we are unable to compute any riding strategies with a holding horizon of less than twelve months.[33]

B LIBOR/Swaps

The riding returns and excess returns from using commercial bank liabilities, i.e. LIBOR deposits and swaps are largely similar to those from using government instruments.[34] As before, riding returns generally tend to increase with the maturity of the instrument and the holding horizon. This is not true for dollar and pound sterling excess returns where the largest return pick-ups are achieved by riding long maturity instruments at shorter holding horizons.

[INSERT TABLES IV, V and VI ABOUT HERE]

Riding a 10-year USD swap for two years yields 12.9% per annum, the highest mean riding returns for dollar instruments. This is a mere 70 basis points more compared to the same riding strategy using Treasuries instead. The highest excess returns (6.6% p.a.) are obtained by riding the same maturity instrument, but only over a three month horizon. As with Treasuries, shorter holding horizons perform best on a risk-adjusted basis and the 2-year maturity bucket offers the most attractive reward-to-variability ratios. The strategy of riding a 2-year dollar swap for three months has got a Sharpe Ratio of 0.54, the highest ratio across all credit strategies. Only riding 6-month U.S. T-Bills over the same horizon offers a superior risk-adjusted profit with a Sharpe Ratio of 0.71.

Sterling mean riding returns are consistently higher than the ones for U.S. dollars and peak at 13.0% for riding a 10-year swap for both 18 months and two years. Mean excess returns are at similar levels as the ones in dollar, albeit marginally more volatile, which stands in stark contrast to riding government instruments where sterling excess returns were only half the size of dollar returns. Riding the yield curve with short maturity instruments for short holding horizons are the least attractive strategies with riding a six-month deposit for three months offering no excess returns. Unlike for government paper, however, none of the riding strategies do worse than the corresponding buy-and-hold investment.

This is not the case for strategies with euro-denominated deposits where money-market rides over a three month period either offer no return enhancement or do worse than matching maturity and investment horizon. In addition, euro credit rides show slightly lower mean returns compared to government rides (10.1% v.s. 10.0% for riding the respective 10-year instrument for two years), whereas mean excess returns are on average only marginally higher than for the risk-free rides. This follows directly from the historic behaviour of euro deposit and swap spreads which are displaying high levels of volatility throughout the entire sample period, despite their very low levels. Despite the fact that euro swaps market has a higher notional amount outstanding than any other currency,[35] the absence of any significant swap spreads suggests that eurozone credit is more expensive than elsewhere. This phenomenon, sometimes referred to as the 'euro credit puzzle', is illustrated in figure 3.

C Conditioned Riding

This section reports the results from applying a variety of statistical and macro-based decision making rules to the different riding strategies. Overall we find strong evidence that the excess returns of a large number of riding strategies can be enhanced significantly by relying on these rules. This in itself points to the existence of sizeable risk premia which can be exploited successfully.

[INSERT TABLES VII and VIII ABOUT HERE]

C.1 Positive Slope

This most simple of ex-ante filtering mechanism produces mixed results at improving mean excess riding returns across most of the instruments, holding horizons and currencies. Generally, the amount by which the excess returns rise tends to be highest for the shortest available holding horizons.

For rides with either U.S. Treasuries or German Bunds, a positive slope is not able to improve the excess returns at any horizon. This is in line with the results by Grieves et al. (1992) whose study covers a similar sample period, but uses daily data. For most other instruments, there are significant excess returns at short horizons, but excess returns fall below the unconditioned riding returns for holding horizons beyond one year. Using dollar-denominated deposits and swaps, for example, the mean excess returns are improved by over 60 basis points, from 4.04% p.a. to 4.68% p.a. for 3-months rides. For any longer horizon, however, the unconditioned returns are higher

Euro deposit perform even better with mean excess returns improving by over 350 basis points for 3-months rides and over 30 basis points for 2-year rides. Conditioned rides with sterling instruments are also produce higher mean excess returns for holding horizons up to one year.

C.2 Positive and 75%ile Cushion

Quantifying how much rates have to increase before a riding trade loses money, it comes as no surprise that using the Cushion as a filter performs better than just looking at the slope. For all rides, except for the percentile Cushion in the case of sterling credit instruments, both Cushion-based conditions increase mean excess returns significantly.

In fact, of all the filtering strategies presented in this paper, the percentile cushion is by far the most effective method to enhance riding returns across all instrument and currencies. This is again a fairly intuitive, yet powerful result which states that the higher the break-even interest rate change at the beginning of the riding period, the more profitable it is to ride. The biggest increases are obtained with dollar-based instruments where mean excess returns jump from 3.8% to 12.3% p.a for six month Treasury rides and from 4.0% to 18.5% p.a riding deposits and swaps for three months. However, while the percentile is the most successful riding strategy in most instances, it also has the drawback of sending the least frequent riding signal. In addition, this strategy seems most effective for shorter horizons, which could be related to the fact that after, say 18 months, the original signal no longer contains much informational content.

Because excess returns surge so drastically with the percentile cushion as a filter, the proportion of individual trades with negative returns falls accordingly. This is illustrated in table X where we see that for both dollar and euro-denominated trades an exceptionally large number of the strategies produce positive returns. This is particularly welcome news for risk-adverse investors, such as central bank portfolio managers, who at all times are bound by capital preservation constraints. In other words, riding the yield curve conditional on the cushion exceeding its 2-year 75%ile not only enhances returns in the long run, it also ensures the highest possible number of individual trades does not suffer a capital loss.

[INSERT TABLE X ABOUT HERE]

C.3 Recessions

The results for using a specific measurement of reduced economic activity, i.e. a recession, are quite mixed and vary between currencies, but not instruments. As indicated in section III.C, we use different definitions of what constitutes a recession for different markets. This does not seem to matter, since the definition proposed by the NBER for the U.S. Market does equally well at improving mean excess riding returns as the more 'trivial' definitions used for the U.K. and Euroland.[36]

For dollar-denominated assets, riding the yield curve only during an economic slump is the second most profitable of all riding strategies. For the shortest Treasury riding horizon, mean excess returns are boosted from from 3.9% to over 9.9%, whereas a one year holding horizon for credit instruments augments excess returns from 4.0% to 8.3% p.a.

Riding the sterling yield curves during a recession is the best of all filtering rules, except in case of short investment horizons for Gilts, where it actually causes substantial underperformance compared to buying and holding. Recessionary riding with German assets does not work well with government paper, but displays some return enhancement potential for credit instruments. In line with the results for the U.K. market, the excess returns are largest for the shorter holding horizons.

As identified above, these results might display a simultaneity bias due to the reporting lag associated with recession (cf. footnote 24). However, some preliminary computations indicate that for most currencies and instruments, excess returns are underestimated rather than overstated as a result of this.[37]

C.4 Taylor Rule

The results for riding strategies conditioned on both the traditional and the dynamically estimated version of the Taylor Rule are less pronounced than for other filters, but encouraging nonetheless; in particular the Dynamic or Judd-Rudebusch specification of the Taylor Rule increases mean excess riding returns by as much as 40 basis points p.a. for a three month holding horizon. In line with the majority of alternative riding conditions, the additional return pick-up for this type of rides steadily declines over longer investment horizons. Nevertheless, for a 2-year investment period Taylor Rule riding still offers an improvement of 3.2% p.a compared to buy-and-hold strategies.

In this paper, we only apply the Taylor Rule to the U.S. market since specification issues of estimating the Taylor Rule for other currencies are beyond our current scope. Given its relative success as a return enhancement strategy for U.S. Treasury rides, however, extending the application to other markets could be an interesting area for further research.

C.5 Market Expectations

As reported in section III.C.3, market participants are fairly good at forecasting changes in the federal funds rate which implies that futures-based proxies for market expectations are a useful predictor of changes in the monetary policy stance. When employing this expectations-based filter to ride the yield curve, however, our empirical results are mixed as average excess riding returns cannot be increased across all holding horizons.

The strategy works well at the 3-month and 6-month horizon holding horizons, roughly increasing excess returns in the same order of magnitude as the Taylor Rule for the same horizons. Excess returns can be pushed up by close to 50 basis points from 2.6% to 3.1% (or +18.5%) over a 3 month period, and increase by 30 basis points over a 6 months horizon. For these horizons, expectation-based riding also represents a superior strategy on a risk-adjusted basis as the conditioned excess returns have higher Sharpe Ratios than unrestricted riding alternatives. For holding horizons beyond 6 months, however, market expectations are not able to enhance excess returns - in the contrary, this strategy even dampens returns while not reducing volatility accordingly. This should be barely surprising, taking into account that the informational content of a short-term instrument such as fed fund futures is unlikely to be relevant for much beyond the instruments maturity.

A more detailed investigation into a possible 'term structure of market expectations' as implied by fed funds futures could investigate if deferred month futures contracts are able to provide an improved signal for longer-dated investment horizons.

D Government vs. Credit

The effectiveness of riding credit instruments instead of risk-free government paper generally increases with the maturity of the instrument and the holding horizon. This strategy appears to work best for dollar-denominated assets where excess returns can be improved by as much as 1.61% p.a. by riding with 10-year swaps as opposed to Treasuries. For euro assets, the success of such trades is at best very modest, whereas for sterling-based trades riding the credit curve instead of the government curve does not seem advisable.

[INSERT TABLE IX ABOUT HERE]

In the case of euro assets, the poor performance of credit relative to government rides is easily explained by the virtual absence of a positive credit spread (cf. bottom graph of figure 3). In the case of sterling assets, however, any attempts of an explanation seem less straight forward, but are most likely linked to the fact that, on balance, the Gilt curve tends to be steeper than the GBP LIBOR/swap curve (cf. figure 2 and 3).

E Duration-Neutral Riding

While we have seen that riding the yield curve may indeed offer an attractive means to enhance returns, there are some practical drawbacks to this strategy. In particular, riding the yield curve instead of buying and holding exposes the investor to a higher amount of interest rate risk because of duration extension implicit in riding the yield curve. Indeed, bond portfolio managers, especially reserve managers at central banks who operate within strict risk management guidelines may not be able to engage in longer maturity rides without being able to control for duration.

E.1 Adjusting for Duration

By definition, any riding strategy is implicitly not only taking a position on the slope of the term structure but also entails some exposure to the level of interest rates. By adjusting for duration, the element of placing an outright bet on the future direction of interest rates is removed and the investor is left with her primary objective of taking advantage of a specific yield curve environment. This may be particularly relevant in our case, since for all currencies there has been a clear downtrend in interest rates over the entire 25 to 30-year sample period (see figure 2).

In our context, the most meaningful duration target is the duration of the different buy-and-hold strategies, i.e. 3, 6, 9, 12, 18 and 24 months. For this purpose, we match the duration of the holding horizon by constructing a duration-neutral barbell portfolio using a weighted combination of the respective riding instrument and an overnight deposit. For instance in the case of riding a 12-month instrument for 3 months, the duration of a portfolio invested in an overnight deposit plus the 12-month instrument should, ex-ante, be equal to the duration of the 3-month instrument. This is expressed as:

$$D^H = \omega D^R + (1-\omega)D^O, \tag{28}$$

where D^H is the target duration of the holding horizon, D^R is the duration of the riding instrument, D^O is the duration of an overnight deposit and ω is the proportion invested in the instrument such that the portfolio is duration neutral. Solving equation 28 for ω gives

$$\omega = \frac{D^H - D^O}{D^R - D^O}. \tag{29}$$

For practical purposes we can assume in the above example that $D^H = 0.25$, $D^R = 1$ and $D^O = 0$, thus $\omega = 0.25$. In line with the notation of equation 13, the duration-neutral riding returns are now defined as

$$\widehat{XR}_{[m,h]} = \omega H^R_{[m,h]} + (1-\omega)H^O_{[h]} - H_{[h]}. \tag{30}$$

where $H^R_{[m,h]}$ is the riding return, $H^O_{[h]}$ is the return of an overnight deposit compounded over the holding horizon h, and $H_{[h]}$ is the return of the buy-and-hold strategy.[38]

E.2 Results

We compute the duration-neutral excess holding period returns for U.S. Treasuries only, since the extension of this concept to other currencies and instruments will add little additional insights. The results of these duration-neutral riding strategies are reported in table XI, which also contains the non-adjusted returns for ease of comparison.

[INSERT TABLE XI ABOUT HERE]

Most strikingly, but nonetheless expected, is the dramatic decline in the mean excess returns when comparing the standard rides with the duration-neutral ones. Since the interest rate exposure of the standard rides is a linear function of the duration of the riding instrument, the duration-neutral excess returns are reduced by a factor roughly equivalent to the duration of the riding instrument. In other words, the duration-adjusted excess riding returns of the 10-year Treasury are approximately ten times smaller than the non-adjusted ones, independent of the holding horizon.

For a given holding horizon, however, the relative riskiness of the different riding instrument remains unchanged. For example, with the exception of the three month holding horizon, using 2-year Treasuries as riding instrument is the most effective riding strategy, whereas using the 10-year invariably seems to be the most risky strategy.

While the risk-adjusted rankings of different riding strategies seem to be transitive between the two scenarios, the duration-adjusted strategies are significantly more efficient on a risk-adjusted basis. Without almost any exceptions, the duration-neutral strategies display a *higher Sharpe Ratio* compared to the unadjusted strategies. This result confirms earlier findings that duration is a good proxy for interest rate risk as up to 90% of yield curve changes are explained by a level change across rates. Thus, as with other investment strategies, an investor is likely to increase her returns by assuming a duration exposure when riding the yield curve - but she does so at the cost of increased relative volatility (cf. Ilmanen (1996*b*; 1996*a*; 2002)). Duration-neutral riding may therefore provide fixed-income managers with an additional tool to increase their portfolio returns without unduly increasing the interest rate risk of their investments.

V Conclusion

Riding the yield curve, a conceptually simple trading strategy, relies on the existence of exploitable risk premia. If market participants are able to earn risk-adjusted excess profits from riding the yield curve, this is stands in contradiction to, at least, the weak form of the efficient markets hypothesis. This paper explores to what extent this proposition holds for two main asset classes across three major fixed-income markets.

We add to the existing literature by looking at riding strategies for maturities beyond one year, by focusing on non-dollar currencies and by comparing rides between risk-free government securities and instruments that contain a limited amount of credit risk. In addition, we propose and test various ex-ante rules to improve the success rate of different riding strategies.

With a sample period covering several interest rate cycles, our findings confirm that investors could have significantly enhanced their returns by riding the yield curve instead of buying and holding. Furthermore, employing relatively straight forward filter rules would have increased these excess returns even more. Since not all conditional rides perform equally well across currencies and instruments, diversification among various strategies may present an additional approach to improve returns over the longer term. By introducing the concept of duration-neutral riding, we are able to show that riding the yield curve is also a superior investment strategy on a risk-adjusted basis.

A Derivation of Formula for Riding Returns

This section provides a detailed derivation of equations (18) and (19). We recall that these equations provide an intuitive approximation to calculate the excess riding returns from selecting one strategy vis-à-vis another. In our case, we are calculating the excess returns from riding down the government curve instead of the (LIBOR-based) credit curve.

A Money Market Version

Our starting point is the explicit money-market version of the excess riding returns, equation (18):

$$\begin{aligned} XH^{M,ride}_{[m,h]} &= \left(\frac{\left(1 + y_{m,t}\frac{m}{z}\right)}{\left(1 + y_{m-h,t+h}\frac{m-h}{z}\right)} - 1 \right) - \\ &- \left(\frac{\left(1 + \hat{y}_{m,t}\frac{m}{z}\right)}{\left(1 + \hat{y}_{m-h,t+h}\frac{m-h}{z}\right)} - 1 \right), \end{aligned} \tag{A-1}$$

where the hats over the variables indicate the corresponding rates for the credit instrument at the respective times and z is the currency-specific day-count basis. We now introduce the following notation:

1. At time t, the interest rate of the m-maturity credit instrument $\hat{y}_{m,t}$ can be expressed as the government rate $y_{m,t}$ plus a yield spread ϵ. This is written as $\hat{y}_{m,t} = y_{m,t} + \epsilon$.
2. Between time t and time $t + h$, the interest rate of the credit instrument $\hat{y}_{m,t}$ has changed by an amount η. This is expressed as $\hat{y}_{m-h,t+h} = \hat{y}_{m,t} - \eta$.
3. Similarly, between time t and time $t + h$, the interest rate of the government instrument $y_{m,t}$ has changed by an amount ψ. This is expressed as $y_{m-h,t+h} = y_{m,t} - \psi$.

Noting that for small x and y, we can assume $\frac{1+x}{1+y} \approx 1 + x - y$, equation (A-1) can now be stated as:

$$
\begin{aligned}
XH_{[m,h]}^{M,ride} &\approx \left(y_m \left(\frac{m}{z}\right) - \underbrace{y_{m-h,t+h}}_{y_{m,t}-\psi} \left(\frac{m-h}{z}\right) \right) - \\
&- \left(\underbrace{\hat{y}_{m,t}}_{y_{m,t}+\epsilon} \left(\frac{m}{z}\right) - \underbrace{\hat{y}_{m-h,t+h}}_{y_{m,t}+\epsilon-\eta} \left(\frac{m-h}{z}\right) \right) = \\
&= \frac{1}{z} \left[-m\epsilon - (y_{m,t} - \psi)(m-h) + (y_{m,t} + \epsilon - \eta)(m-h) \right] = \\
&= \frac{1}{z} \left[-m\epsilon + (\psi + \epsilon - \eta)(m-h) \right] = \\
&= \frac{1}{z} \left[\underbrace{-h\epsilon}_{\text{initial spread}} + \underbrace{(\psi - \eta)(m-h)}_{\text{slope effect}} \right]. \qquad \text{(A-2)}
\end{aligned}
$$

According to equation (A-2), the excess returns from riding the government instead of the credit yield curve are a linear combination of the initial yield pick-up, ϵ, and the relative slope difference of the instruments' yield curve, $\psi - \eta$.

B Bond Market Version

As before, we begin with the explicit version of the excess riding returns, equation (19):

$$
\begin{aligned}
XH_{[m,h]}^{B,ride} &= \left(\frac{(1 + y_{m,t})^{\frac{m}{z}}}{(1 + y_{m-h,t+h})^{\frac{m-h}{z}}} - 1 \right) - \\
&- \left(\frac{(1 + \hat{y}_{m,t})^{\frac{m}{z}}}{(1 + \hat{y}_{m-h,t+h})^{\frac{m-h}{z}}} - 1 \right), \qquad \text{(A-3)}
\end{aligned}
$$

where the hats over the variables indicate the corresponding rates for the credit instrument at the respective times. Again, assuming that $\hat{y}_{m,t} = y_{m,t} + \epsilon$, $\hat{y}_{m-h,t+h} = \hat{y}_{m,t} - \eta$, and $y_{m-h,t+h} = y_{m,t} - \psi$, we can substitute these conditions into equation (A-3). Recalling that $\frac{P_{t+h}}{P_t} - 1 \approx y_{m,t}\frac{h}{z} - \Delta y_t D_{t+h}$[39] from section B.2, we can derive an approximate expression for the excess riding returns from selecting one strategy vis-à-vis another:

$$
\begin{aligned}
XH^{B,ride}_{[m,h]} &\approx \left(y_m \frac{h}{z} - \underbrace{\Delta y_t}_{-\psi} D_{m-h,t+h} \right) - \left(\underbrace{\hat{y}_{m,t}}_{y_{m,t}+\epsilon} \frac{h}{z} - \underbrace{\Delta \hat{y}_t}_{-\eta} D_{m-h,t+h} \right) = \\
&= \left[y_m \frac{h}{z} + \psi D_{m-h,t+h} - (y_{m,t} + \epsilon) \frac{h}{z} - \eta D_{m-h,t+h} \right] = \\
&= \frac{1}{z} \left[\underbrace{-h\epsilon}_{\text{initial spread}} + \underbrace{(\psi - \eta)\left(D_{m-h,t+h} z\right)}_{\text{slope effect}} \right]. \qquad \text{(A-4)}
\end{aligned}
$$

This way of expressing excess returns of different investment strategies may particularly appealing to market practitioners for two reasons. First, because it relies only on inputs that can easily be observed, the formula is straight-forward to compute. Second, excess returns are expressed as a function of two, theoretically meaningful factors. This means that the formula is particularly useful for performing ad-hoc scenario analyses. Furthermore, its use as a decision making tool can easily be extended to many other investment strategies.

B Estimation of Zero Coupon Yields

This section follows closely an unpublished technical manual on the implementation of zero-coupon curve estimation techniques at central banks compiled by the BIS (1999). The non-parametric estimation of a zero-coupon yield curve is based on an assumed functional relationship between either par yields, spot rates, forward rates or discount factors on one hand and maturities on the other hand. *Discount factors* are the quantities used at a given point in time to obtain the present value of future cash flows. A *discount function* $d_{t,m}$ is the collection of discount factors at time t for all maturities m.

B.1 Svensson Method

Whereas for zero-coupon bonds spot rates can be derived directly from observed prices, for coupon-bearing bonds usually only their 'yield to maturity' is quoted. Let $P_{i,t}$ be the price[40] of a bond with maturity $i = 1, 2, \ldots, n$ and a stream of cash flows CF_{ij} at times m_{ij}. The yield to maturity is the constant interest rate y_t that sets the present value of a bond equal to its price:

$$P_{i,t} = \sum_{i=1}^{n} \frac{CF_i}{(1+y_t)^{t_i}}. \tag{B-1}$$

The yield to maturity is therefore an average of the spot rates - and consequently also the discount rates - across different maturities. Consequently, the vector of discount bonds corresponding to the coupon-bearing bonds can be estimated from the following non-linear model:

$$P_{i,t} = \sum_{j=1}^{n} CF_{ij}\delta\left(m_{ij}, \vec{\beta}\right) + \epsilon_{i,j}, \quad i = 1, 2 \ldots n, \tag{B-2}$$

where $\delta\left(m_{ij}, \beta\right)$ is a parametric discount function with the parameter vector $\vec{\beta} = (\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2)$.

In attempting to estimate this discount function, Nelson and Siegel (1987) assume an explicit functional form for the term structure of interest rates. To improve the flexibility of the curves and the fit, Svensson (1994) extended Nelson and Siegel's function and according to this model the zero-coupon rates are given by:

$$\begin{aligned} s\left(m,\vec{\beta}\right) &= \beta_0 + \beta_1 \frac{1-\exp\left(-\frac{m}{\tau_1}\right)}{\frac{m}{\tau_1}} + \\ &+ \beta_2 \left(\frac{1-\exp\left(-\frac{m}{\tau_1}\right)}{\frac{m}{\tau_1}} - \exp\left(-\frac{m}{\tau_1}\right)\right) + \\ &+ \beta_3 \left(\frac{1-\exp\left(-\frac{m}{\tau_2}\right)}{\frac{m}{\tau_2}} - \exp\left(-\frac{m}{\tau_2}\right)\right), \end{aligned} \tag{B-3}$$

and the discount function is

$$\delta\left(m,\vec{\beta}\right) = \exp\left(-\frac{s\left(m,\vec{\beta}\right)}{100} m\right). \tag{B-4}$$

Equations (B-3) and (B-4) are substituted into equation (B-2) and the parameter vector $\vec{\beta}$ is estimated via a non-linear maximization algorithm.

B.2 Spline-based Method

The 'smoothing splines' method developed by Fisher, Nychka and Zervos (1995) represents an extension of the more traditional cubic spline techniques.[41] A cubic splice is a so-called piecewise cubic polynomial joined at 'knot points'. The polynomials are then restricted at the knot points such that their level and first two derivatives are identical. To each knot in the spline corresponds on parameter. In the case of 'smoothing splines' the number of parameters to be estimated are not fixed in advance. Instead, one starts from a model which is initially over-parameterised. Allowing for a large number of know points guarantees sufficient flexibility for curvature throughout the spline. The optimal number of knot points is then determined by minimizing the ratio of a goodness-of-fit measure to the number of parameters. This approach penalizes for the presence of parameters which do not contribute significantly to the fit.

There is a broad range of spline-based models which use the 'smoothing' method pioneered by Fisher *et al.* (1995). The main difference among the various approaches simply lies in the extent to and fashion by which the smoothing criteria is applied to obtain a better fix. The 'variable penalty roughness' (VRP) approach recently implemented by the Bank of England allows the 'roughness' parameter to vary with the maturity, permitting more curvature at the short end.[42]

Generally, the estimation method largely depends on intended use of data: no-arbitrage pricing and valuation of fixed-income and derivative instruments or information extraction for investment analytical and monetary policy purposes. One of the main advantages of spline-base techniques over parametric forms, such as the Svensson method, is that, rather than specifying a single functional form to describe spot rates, they fit a curve to the data that is composed of many segments, with the constraint that the overall curve is continuous and smooth.[43]

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Notes

[1]Apart from the simple or pure REHTS, there exist various other theories of the term structure of interest rates. These theories distinguish themselves by being based on different assumptions about the HPRs. For example, the Liquidity Preference Hypothesis assumes that HRPs also depend on a constant term premium that monotonically increases with the term to maturity. Other variations of the REHTS include the Market Segmentation Hypothesis or the Preferred Habitat Hypothesis. See Miskin (1990) or Cuthbertson (1996) for a thorough overview.

[2]See Cook and Hahn (1990) for a comprehensive review of the literature. Since then a number of authors claim to have found evidence in support of the hypothesis (Rudebusch (1995) or Gerlach and Smets (1997)). Other authors, however, continue to reject the hypothesis either fully (Taylor (1992)) or only for short-dated maturities (Campbell and Shiller (1991)).

[3]The terms *riding* and *rolling* down the yield curve are often used interchangeably. Whilst they are similar, they are not exactly the same. Rolling refers to funding a long-term asset with a short-term liability, for example by borrowing money at the 1-month LIBID rate and investing into a 1 year T-Bill. It is essentially a leveraged ride of the yield curve. In this paper, we will keep the two concepts separate.

[4]Campbell and Shiller (1991) provide an extensive treatment of this point.

[5]See Fehle (2003) for a recent overview of the literature and He (2000) for a concise summary of main drivers of swap spreads.

[6]Duffie and Huang (1996) examine the effects of credit risk on swap rates. They conclude that the credit quality differential between the swap counterparties increases the swap rate by as little as 1 basis point per 100 basis points difference in the bond yields of the two counterparties.

[7]See Dignan (2003) for a recent exposition. Brandt and Kravajecz (2003) find that liquidity can account for as much as 26 percent of the day-to-day variation in U.S. Treasury yields.

[8]Throughout this paper, we use simple compounding for interest rates and yields are expressed in percentage rather than decimal format, whereby $y_{m,t} = 0.035$ is written as $y_{m,t} = 3.5\%$. T-Bill rates can be converted from discount yield to money-market yield using the conversion $y_M = \frac{360 y_d}{360 - d y_d}$.

[9]Different currencies and different fixed-income instruments have different methods of counting days. Money market instruments generally count the actual number of days per month and use a 360 day calendar year. Thus, the convention is $\frac{m}{z} = \frac{ACT}{360}$ except for GBP, where $z = 365$. Corporate bonds generally count 30 days to each month and 360 days per year ($\frac{30}{360}$), while Treasury bonds and swaps count the actual days per month and year ($\frac{ACT}{ACT}$).

[10]This approximation of returns ignores convexity effects. It can be improved by including convexity such that $\frac{P_{t+h}}{P_t} - 1 \approx y_{m,t} h - \Delta y_t D_{t+h} + \frac{1}{2} C_{t+h} \Delta y_t^2$. See Fabozzi (1997) or Grabade (1996) for a derivation of this approximation.

[11]The modified duration of a zero coupon bond is simply its (remaining) time to maturity, i.e. $D_{m-h,t+h} = (m-h)/z$. Consequently, zero coupon bonds have zero convexity which implies that for such instruments equation (14) does not suffer from a convexity bias.

[12]Although we only consider two types of instruments (government and swaps) in this paper, the following analysis can easily be extended to other fixed-income asset classes.

[13]A detailed description of the intuition behind the new notation and the derivation of equations (18) and (19) is provided in appendix A.

[14]It is important to note equations (20) and (21) assume no change in the yield curve between time t and time $t + h$.

[15]Selected Interest Rates (Table H.15 in Statistics: Releases and Historic Data) published by the Board of Governors of the Federal Reserve System.

[16]Until 1999, the Bank of England also employed the Svensson method for yield curve estimation. A detailed account of the motivation for adopting a new approach based on smoothing splines is given by Anderson *et al.* (1999) and Brooke (2000).

[17]From January 1999 the DEM LIBOR and swap rates are replaced by euro interest rates.

[18]This categorization of different curve types is often applied inconsistently in the literature as non-parametric curves also depend upon a set of parameters.

[19]Dai and Singleton (2000) explore the structural differences and relative goodness-of-fit of so-called affine term structure models. Given that for such models there is a trade-off between flexibility in modelling the conditional correlations and the volatilities of the risk factors, they identify some models which are better suited than others to explain historical interest rate behaviour.

[20]Similar results are reported by Dewachter and Lyrio (2002) who find that the level factor is highly correlated to long-run inflation expectations, the slope factor captures temporary business conditions, while the curvature factor appears to represent an independent monetary policy factor.

[21]This is consistent with a number of empirical studies that report a positive relationship between the volatility of short-term interest rates and the shape of the yield curve (e.g. see Christiansen (2002)).

[22]McCallum (1994) shows the theoretical linkage between the Federal Reserve's policy and various tests of the REHTS. For a comprehensive set of results, see Dotsey (1995) and Rudebusch (1995).

[23]See `http://www.nber.org/cycles/main.html` for information on recessions and recoveries, the NBER Business Cycle Dating Committee, and related topics.

[24]In the case of the NBER, there are some curious announcement asymmetries; the peak of business cycles are generally declared with a lag of 7–8 months, whereas troughs take up to 18 months to report. For example, the most recent recession lasting from March to November 2001 was announced on 26 November 2001 and officially declared over only on 17 July 2003. In the case of the UK and Germany, there are no official statements that help identify recessions. Thus, taking the standard definition of 2 quarters of declining GDP, recessions only become known with a lag of 6 months.

[25]Taylor (1993) used a log-linear trend of real GDP over 1984:Q1 to 1992:Q3 as a measure of potential GDP. As discussed below, Judd and Rudebusch (1998) use a more flexible estimate.

[26]Look-ahead bias arises because of the use of information in a simulation that would not be available during the time period being simulated. Using lags of variables as they would have been available at the time of the simulation, we estimate $i_t^{TR} = \pi_{t-3} + r^* + 0.5\,(\pi_{t-3} - \pi_t^*) + 0.5 y_{t-3}$.

[27]In an alternative specification, we defined $\Delta Taylor_t$ as the difference between the Taylor Rule estimate and the actual target rate, which implies that the Taylor Rule is not only useful to predict changes in the federal funds target, but also sets the optimal level. In this instance, there is only mild significance on the predictive power of the Taylor Rule. In particular, the Taylor Rule does well prior to 2000, but then seems to be breaking down. Running the regression from 1989:01 (when the Federal Reserve started moving in multiples of 25 basis points) to 2000:01 (just before the target rate peaked), the predictive power of the dynamically estimated Taylor Rule is highest. See figure 5.

[28]Since a minimum of five years of out-of-sample data are required for a first reasonable Taylor Rule estimate, the overall sample size for U.S. government data is reduced by approximately 60 observations.

[29]One possible explanation for the observation that $\phi < 1$ may be stem from the fact that the parameter estimates suffer from a downward bias due to the implied 'target rate stickiness', i.e. the assumption that the Fed only moves rates in multiples of 25 basis points.

[30]Because the futures settlements price is calculated as 100 minus the average effective fed funds rate for the contract month, the implied futures rate is given by $i_t^f = 100 - p_t^f$, where p_t^f is the price of the contract at time t.

[31]Because the expected average funds rate for the entire contract month is a time-weighted average of the observed rates so far and the expected rates for the remaining days, as the month end approaches, the futures price gets increasingly determined by past daily movements in the effective funds rate rather than expectations. Thus, when the FOMC meeting falls on any time after the middle of the month, we define the next month's contract as the 'relevant contract'.

[32]As with the signal from the Taylor Rule, we put on a riding trade whenever the market expectations signal does not indicate a rate hike.

[33]The German Treasury has only recently started auctioning 6-month discount paper, the Bubills, at regular monthly intervals.

[34]Although a swap is a zero NPV instrument (i.e. not an investment in the strictest sense), a synthetic asset can be created by receiving the fixed rate of the swap and investing the proceeds in a deposit which is continuously rolled-over to meet the floating payments. As such, swaps represent AA credit risk and have less correlation with lower credits except during a 'flight to quality' or other Treasury-driven events.

[35]According to the BIS' Triennial Survey (2002), at end April 2001 approximately 37% of the total notional principal outstanding of $59 trillion were denominated in euros, 33% in dollars and 16% in yen.

[36]Over the respective sample periods for the different currencies, there are 28 months of recession in the United States, 25 months in the United Kingdom and 61 months in Germany.

[37]For both Treasuries and USD Swaps, using lagged NBER recessions increases excess returns even more - across all holding horizons. E.g. For 3-month rides, mean excess returns increase from 9.92% to 13.12% for Treasuries and from 6.84% to 13.72% for Swaps. For Gilts, lagged recessions do slightly worse and for Swaps the results are broadly unchanged (some horizons improve, others get marginally worse). For German Bunds, lagged recessions increase riding returns marginally across all holding horizons compared to the 'simultaneous' recessions. For EUR Swaps it gets worse across the board, though still positive excess returns. For some horizons, however, the excess returns get lower than the unconditional ones.

[38]The returns of the overnight deposits are computed by geometrically linking daily returns of overnight LIBID rates for each month of the sample period. Although we ignore transaction costs, the duration-neutral riding strategies may incur higher transaction costs due the daily rebalancing of the overnight deposit.

[39]see footnote 12. The modified duration of a zero coupon bond is simply its (remaining) time to maturity, i.e. $D_{m-h,t+h} = (m-h)/z$.

[40]Defined as clean price plus accrued interest up to time t.

[41]Spline functions, such as basis or B-splines, are used in the context of yield curve estimation. There is sometime some confusion among practitioners between spline functions and spline-based interpolation. While the former technique uses polynomials in order to approximate (unknown) functions, the latter is simply a specific method to interpolate between two data points.

[42]see Anderson and Sleath (1999).

[43]For example, at the long end of the yield curve, the Svensson model is constrained to converge to a constant level, directly implying that the unbiased expectation hypothesis holds.

C Tables

Table I: **U.S. Treasuries**: HPR Statistics for Different Riding Strategies

The table summarizes returns and excess returns for different riding strategies across selected horizons. The first column lists the maturity of the riding instrument m. In order to compute the holding period returns (HPR) of riding an m-maturity instrument for h months, the $(m-h)$ rate must also be available. XHPR represents the excess riding returns over the buy-and-hold strategy. S.R. is the Sharpe ratio of the excess returns. Returns and standard deviations are annualized for ease of comparison. The standard deviations of the various mean returns were corrected for overlapping data by using a Newey-West (1994) correction on the standard errors of the respective mean, where the lags are set equal to the length of the holding horizon.

Horizon	HPR H^m_{t+h} (%)				XHPR XH^m_{t+h} (%)				
Instrument	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	S.R.
3-month									
6-month	6.3	2.8	0.3	5.0	0.5	0.7	-0.3	1.7	0.71
2-year	7.8	4.9	-1.5	8.4	2.0	3.9	-2.5	5.2	0.52
5-year	9.8	10.1	-5.5	14.8	4.0	9.5	-7.0	12.1	0.42
7-year	10.8	13.2	-7.6	20.0	5.0	12.7	-10.0	17.4	0.39
10-year	12.0	17.9	-11.6	27.4	6.2	17.4	-13.9	24.7	0.35
6-month									
1-year	6.5	5.1	0.6	9.3	0.4	1.6	-1.1	2.3	0.28
2-year	7.7	7.4	-0.3	13.9	1.7	4.8	-2.4	6.8	0.35
5-year	9.9	14.3	-4.7	24.4	3.8	12.7	-7.8	17.3	0.30
7-year	10.9	18.5	-8.1	29.5	4.8	17.1	-11.3	22.4	0.28
10-year	12.1	25.1	-12.7	37.6	6.0	23.8	-17.5	31.0	0.25
12-month									
2-year	7.6	10.4	1.2	18.7	1.2	4.7	-2.4	5.6	0.25
5-year	9.9	18.9	-4.2	29.5	3.5	15.7	-8.9	17.8	0.22
7-year	10.9	24.9	-7.2	39.6	4.5	22.2	-14.1	30.1	0.20
10-year	12.2	33.4	-13.3	54.4	5.8	31.3	-22.4	45.0	0.18
18-month									
2-year	7.4	12.5	4.4	23.7	0.5	2.8	-1.1	3.10	0.19
5-year	9.8	22.0	-1.2	40.9	3.0	16.0	-8.5	22.1	0.19
7-year	10.9	28.5	-3.5	52.2	4.1	23.3	-14.9	35.4	0.18
10-year	12.2	37.3	-10.8	69.7	5.4	33.0	-24.7	51.8	0.16
24-month									
5-year	9.8	25.3	4.4	51.1	2.6	15.0	-6.6	24.6	0.17
7-year	10.9	31.8	1.6	67.1	3.7	22.3	-9.6	40.6	0.17
10-year	12.2	40.1	-1.9	95.3	5.0	31.5	-12.0	68.9	0.16

Table II: **U.K. Gilts**: HPR Statistics for Different Riding Strategies

The table summarizes returns and excess returns for different riding strategies across selected horizons. The first column lists the maturity of the riding instrument m. In order to compute the holding period returns (HPR) of riding an m-maturity instrument for h months, the $(m-h)$ rate must also be available. XHPR represents the excess riding returns over the buy-and-hold strategy. S.R. is the Sharpe ratio of the excess returns. Returns and standard deviations are annualized for ease of comparison. The standard deviations of the various mean returns were corrected for overlapping data by using a Newey-West (1994) correction on the standard errors of the respective mean, where the lags are set equal to the length of the holding horizon.

Horizon	HPR H^m_{t+h} (%)				XHPR XH^m_{t+h} (%)				
Instrument	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	S.R.
3-month									
6-month	5.6	1.4	0.7	3.1	-0.1	0.3	-0.2	0.2	-0.29
9-month	7.8	2.9	0.4	4.2	-0.2	0.7	-0.8	0.5	-0.28
1-year	8.0	3.1	0.1	4.8	-0.2	1.1	-1.1	0.8	-0.19
2-year	8.9	5.1	-1.1	7.6	0.2	2.4	-2.3	2.0	0.10
5-year	10.2	11.4	-8.9	17.0	0.9	6.3	-6.7	4.7	0.14
7-year	10.9	14.4	-11.6	20.3	1.4	8.2	-8.7	6.0	0.17
10-year	11.8	18.1	-13.9	28.4	2.3	10.6	-10.6	7.8	0.22
6-month									
9-month	5.9	2.5	1.5	7.0	-0.1	0.5	-0.7	0.3	-0.21
1-year	8.0	4.8	1.2	8.1	-0.4	1.7	-2.4	1.8	-0.22
2-year	9.0	7.2	0.1	12.0	0.2	4.5	-4.9	6.1	0.04
5-year	10.3	15.0	-8.3	23.8	1.3	12.7	-13.8	17.4	0.10
7-year	11.0	18.7	-12.4	29.5	1.9	16.3	-17.0	20.1	0.12
10-year	11.8	23.0	-17.2	41.8	2.6	20.3	-21.7	21.2	0.13
12-month									
2-year	9.2	10.8	3.0	21.3	0.5	4.8	-4.2	6.8	0.11
5-year	10.6	18.8	-4.6	42.8	1.9	15.6	-13.8	28.3	0.12
7-year	11.4	23.6	-8.4	52.4	2.8	21.0	-17.7	37.9	0.13
10-year	12.3	30.6	-12.8	64.2	3.6	28.9	-23.7	49.7	0.13
18-month									
2-year	9.0	13.7	6.3	25.6	0.2	2.7	-2.8	3.1	0.09
5-year	10.8	21.8	0.9	44.9	1.8	15.2	-12.8	22.6	0.12
7-year	11.7	27.4	-2.6	53.2	2.7	21.9	-18.1	30.8	0.12
10-year	12.7	36.1	-10.3	67.6	3.7	32.4	-25.8	44.6	0.11
24-month									
5-year	11.0	25.4	5.5	52.5	1.6	14.2	-12.3	21.1	0.11
7-year	11.9	31.3	1.0	63.0	2.6	21.7	-18.4	31.7	0.12
10-year	13.0	40.7	-5.2	79.8	3.6	33.6	-27.6	47.8	0.11

Table III: **German Gov't Bonds**: HPR Statistics for Different Riding Strategies

The table summarizes returns and excess returns for different riding strategies across selected horizons. The first column lists the maturity of the riding instrument m. In order to compute the holding period returns (HPR) of riding an m-maturity instrument for h months, the $(m-h)$ rate must also be available. XHPR represents the excess riding returns over the buy-and-hold strategy. S.R. is the Sharpe ratio of the excess returns. Returns and standard deviations are annualized for ease of comparison. The standard deviations of the various mean returns were corrected for overlapping data by using a Newey-West (1994) correction on the standard errors of the respective mean, where the lags are set equal to the length of the holding horizon.

Horizon	HPR H_{t+h}^{m} (%)				XHPR XH_{t+h}^{m} (%)				
Instrument	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	S.R.
12-month									
2-year	6.7	9.6	0.9	16.0	0.8	5.1	-5.2	5.4	0.15
5-year	8.3	17.7	-5.9	23.0	2.4	16.0	-14.0	14.3	0.15
7-year	8.9	22.5	-9.6	26.6	3.0	21.4	-17.7	18.8	0.14
10-year	9.6	29.0	-11.9	37.1	3.7	28.5	-20.0	27.8	0.13
18-month									
5-year	8.4	22.0	-4.0	34.3	2.2	18.0	-13.6	15.2	0.12
7-year	9.1	27.7	-9.0	37.4	2.9	24.8	-18.1	23.1	0.12
10-year	9.9	35.3	-15.6	46.8	3.7	33.4	-22.7	33.0	0.11
24-month									
5-year	8.5	25.4	-3.3	36.7	2.0	18.5	-13.4	14.9	0.11
7-year	9.2	32.1	-8.9	40.3	2.7	26.8	-19.3	23.5	0.10
10-year	10.1	41.1	-15.1	52.4	3.6	37.2	-23.6	35.4	0.10

Table IV: **USD LIBOR/Swaps**: HPR Statistics for Different Riding Strategies

The table summarizes returns and excess returns for different riding strategies across selected horizons. The first column lists the maturity of the riding instrument m. In order to compute the holding period returns (HPR) of riding an m-maturity instrument for h months, the $(m-h)$ rate must also be available. XHPR represents the excess riding returns over the buy-and-hold strategy. S.R. is the Sharpe ratio of the excess returns. Returns and standard deviations are annualized for ease of comparison. The standard deviations of the various mean returns were corrected for overlapping data by using a Newey-West (1994) correction on the standard errors of the respective mean, where the lags are set equal to the length of the holding horizon.

Horizon	HPR H^m_{t+h} (%)				XHPR XH^m_{t+h} (%)				
Instrument	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	S.R.
3-month									
6-month	5.8	2.3	0.3	3.2	0.2	0.4	-0.3	0.4	0.45
9-month	5.9	2.3	0.3	3.5	0.3	1.0	-0.9	0.8	0.29
1-year	6.4	2.7	-0.1	4.4	0.8	1.5	-1.0	1.6	0.53
2-year	7.7	4.5	-1.8	6.4	2.1	3.9	-2.7	3.7	0.54
5-year	9.8	9.5	-6.8	10.3	4.1	9.4	-7.6	8.6	0.44
7-year	10.9	12.2	-9.8	12.5	5.3	12.0	-10.6	10.8	0.44
10-year	12.2	16.2	-11.9	15.2	6.6	16.0	-12.7	14.4	0.41
6-month									
9-month	5.9	3.9	0.6	5.9	0.1	0.7	-0.6	0.7	0.19
1-year	6.2	4.1	0.6	6.5	0.4	1.5	-1.1	1.6	0.29
2-year	7.7	6.1	-0.5	8.7	1.9	4.9	-2.5	5.3	0.39
5-year	9.8	12.6	-5.8	16.6	4.0	12.3	-7.6	13.6	0.33
7-year	11.0	16.3	-8.7	19.2	5.2	16.0	-10.5	18.1	0.32
10-year	12.2	21.5	-12.1	24.8	6.5	21.2	-14.4	23.7	0.31
12-month									
2-year	7.5	8.7	1.1	13.6	1.4	5.1	-2.8	4.9	0.27
5-year	10.0	17.0	-5.7	21.2	3.8	16.2	-9.5	15.2	0.24
7-year	11.2	21.3	-9.2	26.3	5.1	20.8	-12.8	19.8	0.24
10-year	12.6	27.5	-14.4	33.4	6.5	27.0	-18.4	25.6	0.24
18-month									
2-year	7.3	10.1	4.9	19.1	0.7	3.2	-1.1	3.4	0.21
5-year	10.1	20.1	-2.2	29.5	3.5	17.2	-8.4	17.2	0.20
7-year	11.4	24.5	-5.0	33.3	4.7	22.2	-11.9	22.8	0.21
10-year	12.8	30.1	-9.6	41.6	6.2	28.3	-17.1	33.0	0.22
24-month									
5-year	10.1	22.7	4.9	37.8	3.0	16.4	-5.5	18.8	0.19
7-year	11.4	27.7	2.1	45.9	4.3	22.1	-8.6	26.8	0.19
10-year	12.9	33.3	-2.8	55.3	5.8	28.4	-13.2	37.2	0.20

Table V: **GBP LIBOR/Swaps**: HPR Statistics for Different Riding Strategies

The table summarizes returns and excess returns for different riding strategies across selected horizons. The first column lists the maturity of the riding instrument m. In order to compute the holding period returns (HPR) of riding an m-maturity instrument for h months, the $(m-h)$ rate must also be available. XHPR represents the excess riding returns over the buy-and-hold strategy. S.R. is the Sharpe ratio of the excess returns. Returns and standard deviations are annualized for ease of comparison. The standard deviations of the various mean returns were corrected for overlapping data by using a Newey-West (1994) correction on the standard errors of the respective mean, where the lags are set equal to the length of the holding horizon.

Horizon	HPR H^m_{t+h} (%)				XHPR XH^m_{t+h} (%)				
Instrument	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	S.R.
3-month									
6-month	6.7	2.2	0.7	3.6	0.0	0.4	-0.3	0.8	0.00
9-month	6.8	2.3	0.5	4.4	0.2	0.8	-0.6	1.8	0.25
1-year	7.0	2.6	0.3	5.4	0.4	1.3	-1.0	2.7	0.31
2-year	8.0	4.3	-0.8	8.0	1.4	3.2	-2.1	5.3	0.42
5-year	9.7	9.0	-7.3	12.9	3.1	8.1	-8.7	10.3	0.38
7-year	10.8	11.3	-10.7	13.6	4.2	10.6	-12.1	11.0	0.39
10-year	12.4	14.5	-15.0	17.4	5.8	13.8	-16.4	15.9	0.42
6-month									
9-month	6.8	3.8	1.6	6.7	0.1	0.5	-0.4	1.0	0.11
1-year	7.0	4.0	1.3	7.6	0.3	1.2	-0.7	2.1	0.22
2-year	8.0	6.2	0.1	11.9	1.3	4.0	-2.7	6.5	0.32
5-year	9.9	12.5	-8.5	19.4	3.1	10.6	-11.1	14.0	0.29
7-year	10.9	15.6	-13.7	21.1	4.2	13.9	-16.4	15.6	0.30
10-year	12.6	20.1	-20.0	21.0	5.9	18.5	-22.7	18.0	0.32
12-month									
2-year	7.9	8.2	2.7	15.5	1.0	3.6	-2.7	4.6	0.28
5-year	10.0	16.8	-5.4	25.8	3.2	12.7	-10.8	15.1	0.25
7-year	11.2	21.2	-9.6	30.5	4.3	17.2	-15.0	19.7	0.25
10-year	12.9	27.5	-15.1	36.3	6.1	23.7	-20.5	25.5	0.26
18-month									
2-year	7.7	9.1	7.0	19.5	0.5	2.0	-1.0	2.5	0.27
5-year	10.1	19.2	0.8	33.0	2.9	12.8	-7.2	16.5	0.22
7-year	11.2	24.5	-3.2	38.5	4.0	18.3	-11.2	22.5	0.22
10-year	13.0	32.6	-8.5	47.3	5.8	27.0	-16.5	30.9	0.21
24-month									
5-year	10.0	19.5	8.3	41.8	2.4	11.4	-2.6	17.8	0.21
7-year	11.2	25.0	6.4	49.1	3.6	17.4	-4.4	27.0	0.21
10-year	13.0	34.3	4.2	62.8	5.4	27.5	-6.9	40.7	0.20

Table VI: **EURIBOR/Swaps**: HPR Statistics for Different Riding Strategies

The table summarizes returns and excess returns for different riding strategies across selected horizons. The first column lists the maturity of the riding instrument m. In order to compute the holding period returns (HPR) of riding an m-maturity instrument for h months, the $(m-h)$ rate must also be available. XHPR represents the excess riding returns over the buy-and-hold strategy. S.R. is the Sharpe ratio of the excess returns. Returns and standard deviations are annualized for ease of comparison. The standard deviations of the various mean returns were corrected for overlapping data by using a Newey-West (1994) correction on the standard errors of the respective mean, where the lags are set equal to the length of the holding horizon.

Horizon	HPR H_{t+h}^m (%)				XHPR XH_{t+h}^m (%)				
Instrument	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	S.R.
3-month									
6-month	5.3	2.3	0.5	2.7	0.0	0.3	-0.5	0.2	0.00
9-month	5.4	2.3	0.4	3.1	0.0	0.7	-0.9	0.6	0.06
1-year	5.2	2.2	-0.1	3.4	-0.2	1.2	-1.4	1.0	-0.14
2-year	6.0	3.5	-1.5	5.5	0.6	3.1	-2.7	3.0	0.21
5-year	7.2	7.9	-4.0	8.2	1.9	7.8	-5.0	5.7	0.24
7-year	7.8	9.7	-5.7	8.6	2.5	9.6	-7.1	6.3	0.26
10-year	8.5	11.9	-8.2	9.0	3.2	11.9	-10.3	7.5	0.27
6-month									
9-month	5.4	4.2	1.0	5.3	0.1	0.5	-0.5	0.4	0.08
1-year	5.4	4.0	0.9	5.6	0.1	1.1	-1.1	0.9	-0.03
2-year	6.0	5.2	-0.1	8.3	0.6	4.0	-3.1	3.3	0.16
5-year	7.5	11.3	-5.2	14.2	2.1	11.1	-8.9	9.2	0.19
7-year	8.1	14.0	-8.4	16.1	2.7	14.0	-12.1	11.1	0.19
10-year	8.8	17.5	-13.2	17.2	3.4	17.6	-16.9	12.2	0.19
12-month									
2-year	6.1	7.8	1.0	12.8	0.6	4.1	-2.8	4.0	0.14
5-year	7.8	15.4	-3.6	20.3	2.3	14.7	-8.7	13.2	0.15
7-year	8.5	19.4	-6.8	22.5	3.0	19.4	-11.7	14.7	0.15
10-year	9.3	25.1	-11.6	25.5	3.8	25.3	-16.8	16.9	0.15
18-month									
2-year	6.0	10.5	3.0	16.5	0.3	2.4	-1.8	2.2	0.11
5-year	7.9	16.9	-3.2	27.8	2.2	14.7	-10.8	13.0	0.15
7-year	8.7	21.2	-6.8	32.1	3.0	20.4	-14.4	17.3	0.15
10-year	9.7	27.8	-10.9	35.4	3.9	27.8	-18.4	24.6	0.14
24-month									
5-year	8.0	18.0	1.5	31.9	2.0	13.1	-9.3	14.0	0.15
7-year	8.9	21.8	-1.9	37.2	2.9	19.3	-12.6	18.1	0.15
10-year	10.0	28.1	-6.3	41.3	4.0	27.2	-17.0	27.9	0.15

Table VII: **Government Securities**: Mean Excess Holding Period Returns

Mean excess holding period returns for a given riding strategy are aggregated by holding period across all instruments. The first column lists the various conditions for implementing a given riding strategy. All returns are annualized for ease of comparison. Numbers in parenthesis are standard errors which are corrected for serial correlation and heteroscedasticity using Newey-West (1994), where the lags are set equal to the length of the holding horizon (e.g. lags=3 for 3 month riding returns). Asterisks *,** indicate significance at the 90% and 95% level (two-sided test). Dashes (-) indicate that no results were obtained for a given strategy, blanks indicate that no observations exist for a given holding period.

	Holding Period									
Riding Condition	3 Months		6 Months		12 Months		18 Months		24 Months	
	XH^m_{t+h}	Obs.	XH^m_{t+m}	Obs.	XH^m_{t+h}	Obs.	XH^m_{t+h}	Obs.	XH^m_{t+h}	Obs.
U.S. Rates										
Unconditioned	3.88**	261	3.76**	258	3.62**	252	3.33**	246	3.10**	240
	(0.58)		(0.81)		(1.08)		(1.17)		(1.17)	
Slope > 0 bps	3.89**	126	3.20**	127	2.46**	131	1.67**	125	2.05**	131
	(0.72)		(0.88)		(1.08)		(0.88)		(0.67)	
Cushion > 0 bps	4.20**	175	4.06**	179	4.39**	189	4.03**	185	3.24**	179
	(0.70)		(0.89)		(1.20)		(1.41)		(1.40)	
Cushion ≥ 75%ile	11.48**	4	12.34**	9	10.20**	13	6.13**	19	2.37**	15
	(2.94)		(1.85)		(0.49)		(1.04)		(1.07)	
Recession	9.92**	28	9.02**	28	7.24**	28	5.35**	28	4.10**	28
	(1.98)		(2.40)		(1.44)		(1.09)		(1.63)	
Unconditioned†	3.16**	186	3.08**	183	3.18**	177	2.98**	171	2.72**	165
	(0.56)		(0.75)		(0.96)		(1.00)		(0.95)	
Taylor Rule	3.40**	100	2.74**	99	2.46**	94	2.39**	90	2.35**	86
	(0.58)		(0.82)		(1.08)		(1.07)		(0.95)	
Dynamic Taylor Rule	3.52**	144	3.34**	142	3.22**	137	3.08**	131	2.80**	125
	(0.62)		(0.78)		(1.03)		(1.10)		(1.05)	
Unconditioned‡	2.60**	117	2.72**	114	3.00**	108	2.85**	102	2.43**	96
	(0.72)		(0.93)		(1.16)		(1.22)		(1.14)	
Expectations	3.08**	91	3.01**	88	2.71**	82	2.49*	76	2.21	70
	(0.74)		(0.95)		(1.23)		(1.39)		(1.39)	
U.K. Rates										
Unconditioned	1.08	73	1.62**	84	2.12**	89	1.99*	89	2.04**	87
	(0.70)		(0.83)		(0.92)		(1.08)		(1.19)	
Slope > 0 bps	5.76**	5	0.44	4	3.66**	4	-3.15**	4	-0.02	5
	(0.82)		(2.22)		(0.37)		(0.11)		(0.95)	
Cushion > 0 bps	3.52**	11	5.80**	13	3.92**	17	3.71**	13	3.12**	8
	(1.62)		(0.92)		(0.70)		(1.67)		(2.47)	
Cushion ≥ 75%ile	3.04**	11	-	-	-	-	-	-	-	-
	(1.12)		-		-		-		-	
Recession	-	-	-4.06**	1	6.57**	1	6.71**	2	-	-
	-		(0.01)		(0.01)		(1.01)		-	
German Rates										
Unconditioned					2.33**	360	2.29**	354	2.19*	348
					(0.87)		(1.04)		(1.16)	
Slope > 0 bps					2.06*	224	1.38	221	0.91	212
					(1.09)		(1.38)		(1.29)	
Cushion > 0 bps					3.06**	252	2.81**	247	2.46*	242
					(0.93)		(1.16)		(1.39)	
Cushion ≥ 75%ile					7.21**	17	10.23**	21	14.22**	26
					(0.98)		(0.90)		(0.73)	
Recession					3.18	55	3.31*	53	3.32*	50
					(2.03)		(1.84)		(1.92)	

† Excess returns conditioned on the Taylor Rule use a shorter sample period (1988:04 to 2003:12), since a minimum of five years of out-of-sample data are needed for the first estimate. ‡ Excess returns conditioned on market expectations use a sample period from 1994:01 to 2003:12, since the Fed effective rate targeted by the FOMC was not announced prior to 1994.

Table VIII: **LIBOR/Swaps**: Mean Excess Holding Period Returns

Mean excess holding period returns for a given riding strategy are aggregated by holding period across all instruments. The first column lists the various conditions for implementing a given riding strategy. All returns are annualized for ease of comparison. Numbers in parenthesis are standard errors which are corrected for serial correlation and heteroscedasticity using Newey-West (1994), where the lags are set equal to the length of the holding horizon (e.g. lags=3 for 3 month riding returns). Asterisks *,** indicate significance at the 90% and 95% level (two-sided test). Dashes (-) indicate that no results were obtained for a given strategy, blanks indicate that no observations exist for a given holding period.

	Holding Period									
Riding Condition	3 Months		6 Months		12 Months		18 Months		24 Months	
	XH^m_{t+h}	Obs.	XH^m_{t+m}	Obs.	XH^m_{t+h}	Obs.	XH^m_{t+h}	Obs.	XH^m_{t+h}	Obs.
U.S. Rates										
Unconditioned	4.04**	195	4.02**	192	3.99**	186	3.84**	180	3.57**	174
	(0.64)		(0.88)		(1.19)		(1.33)		(1.38)	
Slope > 0 bps	4.68**	103	3.86**	117	3.50**	127	2.75**	120	3.06**	124
	(0.84)		(1.10)		(1.44)		(1.40)		(1.29)	
Cushion > 0 bps	5.28**	102	5.40**	113	4.41**	162	4.16**	166	3.53**	162
	(0.90)		(1.12)		(1.19)		(1.31)		(1.41)	
Cushion ≥ 75%ile	18.48**	8	15.48**	14	11.92**	16	8.01**	17	4.00**	19
	(1.20)		(0.74)		(0.62)		(1.18)		(1.90)	
Recession	6.84**	17	6.30**	17	8.30**	17	9.00**	17	7.90**	17
	(1.62)		(1.20)		(0.87)		(0.24)		(1.15)	
U.K. Rates										
Unconditioned	3.16**	155	3.26**	152	3.43**	146	3.29**	140	3.04**	134
	(0.62)		(0.83)		(1.09)		(1.22)		(1.23)	
Slope > 0 bps	5.60**	44	3.14**	46	4.28**	41	2.64*	41	1.94	48
	(0.50)		(0.96)		(0.31)		(1.49)		(1.84)	
Cushion > 0 bps	3.52**	40	5.04**	51	3.92**	64	2.93**	72	2.94**	66
	(0.74)		(0.72)		(0.62)		(1.17)		(1.17)	
Cushion ≥ 75%ile	1.92	13	4.06	12	3.52	11	0.92	12	0.65	10
	(2.98)		(3.42)		(2.02)		(1.76)		(0.57)	
Recession	4.04**	15	6.80**	15	6.55**	15	8.86**	15	7.47**	15
	(0.88)		(1.13)		(0.73)		(1.04)		(1.48)	
German Rates										
Unconditioned	1.80**	181	2.00**	178	2.29**	172	2.37*	166	2.39*	160
	(0.52)		(0.79)		(1.14)		(1.25)		(1.24)	
Slope > 0 bps	5.32**	66	4.32**	74	2.71**	76	2.99**	80	2.69*	69
	(0.60)		(0.75)		(1.38)		(1.40)		(1.43)	
Cushion > 0 bps	3.20**	69	4.08**	81	4.03**	93	3.40**	95	3.06**	94
	(0.72)		(0.95)		(1.16)		(1.40)		(1.48)	
Cushion ≥ 75%ile	8.24**	6	7.76**	11	7.15**	22	6.23**	28	5.60**	30
	(2.04)		(1.16)		(0.58)		(0.28)		(0.21)	
Recession	4.92**	41	3.72**	41	3.59**	35	3.26**	33	2.58**	30
	(0.82)		(0.95)		(1.22)		(1.71)		(1.41)	

Table IX: Mean Excess HPRs: **Government Bonds vs. LIBOR/Swaps**

Mean excess holding period returns for a given riding strategy are aggregated by holding period across all instruments. The first column lists the various conditions for implementing a given riding strategy. All returns are annualized for ease of comparison. Numbers in parenthesis are standard errors which are corrected for serial correlation and heteroscedasticity using Newey-West (1994), where the lags are set equal to the length of the holding horizon (e.g. lags=3 for 3 month riding returns). Asterisks *,** indicate significance at the 90% and 95% level (two-sided test). Dashes (-) indicate that no results were obtained for a given strategy, blanks indicate that no observations exist for a given holding period.

	Holding Period, $XH_{t+h}^{Swap(m)} - XH_{t+h}^{Govt(m)}$											
Instrument	6 Months			12 Months			18 Months			24 Months		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
U.S. Rates												
1-year	0.10**	-0.7	1.0									
	(0.02)											
2-year	0.56**	-0.8	2.9	0.41**	-0.3	1.3	0.20**	-0.1	0.6			
	(0.04)			(0.03)			(0.02)					
5-year	0.94**	-4.6	7.6	0.94**	-2.2	4.7	0.87**	-1.5	3.7	0.72**	-1.2	3.2
	(0.10)			(0.03)			(0.10)			(0.09)		
7-year	1.20**	-7.3	7.4	1.25**	-3.0	5.6	1.22**	-1.8	5.7	1.07**	-2.1	4.8
	(0.14)			(0.10)			(0.14)			(0.14)		
10-year	1.39**	-13.9	14.9	1.56**	-6.2	8.7	1.62**	-3.8	8.1	1.49**	-3.9	6.3
	(0.21)			(0.14)			(0.22)			(0.23)		
U.K. Rates												
1-year	-0.02	-1.6	1.7									
	(0.02)											
2-year	-0.56**	-8.0	3.9	1.97**	-23.4	15.5	3.48**	-13.6	15.7			
	(0.10)			(0.52)			(0.59)					
5-year	-0.73**	-13.5	16.1	-1.90**	-10.1	7.2	-2.10**	-8.3	3.8	1.88**	-8.3	10.5
	(0.28)			(0.52)			(0.29)			(0.46)		
7-year	0.44*	-8.2	22.7	-0.83**	-12.9	3.9	-0.98**	-11.8	2.7	-1.00**	-11.2	2.4
	(0.24)			(0.28)			(0.20)			(0.20)		
10-year	0.46	-13.5	22.8	-1.07**	-19.7	7.1	-1.30**	-17.2	5.1	-1.34**	-15.6	4.6
	(0.34)			(0.19)			(0.35)			(0.36)		
German Rates												
2-year				-0.05**	-0.6	0.4						
				(0.02)								
5-year				0.08**	-1.7	3.9	0.18**	-1.2	5.3	0.24**	-0.8	3.7
				(0.03)			(0.07)			(0.08)		
7-year				0.09	-2.5	3.0	0.22**	-1.7	7.2	0.34**	-1.0	5.2
				(0.06)			(0.09)			(0.11)		
10-year				0.12	-5.8	4.3	0.27**	-4.2	8.6	0.48**	-2.6	6.9
				(0.08)			(0.13)			(0.15)		

Table X: Positive Mean Excess HPRs: **Gov't Bonds vs. LIBOR/Swaps**

Aggregated positive mean excess returns are expressed as a percentage of total excess returns. For example, riding U.S. Treasuries for 6 months conditional on a 75%ile Cushion, on average 88.9% of the excess returns were positive. All returns are annualized for ease of comparison. Dashes (-) indicate that no results were obtained for a given strategy, blanks indicate that no observations exist for a given holding period.

	Holding Period									
Riding Condition	3 Months		6 Months		12 Months		18 Months		24 Months	
	Govt	Corp	Govt	Corp	Govt	Corp	Govt	Corp	Govt	Corp
U.S. Rates										
Unconditioned	61.3	63.6	67.1	68.2	68.3	74.7	74.4	80.6	78.8	82.8
Slope > 0 bps	63.5	64.1	68.5	66.7	60.3	68.5	69.6	73.3	79.4	79.0
Cushion > 0 bps	62.9	67.6	68.7	71.7	75.7	77.2	77.3	82.5	79.3	82.1
Cushion $\geq$ 75%ile	75.0	100.0	88.9	100.0	100.0	100.0	100.0	100.0	73.3	78.9
Recession	82.1	82.4	89.3	88.2	89.3	100.0	89.3	100.0	89.3	100.0
Taylor Rule	61.1		61.6		66.0		72.2		77.9	
Dynamic Taylor Rule	63.9		68.3		70.8		78.6		81.6	
Expectations	62.9		67.9		72.4		77.3		79.2	
U.K. Rates										
Unconditioned	54.8	67.7	65.5	75.7	74.2	81.5	75.3	77.9	71.3	75.4
Slope > 0 bps	100.0	81.8	75.0	80.4	100.0	97.6	-	73.2	20.0	58.3
Cushion > 0 bps	54.5	65.0	92.3	90.2	88.2	90.6	100.0	80.6	75.0	80.3
Cushion $\geq$ 75%ile	54.6	61.5	-	75.0	-	72.7	-	41.7	-	50.0
Recession	-	66.7	-	93.3	100.0	100.0	100.0	100.0	-	100.0
German Rates										
Unconditioned		58.6		64.6	70.3	71.5	70.1	74.1	72.4	76.9
Slope > 0 bps		80.3		81.1	67.4	76.3	60.2	83.8	58.5	78.3
Cushion > 0 bps		66.7		75.3	74.6	82.8	73.7	83.2	72.3	80.9
Cushion $\geq$ 75%ile		83.3		90.9	100.0	100.0	100.0	100.0	100.0	100.0
Recession		65.9		73.2	78.2	80.0	71.7	75.8	80.0	86.7

Table XI: **U.S. Treasuries**: Statistics for Duration-Neutral Riding Strategies

The table summarizes duration-neutral returns and excess returns for different riding strategies across selected horizons, where the duration target is set equal to the holding horizon. The first column in this table lists the maturity of the riding instrument m. In order to compute the holding period returns (HPR) of riding an m-maturity instrument for h months, the $(m-h)$ rate must also be available. XHPR represents the excess riding returns over the buy-and-hold strategy. Hats indicate the relevant duration-neutral variables. S.R. is the Sharpe ratio of the excess returns. $\omega H^{R}_{[m,h]}$ is the weighted ride return and $(1-\omega)\tilde{H}_{[h]} = (1-\omega)H^{O}_{[h]} - H_{[h]}$ is the weighted return of the overnight rate minus the return of the buy-and-hold strategy as defined in equation 30. Returns and standard deviations are annualized for ease of comparison. The standard deviations of the various mean returns were corrected for overlapping data by using a Newey-West (1994) correction on the standard errors of the respective mean, where the lags are set equal to the length of the holding horizon.

Horizon	HPR $H_{[m,h]}$ (%)					XHPR $XH_{[m,h]}$ (%)			XHPR $\widehat{XH}_{[m,h]}$ (%)		
Instrument	Mean	S.D.	ω	$\omega H^{R}_{[m,h]}$	$(1-\omega)\tilde{H}_{[h]}$	Mean	S.D.	S.R.	$\widehat{\text{Mean}}$	$\widehat{\text{S.D}}$	$\widehat{\text{S.R.}}$
3-month											
6-month	6.3	2.8	0.500	3.15	-2.67	0.49	0.68	0.71	0.48	0.40	1.20
2-year	7.8	4.9	0.125	0.98	-0.34	2.00	3.88	0.52	0.64	0.56	1.14
5-year	9.8	10.1	0.050	0.49	0.11	4.00	9.54	0.42	0.60	0.60	1.00
7-year	10.8	13.2	0.036	0.39	0.21	4.96	12.66	0.39	0.60	0.58	1.03
10-year	12.0	17.9	0.025	0.30	0.30	6.16	17.44	0.35	0.60	0.58	1.03
6-month											
1-year	6.5	5.1	0.500	3.25	-2.93	0.44	1.60	0.28	0.32	0.55	0.58
2-year	7.7	7.4	0.250	1.93	-1.37	1.66	4.78	0.35	0.56	0.89	0.63
5-year	9.9	14.3	0.100	0.99	-0.43	3.80	12.66	0.30	0.56	1.05	0.54
7-year	10.9	18.5	0.071	0.77	-0.25	4.76	17.08	0.28	0.52	1.07	0.48
10-year	12.1	25.1	0.050	0.61	-0.13	6.00	23.84	0.25	0.48	1.10	0.44
12-month											
2-year	7.6	10.4	0.500	3.80	-3.21	1.19	4.72	0.25	0.59	1.55	0.38
5-year	9.9	18.9	0.200	1.98	-1.30	3.47	15.68	0.22	0.68	2.13	0.32
7-year	10.9	24.9	0.143	1.56	-0.92	4.53	22.18	0.20	0.64	2.31	0.28
10-year	12.2	33.4	0.100	1.22	-0.65	5.78	31.25	0.18	0.57	2.44	0.23
18-month											
2-year	7.4	12.5	0.750	5.55	-5.22	0.55	2.83	0.19	0.33	1.26	0.26
5-year	9.8	22.0	0.300	2.94	-2.26	3.01	16.04	0.19	0.68	2.81	0.24
7-year	10.9	28.5	0.214	2.33	-1.70	4.17	23.27	0.18	0.63	3.18	0.20
10-year	12.2	37.3	0.150	1.83	-1.30	5.37	33.00	0.16	0.53	3.53	0.15
24-month											
5-year	9.8	25.3	0.400	3.92	-3.23	2.61	14.96	0.17	0.70	3.34	0.21
7-year	10.9	31.8	0.286	3.12	-2.47	3.75	22.30	0.17	0.65	3.78	0.17
10-year	12.2	40.1	0.200	2.44	-1.90	5.04	31.54	0.16	0.55	4.24	0.14

Table XII: The Fed funds rate and the slope of the yield curve

The impact of a change in the Fed funds rate on the slope of the term structure is assessed by regressing the changes in the 10–2 year yield differential ($\Delta Slope$) on the changes in the Fed funds target rate ($\Delta FFTR$). Estimates are multiplied by factor of 10^2 for ease of interpretation. Standard errors appear below the coefficient estimates in parenthesis and are corrected for serial correlation and heteroscedasticity using Newey-West (1994). Asterisks *,** indicate significance at the 90% and 95% level (two-sided test). All variables are stationary according to augmented Dickey-Fuller unit root tests.

$$\Delta Slope_t = \phi_0 + \phi_1 \Delta FFTR_t + \varepsilon_t$$

Constant	ϕ_0	-0.21
		(0.11)
$\Delta FFTR_t$	ϕ_1	-25.35**
		(0.43)
Sample Period		1982:02–2003:12
N. Obs.		263
Adjusted R^2		0.1715
Durbin-Watson		2.09

Table XIII: The Federal funds rate and the Taylor Rule

In order to assess the predictive power of the Taylor Rule with regards to changes in the Fed funds rate, actual target rate changes ($\Delta FFTR$) are regressed on rate changes implied by the Taylor Rule ($\Delta Taylor$). Assuming no inter-meeting rate changes, the dummy variable $FOMC$ tests if the relationship is particularly strong prior to a potential target rate decision. Thus, $FOMC$ only has a value in the month prior to an FOMC meeting when it is equal to $\Delta Taylor$. Estimates are multiplied by factor of 10^2 for ease of interpretation. Standard errors appear below the coefficient estimates in parenthesis and are corrected for serial correlation and heteroscedasticity using Newey-West (1994). Asterisks *,** indicate significance at the 90% and 95% level (two-sided test). All variables are stationary according to augmented Dickey-Fuller unit root tests.

$$\Delta FFTR_t = \phi_0 + \phi_{1,3}\Delta Taylor_{t-1}^{(Dynamic)} + \phi_2 FOMC_{t-1} + \varepsilon_t$$

		(1)	(2)	(3)	(4)
Constant	ϕ_0	-2.98*	-2.99	-2.56	-2.50
		(1.84)	(1.83)	(1.77)	(1.74)
$\Delta Taylor_{t-1}$	ϕ_1	15.39**	0.02		
		(7.23)	(2.05)		
$FOMC_{t-1}$	ϕ_2		21.29**		31.34**
			(9.79)		(10.44)
$\Delta Taylor_{t-1}^{Dynamic}$	ϕ_3			28.92**	2.67
				(8.32)	(3.83)
Sample Period		88:04–03:12	88:04–03:12	88:04–03:12	88:04–03:12
N. Obs.		189	189	190	190
Adjusted R^2		1.53	1.80	6.79	7.68
Durbin-Watson		1.29	1.31	1.34	1.35

Table XIV: The Federal funds rate and market expectations

Fed funds futures contracts provide a useful tool for measuring market participant's expectations with respect to target rate changes. The accuracy of these expectations is gauged by regressing actual changes ($\Delta FFTR$) on a conditional measure of expected changes. The variable $MarketSignal$ serves as such a measure and is non-zero whenever the implied probability a target rate change exceeds 50% (i.e. the signal strength is positive and increases as the implied probability of a rate rise exceeds 50%, negative as the probability of a cut exceeds 50% and 0 otherwise). As in table XIII, the dummy variable $FOMC$ tests if the relationship is particularly strong prior to a potential target rate decision and is equal to $MarketSignal$ before an FOMC meeting. Estimates are multiplied by factor of 10^2 for ease of interpretation. Standard errors appear below the coefficient estimates in parenthesis and are corrected for serial correlation and heteroscedasticity using Newey-West (1994). Asterisks *,** indicate significance at the 90% and 95% level (two-sided test). All variables are stationary according to augmented Dickey-Fuller unit root tests.

$$\Delta FFTR_t = \phi_0 + \phi_1 MarketSignal_{t-1} + \phi_2 FOMC_{t-1} + \varepsilon_t$$

		(1)	(2)	(3)
Constant	ϕ_0	-3.66*	-2.87	-0.030
		(2.01)	(1.96)	(0.076)
$MarketSignal_{t-1}$	ϕ_1	8.99**	0.97	0.001
		(2.25)	(0.72)	(0.000)
$FOMC_{t-1}$	ϕ_2		10.90**	1.981**
			(3.03)	(0.812)
Sample Period		94:01–03:12	94:01–03:12	94:01:03–03:12:31
N. Obs.		116	116	2480
Adjusted R^2		21.01	26.91	21.51
Durbin-Watson		1.81	1.72	2.00

D Figures

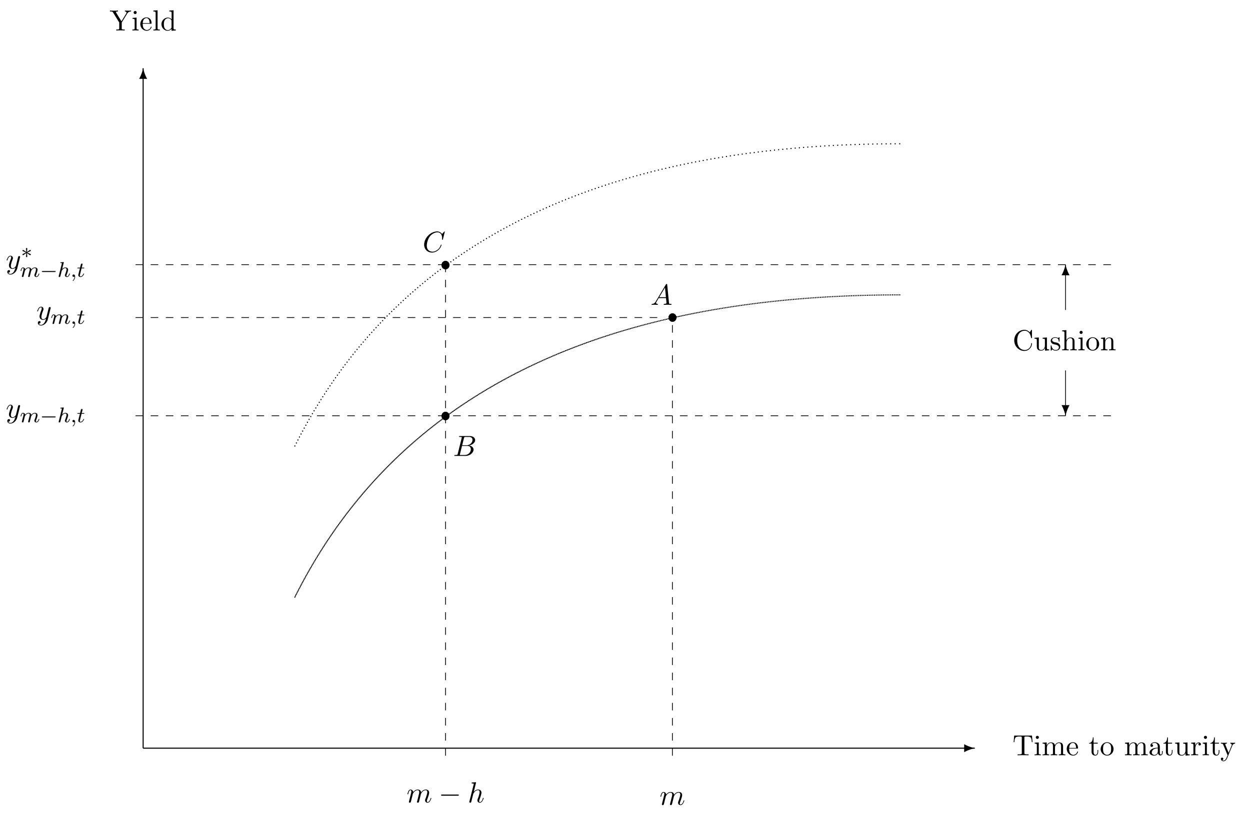

Figure 1: Break-even rate and the Cushion

If the yield curve remains unchanged over a horizon of h, the yield of an m-maturity instrument falls from point A at the beginning of the period to point B as its maturity shortens to $m-h$ at the end of the period. The Cushion is defined as the amount by which interest rates have to rise in order to offset any capital gains arising from such a drop in yields. The size of the Cushion corresponds to the vertical distance between points B and C.

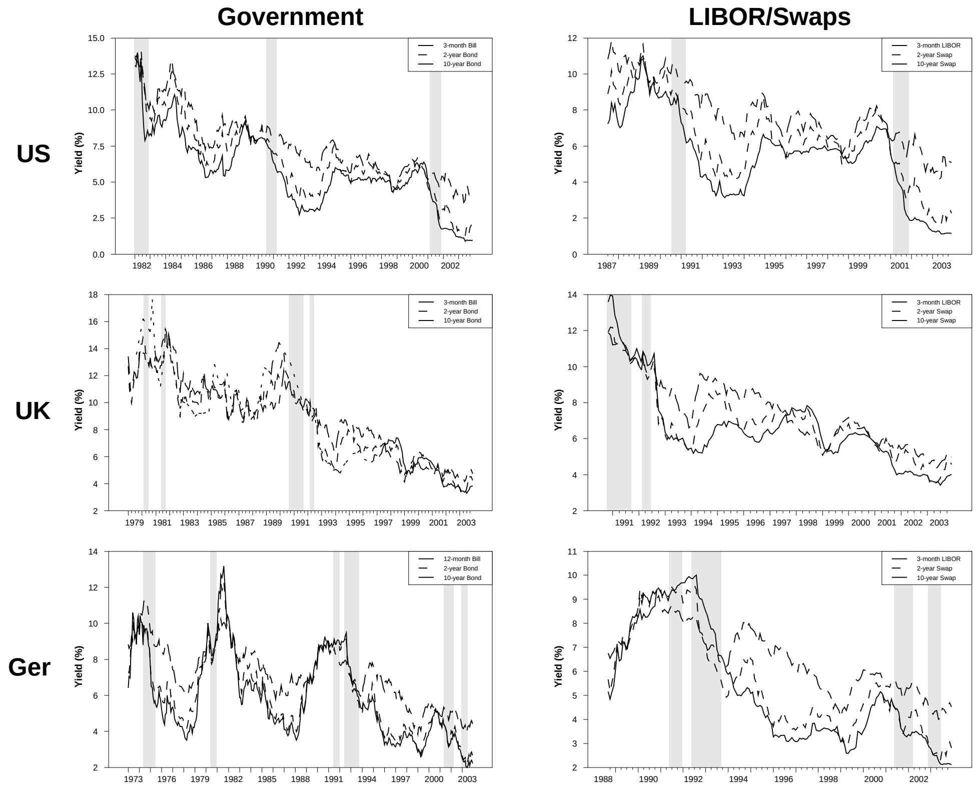

Figure 2: Evolution of zero coupon yield curves with shaded recessions

For the United States, recessions are defined according to the NBER's Business Cycle Dating Committee methodology whereby "[...] a recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales". For the United Kingdom and Germany, recessions are defined in terms of a fall of (seasonally adjusted) GDP over the course of al least two consecutive quarters.

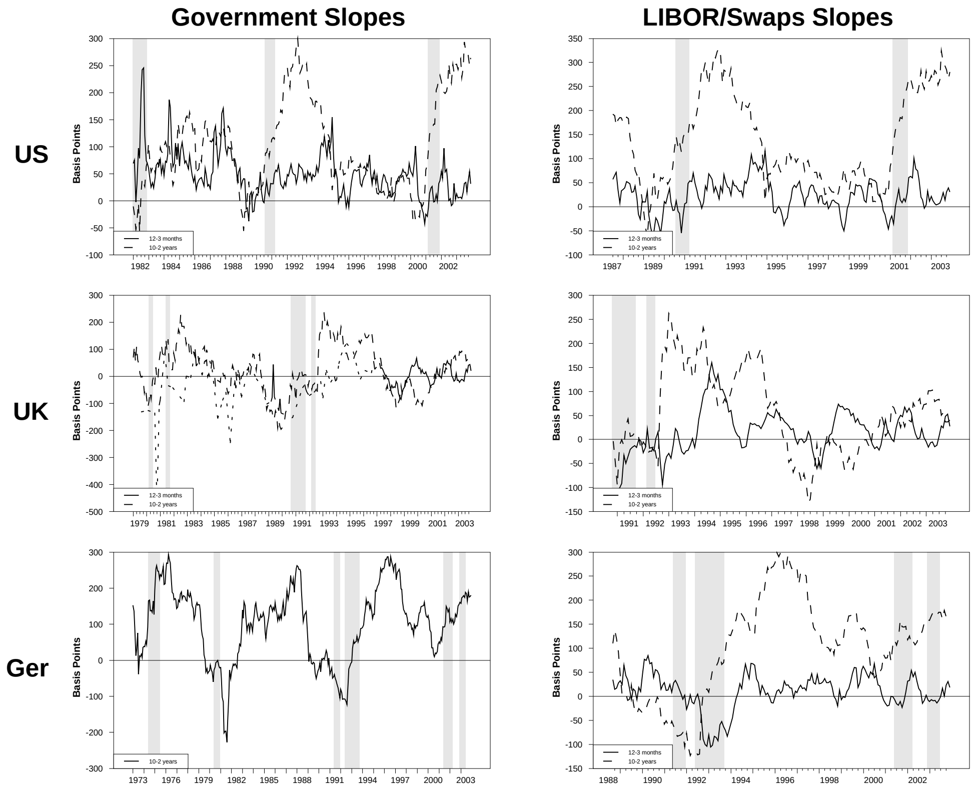

Figure 3: Evolution of zero coupon yield curve slopes

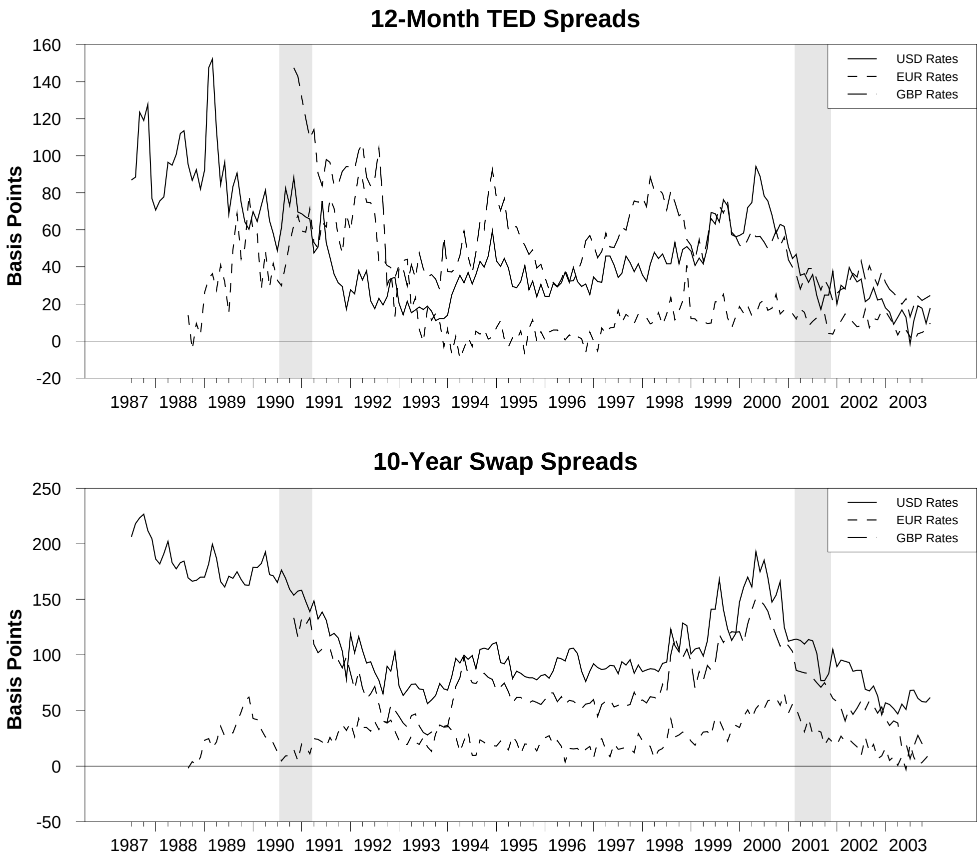

Figure 4: Evolution of TED and swap spreads

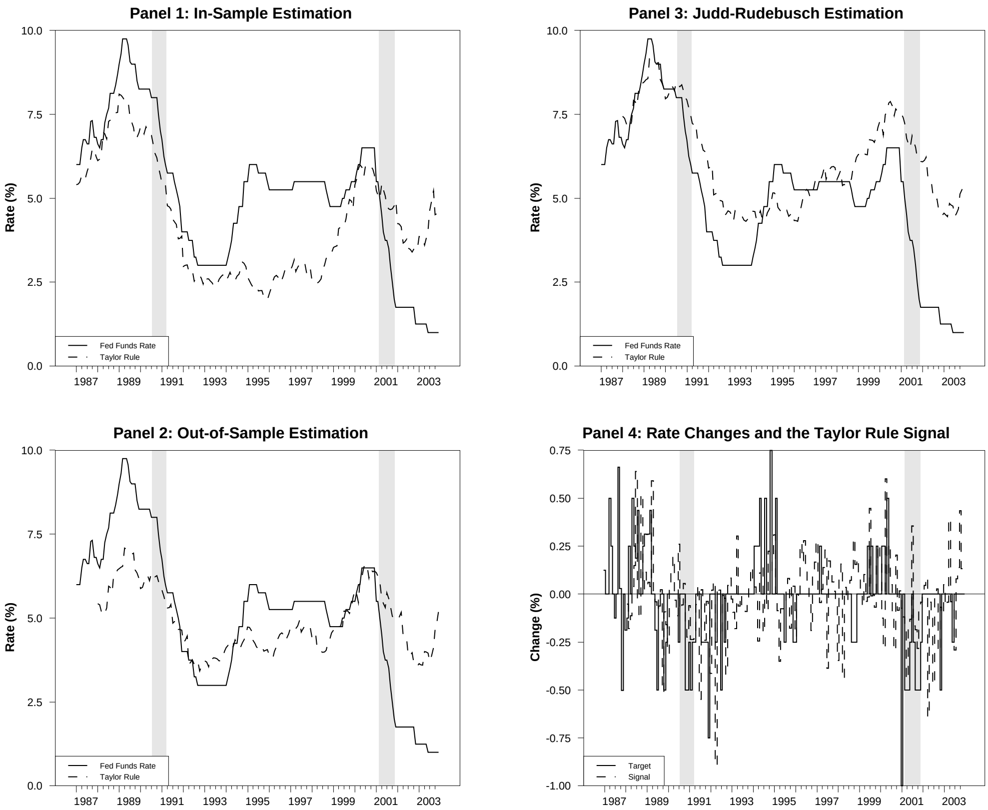

Figure 5: Modelling the Fed funds rate using the Taylor Rule

(i) Panels 1 to 3 display Taylor Rule predictions of the Fed funds target using different estimation techniques. (ii) In Panel 4, changes in the actual target rate (solid line) are plotted against target rate changes predicted by the Judd-Rudebusch version of the Taylor Rule (dashed line).

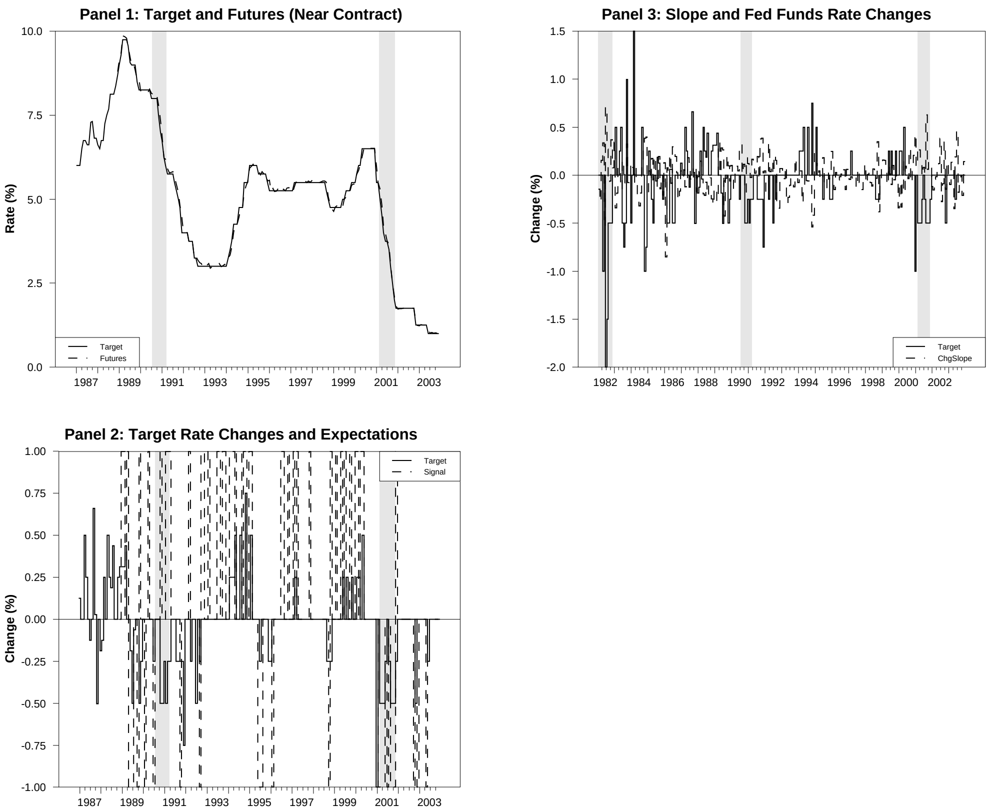

Figure 6: Fed Fund Futures, Market Expectations and Slope Changes

(i) Panel 1 displays the daily evolution of the Fed funds target rate against the target rate implied by the nearest Fed fund futures contract. (ii) In Panel 2, changes in the actual target rate (solid line) are plotted against target rate changes predicted by market expectations. Expectations are derived from fed funds futures. (iii) In Panel 3, changes in the actual target rate (solid line) are plotted against changes in the slope of the yield curve. The slope is defined as the yield differential between the 2-year and 10-year Treasury note.