

A Multi-country Analysis of Term Structure Behavior

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Abstract

This thesis aims to shed some further light on the much debated Expectation Hypothesis (EH). To test the theory we use the term structure, from 2000 to 2013, of four different countries, namely Italy, Sweden, Germany and the US. Our work presents four main tests of the EH, from standard term spread regressions to a more articulated VAR model. The methodology is applied on an extensive number of maturities so that we can get a thorough understanding of the behaviors of the yield curve. Except for some cases of intermediate maturities in Italy and Germany, we find that the EH is soundly rejected in almost every sample. Conversely, Sweden and the US present convincing evidence in favor of an overreaction theory.

Keywords: Expectation Hypothesis, Term Structure of Interest Rates, Term Spread, Vector Autoregressive Model, Forward Rates.

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Introduction

The Expectation Hypothesis of the term structure (EH) is perhaps one of the most puzzling topics in financial research. Many papers have been written without yielding a final response on the validity of the theory. Because of the importance of the market and the availability of data, the US yield curve has been the main object of investigation, even though there is an increasing number of studies focusing on other markets. Aside from its academic relevance, understanding the EH would prove to be valuable to many subjects including, but not limited to, central banks, investors and financial institutions.

The EH claims that current long-term rates are determined by expectations on future short-term yields and, depending on the formulation being used, a constant or nil risk premium. It is easy to see why this statement may have important implications for market participants. For instance, central banks, which affect money supply and short-term interest rates in the economy, may be interested in knowing whether or not such moves cause changes in the long-term end of the yield curve, as it is theorized by the EH (Ludvigson and Ng, 2009). In light of the current status of the world economy and the heavy intervention in the market by central banks, a correct understanding of the underlying mechanisms regulating the yield curve seems more important than ever. This point is further clarified by the Chairman of the Federal Reserve, Ben Bernanke¹:

“What does the historically unusual behavior of long-term yields imply for the conduct of monetary policy? The answer, it turns out, depends critically on the source of that behavior. To the extent that the decline in forward rates can be traced to a decline in the term premium . . . the effect is stimulative and argues for greater monetary policy restraint . . . However, if the behavior of long-term yields reflects current or prospective economic conditions, the implications for policy may be quite different—indeed, quite the opposite.”

Furthermore, bondholders who consider the positive slope of the term structure as a sign of increasing future short-term rates would be interested in liquidating their position in face of potential capital losses (Veronesi, 2010). Yet another reason as to why forecasting future short-term rates is paramount would be the importance of

¹Ben Bernanke’s speech before the Economic Club of New York, New York, March 20, 2006.

discount rates in financial instruments and derivatives pricing, which would benefit from a better understanding of the term structure (Sangvinatsos, 2010).

Campbell and Shiller (1991) represents the main reference on the topic. The authors introduce a series of instruments that test some of the yield curve relationships implied by the EH on US data and prove that the EH does not work well in practice. Our study purports to apply the methodology developed by Campbell and Shiller (1991) on a more recent dataset for Italy, Sweden, Germany and the US. Although we use a relative small number observations, our analysis has the merit to test the EH for an extensive combination of maturities between the long-term and short-term bond. In addition, while studies of the term structure are common for the US and Germany, there are not many for other countries, and, to the best of our knowledge, our paper could be one of the first, if not the first, to test the EH on Italian and Swedish data. Briefly, we find that the EH does not work well in our data, except for Italy and Germany wherein we get more encouraging results for some selected pairs of maturities. However, we find that an overreaction model of the term structure explains the results we have in Sweden and in the US well.

The remainder of the thesis is organized as follows. In the first section, we briefly introduce an overview of the sovereign debt markets in the countries considered in the study. We primarily focus on the main descriptive statistics and analyze the liquidity of these markets. In the second section, we analyze the theoretical framework that states the main implications of the Expectation Hypothesis and review the main literature on the argument. In this section, we thoroughly discuss the aforementioned Campbell and Shiller (1991). In the third section, we assess the data used for the empirical part of our study and we run some econometric tests regarding the quality and the significance of this data. In the fourth section, we present the econometric techniques as well as regressions adopted in this paper and explain the economic intuition behind these. Once again a rather large part of the text is devoted to Campbell and Shiller's methodology, as this is the backbone of our analysis. In the fifth section, we explain the empirical results of this paper. In this part, we focus on describing the coefficients we obtain with the different regressions and we provide a detailed comparison of these results in two samples, one aggregate and one which does not include observations from during and after the financial crisis. In the sixth section, we then try to explain the theoretical reasons as to why the EH fails. In this part, we pay deeper attention to the overreaction model, which is thoroughly described in Campbell and Shiller (1991)

and Hardouvelis (1994). In the seventh section, we briefly summarize the limits of our study and methodology used to test the theory. The final part of the paper consists of a brief conclusion and some general remarks.

1 Government Debt Markets Overview

1.1 Main Facts

The fixed-income markets have, especially recently, been at the center of the discussion in financial economics. The reason underpinning such focus on the topic is the impressive growth in size and complexity that has characterized these markets in recent years. This extensive development has been primarily seen in the markets of fixed-income derivatives, e.g. mortgage-backed securities and asset backed securities. Furthermore, as under the definition of fixed income securities fall very complex and diverse instruments, many authors tried to assess to what extent these different instruments are correlated and to analyze the effect of this correlation within different markets (Veronesi, 2010). Moreover, a good understanding of the functioning of these is vital, given the importance of the role they cover in the economic environment. As a matter of fact, they answer different needs such as matching demand and supply of capital or easing the investment of surpluses, and providing short and medium term financing (Sveriges Riksbank, 2012b).

The fixed-income markets were historically dominated by the US. Nowadays, this market is still the largest, having outstanding securities for more than \$38,137 billion (Securities Industry and Financial Markets Association, 2012). However, it has gradually lost importance, given the development that has characterized new markets around the world. This fact is mainly due to the role assumed by some foreign countries as reference entities for fixed-income pricing (Veronesi, 2010). Undoubtedly, one of the markets that has become more and more important in this respect is the European one. Its structure, however, is still somewhat different from the US market, given that each member of the European Union has its own domestic debt marketplace. Nonetheless, recently, with the centralization of the role of the EU in these countries' policies, this market started also to act as a unique entity (Association for Financial Markets in Europe, 2012).

One of the most important fixed-income markets is the government debt market, which has become an even more discussed argument recently, as the economic crisis has brought the fiscal situation of western economies to deteriorate and led to a significant deterioration in these economies' public finances (Becker et al., 2010). The government debt market consists of the universe of debt instruments directly issued by central governments to finance their public operations. In this regard, the American sovereign debt is the biggest among those considered in this study, with an amount of \$16,432 billion at the end of 2012. On the same date, the Italian government debt amounted to €1,998 billion, Germany's to €2,129 billion, and Sweden's to €137.06 billion (DataStream). Providing data regarding the amount of debt is useful for understanding the size of these markets, but not so much for describing the ability of a country to grow through this source of financing. This purpose is well fulfilled by the Public Debt to GDP ratio. In this respect, during year 2012 Italy registered a ratio of almost 126%. Conversely, Germany and Sweden's average 2012 ratios were the lowest, with 80.5% and 37.9% respectively. The US, on the other hand, had a Public Debt to GDP ratio of almost 107.18%. In Figure 1, we report the trend of yearly Public Debt to GDP Ratio

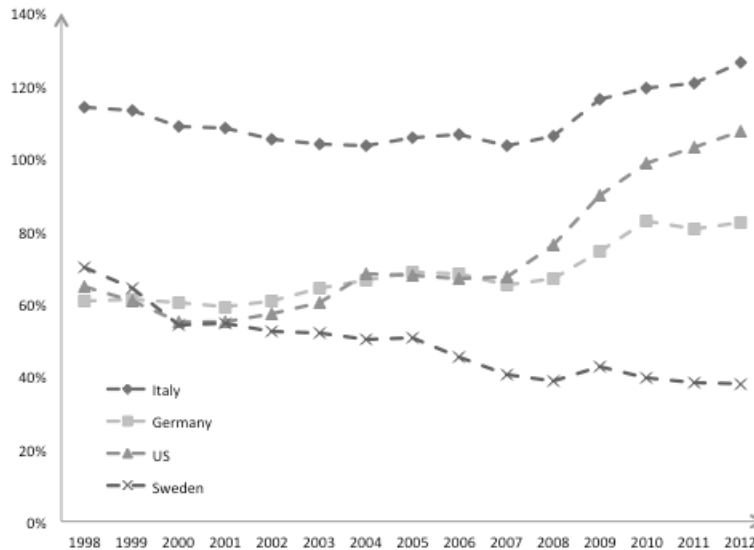


Figure 1: Debt to GDP Ratio

(DataStream). What is worth noticing is the increasing trend that has characterized all these ratios from 1998 onward. The only exception is Sweden, which has been able to decrease this figure, both through an increase in its GDP and a reduction in the amount of debt outstanding. It is important to see the sharp hike in public indebtedness after

2007 for the other three nations. This follows the large fiscal stimulus put in place after the financial crisis. This increase is evident for the US, which adopted an extensive fiscal policy in order to stimulate economic growth. Additionally, also Germany and Italy experienced a deterioration in their ratios. In Italy, the sharpest increase has been registered in the last three years, in conjunction with the sovereign debt crisis that has involved Europe. Undoubtedly, this country faces problems in growing through its public spending. In the case of Germany, however, the trend has been slightly different: it increased soon after 2007, but in the past three years the economy started growing again and Germany was able to reduce this figure significantly.

We then decided to focus on the average term to maturity of government debt, which is simply the average number of years that are needed by a country to repay its outstanding debt. It is important to report this, as it can well describe the structure of the public debt and the mechanism through which central banks regulate their fiscal policy. The US has an average term to maturity of 4.9 years², which means that among the countries we analyze, it has the highest ability to roll over its debt and is able to lower its effective government interest rate. On the other hand, the country is more exposed to fluctuation of market interest rates. Sweden has a term to maturity very similar to the US, with 5.2 years. Also in this case, this is a sign of the fact that these countries are less exposed to roll over risk and so can afford to issue debt with a shorter maturity. Germany and Italy have an average term to maturity of 5.94 and 7.2 respectively (OECD, 2010). In particular, Italy, for which the opposite argument with respect to US and Sweden is true, has the longest the term to maturity with respect to other countries (Becker et al., 2010).

1.2 Liquidity and Efficiency

In bond markets, efficiency is as important an element as size for understanding how they function. It is therefore interesting to assess how efficient and liquid these markets are (The World Bank, 2006). Normally, the secondary markets for government bonds are considered to be the most liquid among the totality of fixed-income markets. The reason why this is true can be linked to the role held by government securities. These are often used as collateral and, given the relative low credit risk by which they are characterized, are usually issued in large amounts (Sarr and Lybek, 2002). Further-

²This data is taken from OECD Statistics Library, and is data as of 2010.

more, if a market is adequately liquid, it can properly reach its objectives, i.e. risk diversification, control on the issuers and allocation of resources to the most productive processes (The World Bank, 2006).

There are different measures to rate the level of efficiency for these entities, but for our study we decided to use the Bond Turnover Ratio. This figure, which is defined as the ratio between the values of bonds traded and the average amount of securities outstanding in a specific year, is a measure of the liquidity characterizing secondary markets. The higher the ratio, the more liquid is the market considered. We have collected the government debt turnover for year 2012³ and computed the ratio using as denominator the amount of debt outstanding at the end of 2012⁴.

Country	Amount Outs. (in bil.)	Debt/GDP Ratio (%)	Avg. Term to Mat. (in years)	Bond Turn. Ratio
US	\$16432	107,5	4,90	8,21
Italy	€1989	126	7,20	0,41
Germany	€2129	80,5	5,94	2,88
Sweden	€137,06	37,9	5,20	23,6

Table 1: Government Bond Markets

We found that in 2012 Sweden showed an extremely liquid market, with a ratio of 23.6. Following are the US with a ratio of 8.21, Germany with 2.88, and Italy with 0.41. The striking difference between the Swedish markets and the others may be probably due to the fact that the Scandinavian country has a relative safe economy, which foreign investors consider to be better hedged against macroeconomic shocks. Next is the US, whose market is one of most liquid as it shows a ratio of more than 8 units. This can be linked to the fact that US government securities have been considered for many years as those which better resembled risk-free securities. Given the role they play as benchmark treasuries for most countries on a worldwide scale, they are among the most traded bonds in the government securities secondary market. Among the EMU countries, Germany has one of the most liquid markets. This is somehow due to the fact that the German bund is the reference government security for those who want to invest in the Euro market. However, being part of a larger monetary union, the German market is dependent on the fate of the other economies that are members of

³For Germany we use 2011 data, given that we could not find any reliable data source for 2012 Debt Turnover.

⁴The data is taken from different sources, namely Riksbank, SIFMA, Banca d'Italia, and Finance Agency of Federal Republic of Germany.

EMU and this fact could be at the base of the lower level of liquidity registered with respect to Sweden and the US. Lastly, Italy shows a very low ratio, which indicates a poor liquidity level with respect to those considered in this study.

For our paper, it is important to understand that if bond markets are efficient and so extremely liquid, there ought to be a similar foresight of the expected rates among investors. This assumption, along with the fact that investors should be indifferent between choosing long-term or short term securities, would make forward rates unbiased proxies for the expected future rates, which in turn would make significant the test of EH (Bierwag and Grove, 1967).

2 Literature Review

2.1 Notation

Before we start testing the EH, it is convenient to write down the notation that will be used throughout this paper. As in this document we use mainly continuous-time models, we introduce all the variables, formulas and notation in continuous time. We begin analyzing a *zero coupon bonds* and their notation. First, we derive the relationship between the log price and log yield of such securities, which pay only the face value at maturity. At time t , the price $P_t^{(n)}$ of *zero coupon bond* that pays n years from now is obtained discounting for n periods the face value with the spot n -year rate $y_t^{(n)}$. From this relation is easy to derive the equivalent log-price $p_t^{(n)}$

$$\begin{aligned} P_t^{(n)} &= 100e^{-y_t^{(n)}n} \\ \frac{P_t^{(n)}}{100} &= e^{-y_t^{(n)}n} \\ p_t^{(n)} &= -y_t^{(n)}n \end{aligned}$$

If one buys this bond at time t and sells it at time $t + m$, this strategy generates a log holding period return $r_{t \rightarrow t+m}^{(n)}$ which is generally unknown at time t

$$r_{t \rightarrow t+m}^{(n)} = p_{t+m}^{(n-m)} - p_t^{(n)}$$

It is possible to combine bonds so as to guarantee a fixed interest rate on an investment

to be made in the future. This interest rate is commonly referred to as the *forward rate*. The *forward* on an investment agreed upon today t to be made at time $t + m$ until $t + n$, where $m < n$ is given by

$$f_t^{(m,n)} = \frac{p_t^{(m)} - p_t^{(n)}}{n - m}$$

or alternatively

$$f_t^{(m,n)} = y^{(m)} + \frac{n}{n - m} (y^{(n)} - y^{(m)})$$

2.2 The Expectation Hypothesis

The Expectation Hypothesis is the most popular theory regarding the structure of the yield curve. Various authors test different implications that follow from its main characterization; however, a clear and thorough explanation of the diverse equations derived from the EH is oftentimes lacking. In this subsection, we present a brief description of two of the term structure relations implied by the EH that are tested in the remaining part of the paper. The EH states that long-term rates are the average of current and expected future short-term rates

$$\begin{aligned} ny_t^{(n)} &= my_t^{(m)} + m\mathbb{E}\left(y_{t+m}^{(m)} + y_{t+2m}^{(m)} + \dots + y_{t+n-m}^{(m)}\right) \\ ny_t^{(n)} &= my_t^{(m)} + m\mathbb{E}\left(\sum_{i=1}^{k-1} y_{t+im}^{(m)}\right) \quad k = n/m \end{aligned} \quad (2.1)$$

where k is an integer. We can rewrite 2.1 so as to define the current short-term rate using log price and log holding period return

$$my_t^{(m)} = ny_t^{(n)} - m\mathbb{E}\left(\sum_{i=1}^{k-1} y_{t+im}^{(m)}\right) \quad k = n/m \quad (2.2)$$

$$\begin{aligned} my_t^{(m)} &= \mathbb{E}\left(p_{t+m}^{(n-m)}\right) - p_t^{(n)} \\ y_t^{(m)} &= \frac{1}{m}\mathbb{E}_t\left(r_{t \rightarrow t+m}^{(n)}\right) \end{aligned} \quad (2.3)$$

The above equation states that the yield on a short-term bond m must be equal

to the expected return on a long-term bond over the life of the short-term bond. All the above definitions purportedly neglect the existence of a log risk premium for convenience. However, an alternative version of the EH states that the risk premium exists and is constant over time.

2.3 Campbell and Shiller's Milestone

In one of the most important papers on the topic, Campbell and Shiller (1991) present evidence against the EH. They study a sample of data on the US market from 1952 to 1987 using monthly observations of the zero curve provided by McCulloch (1975). These are yields on pure zero coupon bonds that have been obtained by applying the cubic spline methodology. Their main finding is that yield spreads do not predict movements in future long-term rates as implied by the EH. In fact, with few exceptions, the forecasts of the short-term changes in the future long-term rates go in the opposite direction. Nonetheless, they find that the term spread contains information useful to forecast changes in future short-term rates and that the forecast power of the term structure to predict such rates improves along the horizon. Without delving into analyses of time-varying risk premia, they hypothesize that a failure of the EH might be due to an overreaction model of the yield spreads. If this were the case, the difference between long and short rates would behave accordingly to the EH, but the magnitude of the spread between the two rates would be bigger than the one implied by rational expectations.

2.4 Past Research and Evidence

Though there is a general consensus regarding the poor performance of the Expectation Hypothesis in the US, as shown by Campbell and Shiller (1991), in other countries the results seem to vary according to the different samples considered. Many authors evaluated the performance of this theory on various markets, e.g. Germany, United Kingdom, Ireland, Switzerland, and France, but, as far as we know, there are very few papers concerning Italy or Sweden.

One major reference in the field is represented by Fama and Bliss (1987) that investigates the information contained in forward rates regarding future interest rates and current expected returns on bonds. The authors use different datasets for their regressions. These samples range from January 1964 to December 1984 for the forward

spot spreads and from January 1965 to December 1985 for the term premiums and for the one-year changes in the one-year spot rate. They find that one-year expected returns on US Treasuries with maturities of up to 5 years change through time and explain that this variation could be linked to a reward for risk, but that this varies according to business cycles. Secondly, they show that forward rates have very little power in predicting near term changes in interest rates, but this predictive force increases along the forecast horizon. Furthermore, they affirm that this power is due to a mean-reverting tendency of interest rates.

The findings of Campbell and Shiller (1991) seem to be confirmed in other papers, and, to this extent, many authors try to give different explanations for the failure of the EH. Different studies identified actions of the central banks as the main variable underpinning such a poor performance of the EH. In the case of US, for example, it has been argued that the Fed, in determining short-term rates, brings these to behave like a random walk and this would inevitably affect the ability to determine any predictable variation in the term structure (Mankiw and Miron, 1986; Rudebusch, 1995). Tzavalis and Wickens (1997) try to give a rational explanation of the reasons at the base of the well functioning of EH in the long run with respect to a poor performance of the theory on a short-term horizon. They test the EH on a sample of monthly observations, from January 1970 to February 1991. They hypothesize two main causes for this failure. First, they theorize that long-term rates are determined by a risk premium term along with information embedded in short-term rates. Second, they consider the existence of an overreaction factor of long-term rates to short-term rates. However, they conclude that an empirical failure of the EH is mainly due to the presence of a risk premium, but this is far less significant as a determinant of current rates than the news regarding future short-term rates. In a recent working paper of the ECB, Guidolin and Thornton (2008) calculate theoretical forecasts of the future short-term rates and use an approximation of the Nelson-Siegel forward curve to estimate the yield curve (Diebold and Li, 2006). They demonstrate that the theoretical forecast implied by the EH is not far from the term structure forecasts, using a sample of monthly observations in the period January 1970 - December 2003. They also find the unpredictability of future short-term rates to be the main reason as to why the spread between long and short rates is not a good estimator for the future short-term rate.

However, in countries other than the US, many authors found evidence supporting the empirical success of the EH. In a study regarding the G7 countries, Hardouvelis

(1994) gives substantial credit to the well functioning of the theory in all the nations, but the US. The author takes different samples for each country from the oldest quarterly observation available to June 1992, and shows how long-term interest rates in France and Italy move in the correct direction according to the EH, whereas in the other G7 countries the counterintuitive movements might be explained by white noise deviation of the long-term rate from the one predicted by the EH. This explanation, however, does not work for the US, where the author explains this contrasting result in light of an overreaction of the long-term rates to the future short-term rates predicted by the EH, following the reasoning proposed by Campbell and Shiller (1991). In a paper on the UK market, Cuthbertson (1996) finds some evidence in favor of the EH. Through the Campbell and Shiller's methodology, applied on a weekly dataset, from January 1981 to February 1992, the author notices how the EH seems to work properly according to the Perfect Foresight Spread regression, which shows significant and coherent results in most cases. However, Cuthbertson (1996) finds more conflicting evidence when he uses the VAR methodology. Overall, he finds more evidence supporting the validity of the theory in the UK. Boero and Torricelli (1997) test the EH on German data in the period from February 1985 to December 1994 and find evidence that seems to confirm the validity of the theory in this country. Their test of the EH is developed through two different approaches. First, they use the more "classical" method of finding a correspondence between the term spread and the expected change in short-term interest rates. Secondly, they take the spread between the forward rate and the spot rate and test it as a predictor for changes in future spot rates. For both methods, they find strong results supporting the validity of the EH. The only evidence against the EH is justified by the influence of the central bank on German monetary policy, especially for the 3-month rate. In another study, Cuthbertson and Bredin (2000) test the EH on the Irish market, following the approach undertaken by Campbell and Shiller (1991). The authors use monthly observations of the zero-coupon curve from the period 1984-1997. They apply the VAR methodology on the Irish market and find that in this case the EH cannot generally be rejected (apart from the combination 3M-1M). By adopting the other methods tested by Campbell and Shiller (1991), i.e. Perfect Foresight Spread, Theoretical Spread and Correlation Ratio, they also find significative support to the EH for short-term maturities. Longstaff (2000) tests the EH at the very short end of the term structure. The author uses daily observations of government repo rates with maturities that range from overnight to 3 months in the period 21 May 1991 - 15 October 1999. Longstaff (2000) shows that term premia are very small and statistically

insignificant for weekly and monthly rates. Additionally, he finds that the test is also consistent with the pure version of EH, as the hypothesis of nil term premia in repo rates cannot be rejected for almost any of the maturities. Bataa et al. (2006) extend the study of Bekaert and Hodrick (2002) in testing the EH theory on the UK market. They test the theory on different pairs of maturities for the period January 1979 - May 2004 and compare their results with previous studies on the UK. What emerges from their findings is that the EH is very dependent on both the maturity pair taken into consideration and the sample in which the EH is tested.

Authors	Sample	Country	Evidence
Campbell&Shiller (1991)	Jan. 1952 - Feb. 1987	US	Strong rejection of EH
Fama&Bliss (1987)	Jan. 1964 - Dec. 1985	US	Rejection of EH
Mankiw&Miron (1986)	Jan. 1959 - Feb. 1979	US	Mild rejection of EH
Tzavalis&Wickens (1997)	Jan. 1970 - Feb. 1991	US	Strong rejection of EH
Guidolin&Thornton (2008)	Jan 1970 - Dec. 2003	US	Mild rejection of EH
Hardouvelis (1994)	Until Jun. 1992	G7 countries	EH depends on countries
Cuthbertson (1996)	Jan. 1981 - Feb. 1992	UK	Mild support of EH
Boero&Torricelli (1997)	Feb. 1985 - Dec. 1994	Germany	Strong support of EH
Cuthbertson&Bredin (2000)	Jan. 1984 - Oct. 1997	Ireland	Strong support of EH
Longstaff (2000)	May 1991 - Oct. 1999	US	Strong support of EH
Baata et al. (2006)	Jan. 1979 - May 2004	UK	EH depends on countries and samples

Table 2: Literature Review

2.5 Contribution to Research

As already mentioned, the EH has been thoroughly examined from Fama and Bliss (1987) onward. Research provides contrasting evidence and it is difficult to find a univocal consensus on the performance of the theory, whose validity tests bring substantially controversial results among the different countries considered. However, the vast majority of the studies we analyzed, apart from Campbell and Shiller (1991), fails to offer an empirical analysis based on an exhaustive range of maturities and mainly focuses on a specific part of the term structure (Cuthbertson and Bredin, 2000; Boero and Torricelli, 1997; Cuthbertson, 1996; Guidolin and Thornton, 2008). Besides, we could not find any significant test of the theory for the last decade, as the longest datasets analyzed reached the early 2000s at most.

With this paper, our intention is to present an additional empirical test of the EH. However, we decide to analyze the performance of this theory in a sample of four different countries, in which we include Sweden and Italy. As far as we know, no previous studies have been conducted on the Scandinavian country, and, for what concerns Italy, a detailed and specific analysis of this argument is lacking. Furthermore, we test four different methodologies, with a special focus on Campbell and Shiller (1991), in order to be able to derive a general conclusion regarding the performance of EH in these nations. In order to be as exhaustive as possible and to be able to assess properly the theory, we focus on a more complete range of monthly maturities, from 1 month to 10 years. In this respect, we are able to provide a deeper analysis of the term structure, and to observe in which part of the curve the EH performs better. In addition, another interesting feature of our study is the dataset we use to test the theory. As a matter of fact, we decide to evaluate the EH on two different samples; one that ranges from 2000 to 2012, and the other from 2000 to 2007. The reason behind this particular choice is to see if the EH was affected by the recent financial crisis.

3 Data

3.1 Data Sources

We test the EH on a set of four countries, namely Italy, Sweden, Germany and the United States. The data spans the zero-coupon yield curve for each country month by month up to 10 years. The term structure, obtained as such, is observed through time. The data is downloaded from DataStream, which in turn uses the term structure built by Intercapital (ICAP). This curve is constructed by taking into consideration yields from the cash, future, bond and swap markets. Quite generally, to derive the curves the linear interpolation or cubic spline method are used.

Country	Time Window	# of Observations	Methodology
Italy	Feb. 2000 to Jun. 2011	137	Linear Interpolation
Sweden	Feb. 2000 to Feb. 2013	157	Linear Interpolation
Germany	Mar. 2000 to Jul. 2011	137	Linear Interpolation
United States	Mar. 2000 to Mar. 2013	157	Cubic Spline

Table 3: Data Overview

Figure 2 shows the term structure of each country. It can be noted how these curves exhibit similar patterns, as these states were somehow exposed to the same shocks in the economy. Signs of the last financial crisis are evident in all the yield curves and are shown by the spike in short-term rates from 2007 to 2008. It is also interesting to notice how in this period the term structures had a tendency to invert, as short-term rates were somewhat higher than long-term rates. From the figure, we can also trace some early signs of the European sovereign debt crisis, since we can see that the interest rates in Italy as well as Germany were rising in the last months of our sample. The depression of interest rates from 2010 onward is probably due to the Quantitative Easing programs of the Fed.

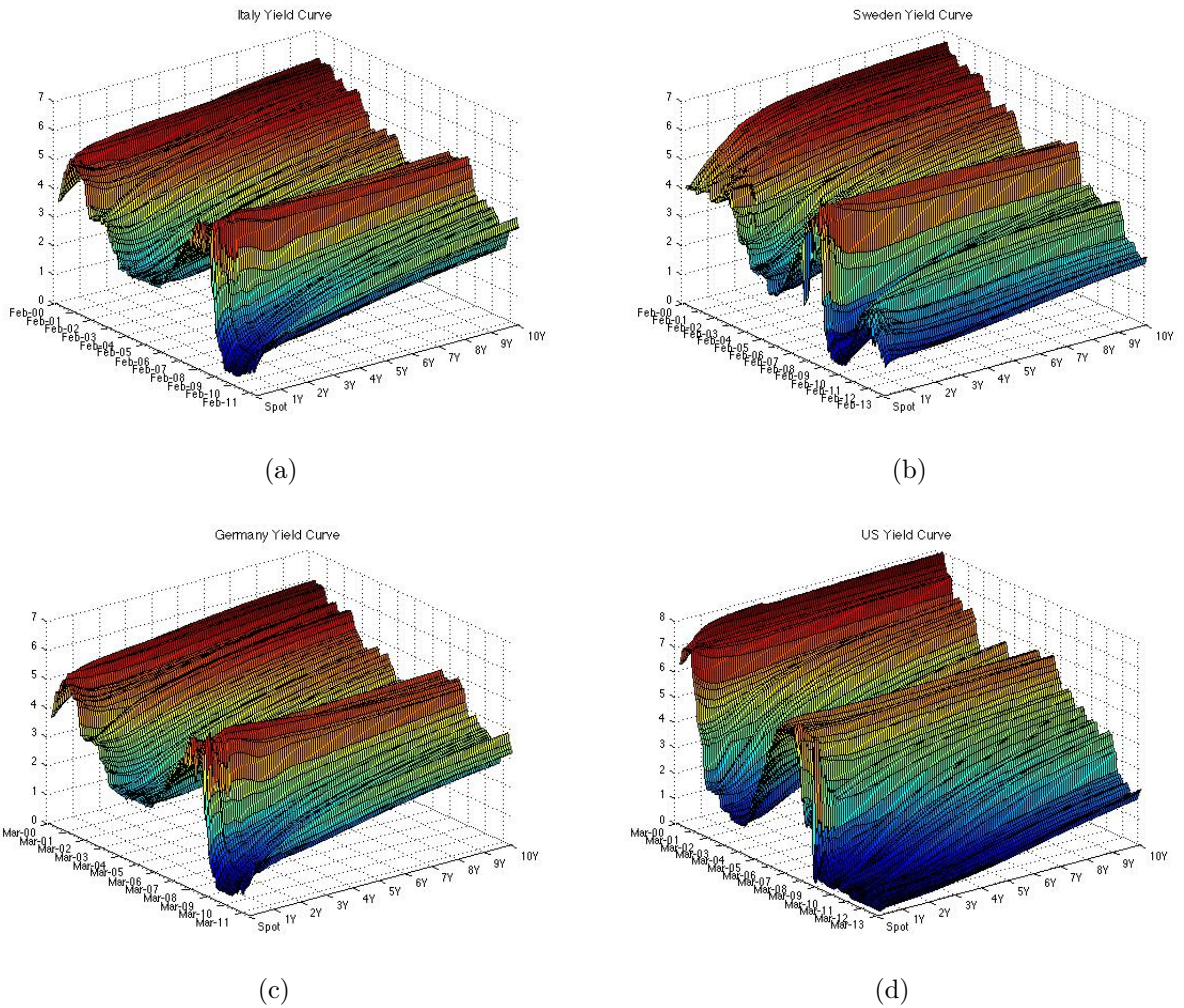


Figure 2: Yield Curves

3.2 Descriptive Statistics

In this section we present some descriptive statistics about our data. As it would be cumbersome to report statistics for every maturity of the term-structure, we decide to focus on only a few of them, namely 1, 12, 60, and 120 months. Table 4 reports the mean, standard deviation, minimum, first, second, third quartile and maximum of each series. At first glance, we can see how the US present the biggest swings in the yield curve. For each time series, in the US we observe the biggest difference between the first and third quartile and the largest standard deviation. Another interesting point is that Italy's and Germany's term structures behaved very much alike from 2000 to 2011 according to these statistics. As opposed to the current situation, interest rates in Italy were also on average just few basis points higher than in Germany. In the next subsection, we test our time series for unit roots.

		Mean	Std. Dev.	Min	25th	Median	75th	Max
ITALY	1 month	2,821	1,423	0,389	2,120	2,737	4,047	5,135
	12 months	3,078	1,284	1,086	2,142	2,905	4,236	5,418
	5 years	3,791	0,953	1,788	3,048	3,773	4,562	5,731
	10 years	4,331	0,826	2,427	3,629	4,290	4,866	6,016
SWEDEN	1 month	2,741	1,351	0,338	1,800	2,388	4,019	5,641
	12 months	3,013	1,333	0,730	1,987	2,839	4,309	5,397
	5 years	3,890	1,237	1,525	2,851	3,995	4,802	6,281
	10 years	4,302	1,167	2,062	3,437	4,353	5,162	6,577
GERMANY	1 month	2,817	1,428	0,397	2,121	2,717	4,080	5,239
	12 months	3,063	1,276	1,066	2,156	2,861	4,312	5,372
	5 years	3,765	0,944	1,903	2,929	3,731	4,499	5,723
	10 years	4,310	0,814	2,604	3,597	4,308	4,802	6,007
US	1 month	2,468	2,212	0,186	0,279	1,830	4,493	7,022
	12 months	2,692	2,095	0,307	0,636	2,271	4,496	7,626
	5 years	3,806	1,692	0,751	2,569	3,896	5,073	7,826
	10 years	4,536	1,420	1,648	3,621	4,733	5,393	7,945

Table 4: Descriptive Statistics

3.3 Preliminary Unit-root Tests

The VAR methodology that we use in this paper is based on the assumption that the change in the short-term interest rate $\Delta y_t^{(m)}$ and the term spread $S_t^{(n,m)}$ are cointegrated $\mathbb{CI}(1, 1)$. In fact, if these time series do not converge to a long-run equilibrium the VAR regression cannot be applied. To test for cointegration, we first check that the series are integrated of order 1 and then perform the Engle-Granger test. Unit-root tests for the individual time series are carried out by implementing the Augmented Dickey-Fuller test (ADF) (Dickey and Fuller, 1979). This procedure is based on the following regression

$$y_t = c + \phi y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \dots + \delta_p \Delta y_{t-p} + \epsilon_t$$

In this case, we test the null hypothesis of nonstationarity $H_0 : \phi = 1$ against the alternative $H_1 : \phi < 1$. We test different specifications of the regression, with a number of lags from 1 up to 10, and we pick the one with the lowest Akaike Information Criterion so as to ensure that there is no serial correlation in the residuals. We first consider the evidence relating to the change in short-term rates. As to Italy, Germany and Sweden the test unanimously rejects the null hypothesis of unit root and thus we do not report the relative statistics. Conversely, in the US we fail to reject the null hypothesis. Figure 3 plots the first difference of the level of interest rates for different maturities. A graphical inspection of $\Delta y_t^{(m)}$ reveals that there is a structural break in the data, which in turn is the reason for the apparent nonstationarity of the time series, given that the ADF is known not to cope well with this kind of data. In addition, the fact that we do not have many observations is likely to further reduce the power of our test. A methodology that fares better with this data is the Philips-Perron test (PP), which revises the ADF in order to have a reliable test in the presence of structural breaks in the time series (Phillips, 1987; Phillips and Perron, 1988). Table 5 shows the t-stats for both the tests: as we can see, the PP allows us to reject the hypothesis that the first difference in interest rate levels is nonstationary.

If we are positive that interest rate levels are $\mathbb{I}(1)$, we are less sure about the stationarity of the term spread. Table 6 contains the ADF statistics which all share a common critical value at a 5% significance level of -2.88. Since this is a one-tailed test, the more negative our statistic, the stronger the rejection of the null hypothesis. As we can see from the table, we cannot always reject the null hypothesis of nonstationarity,

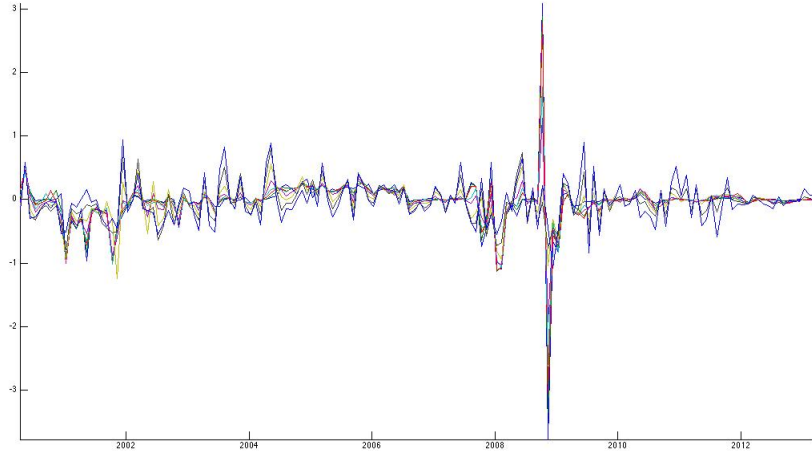


Figure 3: Change in Short-term Rates in the US

in particular at the short and long ends of the yield curve. Alas, in this case the PP does not provide better results since we do not observe any structural break in the data. This is potentially a problem for our VAR analysis, since the stationarity of time series is the underlying assumption which allows us to run the regressions. However, as noted earlier, the relatively small number of observations strongly reduces the power of our test and may be the cause of the non rejection of the null hypothesis of nonstationarity. Therefore, we still proceed with our analysis even though we advise the reader to look at the results *cum grano salis*.

The final test on our data consists of performing the Engle-Granger cointegration test (EG) between the changes in short-term rates and the term spread (Engle and Granger, 1987). The basic idea behind this method is that if the two series move together, i.e. they are cointegrated, a linear combination of the two is stationary. Hence, to test this hypothesis we can regress one series on the other and assess the stationarity of the residuals. Formally, if we define a linear combination u of the time series y and x such that

$$y - \beta x = u$$

then we could test the stationarity of u performing an ADF or PP test. Unfortunately, we do not observe u , but we need to estimate it, for instance, through OLS regression. In this case, we can then apply the stationarity tests on the residuals from the regression.

In Sweden, Germany and Italy, results from the Engle-Granger procedure reveal that the term spread and changes in short-term rates are undoubtedly cointegrated, as the p-values are well below 1% for every pair of maturities. On the other hand, if we apply the ADF variant of the EG two-step procedure on US data, we find that most pairs of maturities are not cointegrated. Nonetheless, by looking at a plot of the residuals from the EG regression, which is not shown here, we can see in most cases there are structural breaks in the data. Hence, we decide to apply the Philips-Perron unit-root test on the residuals, which strongly rejects the null hypothesis of non-stationarity in every case. All in all, we are confident that our data is suitable for the application of the VAR methodology and thus we proceed with our analysis.

4 Methodology

4.1 The Term Spread and Forward-spot Spread Regressions

We start this section with a description of the first regression that we perform in our study. As predicted by the EH, the slope of the yield curve and the future long-term rates should be positively related. To see this, we start from equation 2.3 in which we multiply both sides by m for convenience

$$\begin{aligned} my_t^{(m)} &= \mathbb{E}\left(r_{t \rightarrow t+m}^{(n)}\right) \\ my_t^{(m)} &= \mathbb{E}\left(p_{t+m}^{(n-m)}\right) - p_t^{(n)} \\ my_t^{(m)} &= ny_t^{(n)} - (n-m)\mathbb{E}\left(y_{t+m}^{(n-m)}\right) \\ y_t^{(n)} &= \frac{m}{n}y_t^{(m)} + \frac{n-m}{n}\mathbb{E}\left(y_{t+m}^{(n-m)}\right) \end{aligned}$$

Subtracting $\frac{n-m}{n}y_t^{(n)}$ from both sides yields

$$\begin{aligned} y_t^{(n)} - \frac{n-m}{n}y_t^{(n)} &= \frac{m}{n}y_t^{(m)} + \frac{n-m}{n}\mathbb{E}\left(y_{t+m}^{(n-m)}\right) - \frac{n-m}{n}y_t^{(n)} \\ \mathbb{E}\left(y_{t+m}^{(n-m)}\right) - y_t^{(n)} &= \frac{m}{n-m}\left(y_t^{(n)} - y_t^{(m)}\right) \end{aligned}$$

By defining a variable $s_t^{(n,m)} = \frac{m}{n-m}\left(y_t^{(n)} - y_t^{(m)}\right)$ the last equation leads to the

following regression, which is equivalent to the first regression in Campbell and Shiller (1991)

$$y_{t+m}^{(n-m)} - y_t^{(n)} = \alpha + \beta s_t^{(n,m)} + \epsilon_t \quad (4.1)$$

If the EH is true then β must be equal to one, whereas α should be either equal to nil or the opposite of the risk premium, depending on the version of the EH considered (Boero and Torricelli, 1997). The meaning of this equation is that if the yield of the long-term bond rises over the life of the short-term bond, this gives a capital loss to the holders of this instrument. In order for them to be indifferent between the long and short-term bond, the longer-term security must give them a higher yield (Campbell and Shiller, 1991).

Instead of using the term spread to test the EH, an alternative method adopts the forward-spot spread. The EH implies that forward rates are unbiased predictors of future short rates (Boero and Torricelli, 1997)

$$E_t \left(y_{t+n-m}^{(m)} \right) = f_t^{(n-m,n)} + \phi$$

where ϕ is a constant risk premium. By subtracting the short-term yield $y_t^{(m)}$ from both sides of the above equation and removing expectations we get the following regression

$$y_{t+n-m}^{(m)} - y_t^{(m)} = \alpha + \beta \left(f_t^{(n-m,n)} - y_t^{(m)} \right) + \epsilon \quad (4.2)$$

This is similar to one of the equations tested in Boero and Torricelli (1997), with the difference that in our case m is set to 12 months as opposed to 1, and identical to the main regression in Fama and Bliss (1987). If the EH is true, we would expect the slope coefficient to be equal to one and the intercept to the risk premium. On the other hand, the pure version of the EH states that the intercepts should be nil.

4.2 Perfect Foresight Spread and VAR

A second test carried out by Campbell and Shiller (1991) is derived by rearranging Equation (2.2). The authors define the so-called Perfect Foresight Spread (PFS) $S_t^{(n,m)*}$

$$S_t^{(n,m)} = \mathbb{E} S_t^{(n,m)*} \quad (4.3)$$

$$y_t^{(n)} - y_t^{(m)} = (1/k) \sum_{i=0}^{k-1} \mathbb{E} \left(y_{t+im}^{(m)} \right) - y_t^{(m)} \quad k = n/m$$

$$S_t^{(n,m)*} = (1/k) \sum_{i=0}^{k-1} y_{t+im}^{(m)} - y_t^{(m)} \quad k = n/m \quad (4.4)$$

This is the spread that would be obtained if market participants had perfect foresight of future interest rates. From another standpoint, Equation 4.4 says that the slope of the term structure should amount to the average of the future change in short-term rates. To test this hypothesis the authors regress the PFS onto the actual spread and a constant. The slope coefficient of this regression should be one if the EH were true

$$S_t^{(n,m)*} = \alpha + \beta S_t^{(n,m)} + \epsilon \quad (4.5)$$

This regression has the disadvantage that it uses overlapping observations and therefore OLS standard errors tend to be too small. In order to attain unbiased standard errors, the authors used the correction suggested by Hansen and Hodrick (1980), which in this case implies that we should adjust by $n-m-1$ overlapping observations. Another drawback of this methodology is that to obtain the PFS we lose $n-m$ observations at the end of the sample period. Given that we do not have many observations, this can cause serious inference problem particularly for large values of $n-m$, which mostly happens at the long-end of the yield curve. In addition, the Hansen-Hodrick correction does not work too well when $n-m-1$ is large relative to the sample size (Bataa et al., 2006). Finally, the independent variable is serially correlated and correlated with the dependent variable (Bataa et al., 2006; Campbell et al., 1996) which can cause inference problems as well.

In order to overcome the problems from the OLS regression method, Campbell and Shiller (1988) propose a VAR methodology to evaluate present value models that is suitable for a test of the EH. First, they define an information subset Y_t that is used to form an optimal forecast of future increases in short-term rates. This subset is composed of $\Delta y_t^{(m)} = y_{t+m}^{(m)} - y_t^{(m)}$ and the spread itself $S_t^{(n,m)}$, which are assumed to be stationary $\mathbb{I}(1)$. This information subset can be represented by a p -order VAR and rewritten as a first-order VAR using the companion form $z_t = Az_{t-1} + u_t$. The companion matrix has

the following representation (Jondeau, 1997; Campbell and Shiller, 1988)

$$A = \begin{bmatrix} a_{11}^1 & a_{11}^2 & \cdots & a_{11}^p & a_{12}^1 & a_{12}^2 & \cdots & a_{12}^p \\ 1 & \cdots & 0 & 0 & & & & \\ \vdots & \ddots & & \vdots & & 0 & & \\ 0 & \cdots & 1 & 0 & & & & \\ a_{21}^1 & a_{21}^2 & \cdots & a_{21}^p & a_{22}^1 & a_{22}^2 & \cdots & a_{22}^p \\ & & & & 1 & \cdots & 0 & 0 \\ & & & & \vdots & \ddots & & \vdots \\ & & 0 & & 0 & \cdots & 1 & 0 \end{bmatrix}$$

The vector z_t has $2p$ elements: $\Delta y_t^{(m)}$ and $p - 1$ lags and $S_t^{(n,m)}$ and $p - 1$ lags. Next, they define two vectors, g e h , such that $g'z_t = S_t^{(n,m)}$ and $h'z_t = \Delta y_t^{(m)}$. Both vectors have $2p$ zero elements, except for the first element of h and the $p + 1$ -st element of g which equal one. According to this formulation, Campbell and Shiller (1991) shows that the PFS $S_t^{(n,m)}$ can be written as

$$S_t^{(n,m)} = h'A [I - (m/n)(I - A^n)(I - A^m)^{-1}] (I - A)^{-1} z_t \quad (4.6)$$

$S_t^{(n,m)}$ is called the “theoretical spread”. It can be shown that if the EH were true, then $S^{(n,m)} = g'z_t = S_t^{(n,m)}$. The researchers analyze the historical behavior of the actual and theoretical spread by comparing the correlation and the ratio of standard deviations of the two variables, which should both equal one if the EH were true. It is also possible to regress the theoretical spread onto the actual spread. The coefficients resulting from this procedure in theory should be equivalent to the ones from equation 4.5 (Campbell and Shiller, 1988, 1991; Jondeau, 1997).

5 Empirical Results

5.1 Evidence from 2000 onward

Table 8 and 9 show the slope regression coefficients from equation 4.1. As we can see, the results are quite different from Campbell and Shiller’s. They find that a higher term spread is not associated with an increasing long-term yield. Conversely, our results seem

to indicate that at least in this regard the EH works. For almost any pair of maturities when the spread is large, the yield of the long-term bond rises over the life of the short-term bond. Exceptions to this general statement are mainly found when m and n are low, or when $n = 120$. With respect to the US results, we also find a different pattern of the coefficients. In Campbell and Shiller (1991) these become increasingly negative with the horizon, whereas our results show a hump pattern. The ability of the spread to forecast movements of the longer-term yield improves along the horizon up to one or two years and worsens afterwards. Interestingly, this observed pattern in the coefficients seems to be quite persistent in every country but Sweden. Figure 4 plots the slope coefficients from equation 4.1 for $m = 1, 3, 12, 24$. As we can see, the hump pattern is rather consistent for Italy, Germany and the US, whereas is not evident for Sweden. Table 8 and 9 also report Hansen-Hodrick standard errors in parentheses. We can see how these generally increase with the maturity of the short-term bond m , since we correct for an increasing number of overlapping observations. As we can see from the p-values in the table, the majority of the coefficients is not statistically different from zero. The main exceptions are found when n is either 9 or 12. In addition, Figure 5 plots the opposite of the intercept coefficients from the regression. If we believe in the pure version of the EH, these should all be zero, whereas the standard EH only implies that these are equal to the opposite of a constant risk premium. As we can see, the intercepts considerably differ according to the pair of maturities. Since these numbers should in theory reflect the risk premium, we can expect the pattern that we observe in the figure as investors probably require higher risk premia for longer investment horizons.

In order to test for the validity of the EH, we perform a Wald test on the regression coefficients. In particular, we test the null hypothesis $H_0 : \alpha = 0 \text{ and } \beta = 1$. The Wald statistic is distributed according to a chi-squared distribution with two degrees of freedom $W \sim \chi^2(2)$, which implies a 5% rejection statistic of 5.99. As we can see in Tables 10 and 11, the EH is vastly rejected. However, it appears that the EH sometimes works when m is between 2 and 6 months and n between 6 and 36. This is true for Germany and Italy, whereas it is not for US and Sweden, wherein the EH is almost never confirmed.

After having considered evidence from the term spread regression, we present evidence regarding the forward-spot spread. For the sake of brevity, we consider just a few couples of maturities. Table 7 shows the empirical results from running Equation

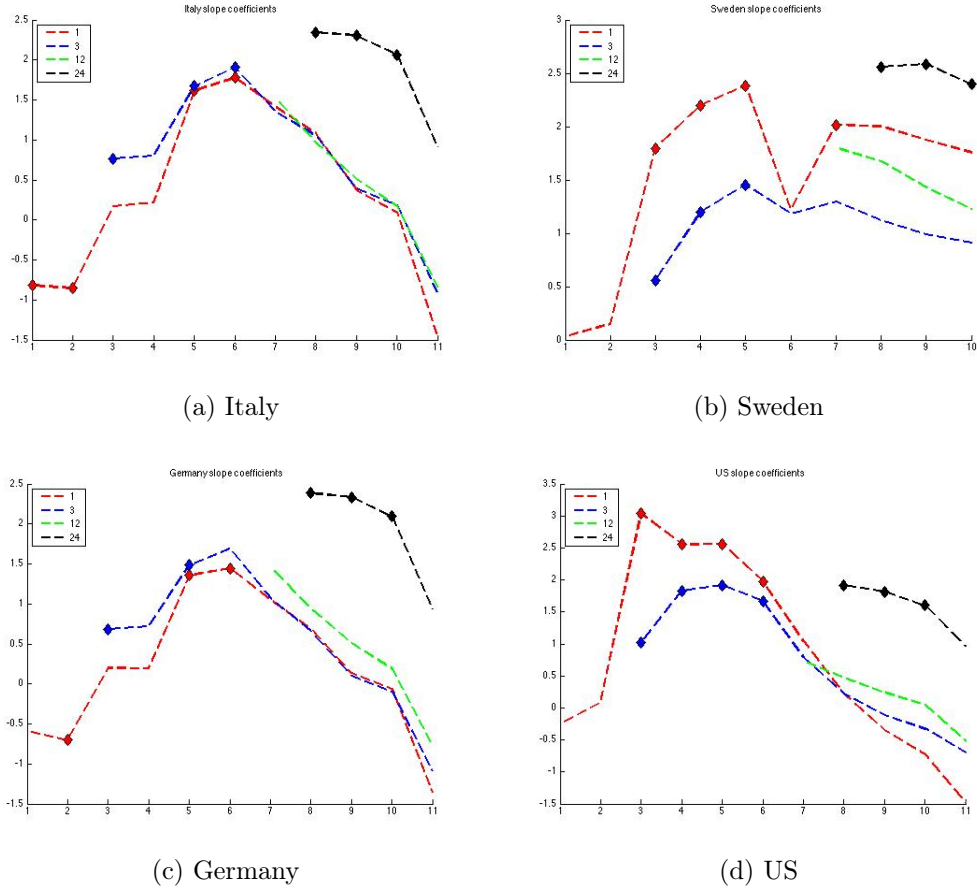


Figure 4: Slope Coefficients - Term Spread Regression

The figure plots the columns of Table 8 and 9 for m equal to 1, 3, 12 and 24. Diamonds in the figure indicate that we can reject the null $H_0: \beta = 0$.

4.2. According to this specification, the EH fares pretty well in all sample when n is set to either 24 or 36. In these instances, the slope coefficients are somewhat close to, and never statistically different from unity in all samples but Sweden's. However, the intercepts are vastly significantly different from zero, which invalidates the pure EH. As for the rest of the evidence, when n is either equal to 48 or 60, the Wald test rejects the null that β equals 1 in all samples but Sweden's. Therefore, for these maturities we have a sounding failure of the EH. Our evidence is rather distant from what Boero and Torricelli (1997), which almost never rejects the EH according to this metric, and more in line with Fama and Bliss (1987), even though in our study the magnitudes of the coefficients are considerably bigger. In the US is also astonishing the power of our regression, which improves along the horizon up to almost 90% in the five-year case.

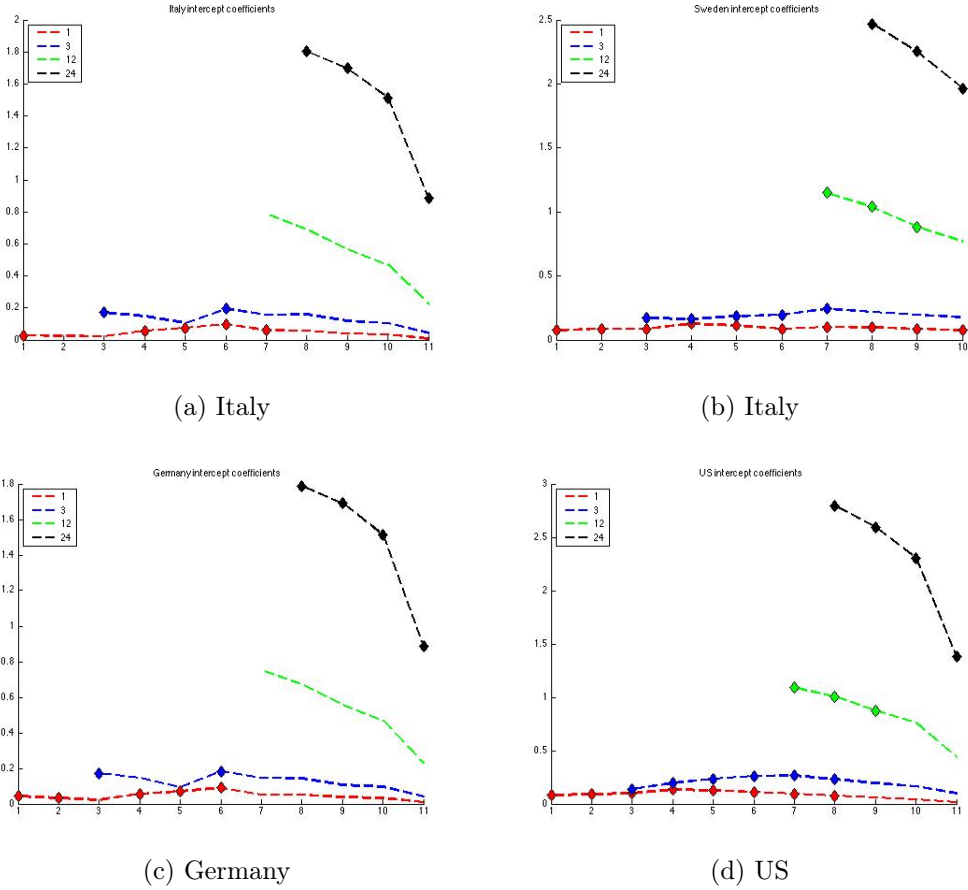
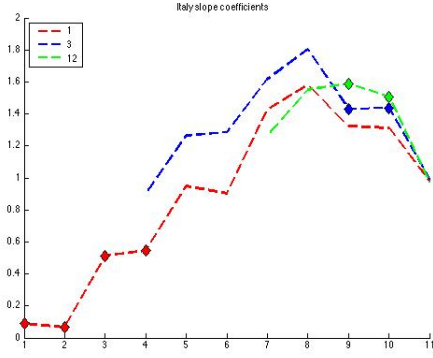


Figure 5: Intercept Coefficients - Term Spread Regression

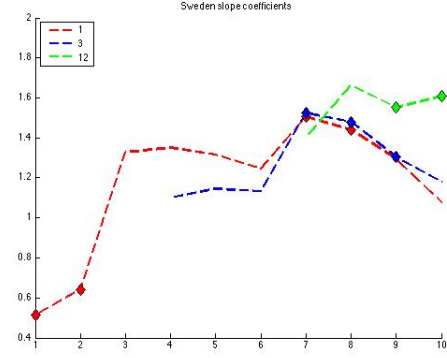
The figure plots the intercepts from Equation 4.1 for m equal to 1, 3, 12 and 24. Diamonds in the figure indicate that we can reject the null $H_0: \beta = 0$.

This dwarfs the still meaningful 48% obtained in Fama and Bliss (1987).

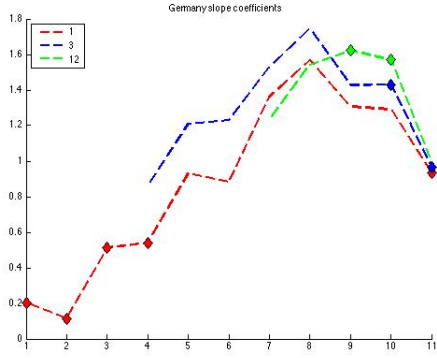
Next, we run the regression of the PFS on the actual spread. Table 12 and 13 and Figure 6 show the slope coefficients when running regression 4.5. From the table we can conclude that a rejection of the EH is granted mostly at the very short-end of the term structure, whilst the rest of the evidence from the regression is somewhat in favor of the EH. This is generally very true for intermediate maturities. In the US the results are more dubious, as the coefficients are considerably larger than one. This is in stark contrast to Campbell and Shiller's coefficients, which are usually well under unity. As to the forecast power of the term structure for changes in short-term rates, we find that this steadily improves up to 2/3 years and then declines. This is also in contrast



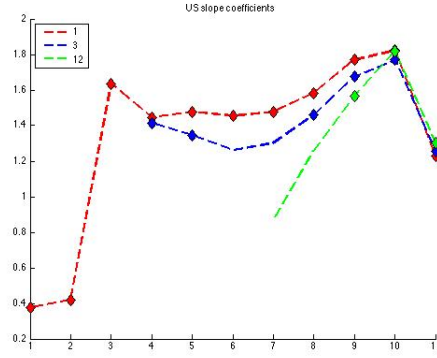
(a) Italy



(b) Sweden



(c) Germany



(d) US

Figure 6: Slope Coefficients - PFS Regression

The figure plots the columns of Table 12 and 13 for m equal to 1, 3, 12 and 24. Diamonds in the figure indicate that we can reject the null $H_0 : \beta = 1$.

to the “U-shaped” pattern found using the US data (Campbell and Shiller, 1991), as in this case we find a hump pattern.

Finally, we present evidence on our data regarding the VAR specification, where p , i.e. the number of lags to be included in the VAR, is set to 4 as in the original study of Campbell and Shiller. The regression coefficients in Table 14 and 15 should be the same as in Table 12 and 13. However, for large n they differ quite drastically probably because the sample used to construct the PFS has fewer observations than the VAR sample (Campbell and Shiller, 1991). Most slope coefficients differ from one at traditional statistical level, even though it looks like that the EH is economically valid when n and m are relatively low. Even in these cases, however, formal statistical

tests would lead to a rejection of the EH, as the VAR model produces extremely low standard errors (Cuthbertson and Bredin, 2000; Campbell and Shiller, 1991). It is hence worthwhile to compare the historical behaviors of the two time series. Table 16 and 17 report the correlation coefficient and standard deviation ratio $\sigma \left(S_t'^{(n,m)} \right) / \sigma \left(S_t^{(n,m)} \right)$ between the theoretical and actual spread. The correlation between the two time series usually improves with the maturity of the long-term bond, as this, for all countries, is closer to one when $n = 120$. All the samples, but the US' and Sweden's, point to a strong rejection of the EH for low n and m , as the correlations are considerably small. Among the countries analyzed, US data lends the strongest support in favor of the EH. As to the standard deviation ratios, we note how these are generally below one. This implies that the theoretical spread is less volatile than the actual. Exceptions to this finding are found for intermediate maturities.

Figure 7 plots the theoretical versus the actual spread for some pairs of m and n , namely, from top-left to bottom-right, $(1, 12)$ $(3, 12)$ $(1, 120)$ and $(3, 120)$. At first sight, it is evident that VAR spread and actual spread look pretty much alike for low n . This is somehow striking since the correlation coefficient resulted to be lower in this case. Obviously, the different standard deviations between the time series seem to be the reason for this divergence. In addition, in these specific instances, the series move better together for higher m . Among the different samples, the US seems to be the one in which the theoretical spread best approximates the actual.

5.2 Evidence from 2000 to 2007

The sample we have been using so far includes observations throughout the recent financial crisis in which the yield curve is often downward sloping. In order to test the EH in a more standard setting, we perform the tests from the previous section in a reduced sample, from February 2000 to February 2007. For what concerns such sample, we present evidence just for some selected pairs of maturities. Table 18 presents evidence for Campbell and Shiller's first regression on the reduced sample. In this case, the performance of the EH considerably varies from country to country. However, Germany and Italy have somewhat positive results when m equals 1 or 3 months and n is equal or below 12 months. In these instances the spread forecasts movements in the short-rates roughly as it is predicted by the EH. Conversely, when m is set to 12 months and n is larger as well, the EH seems to fail since most coefficients are negative.

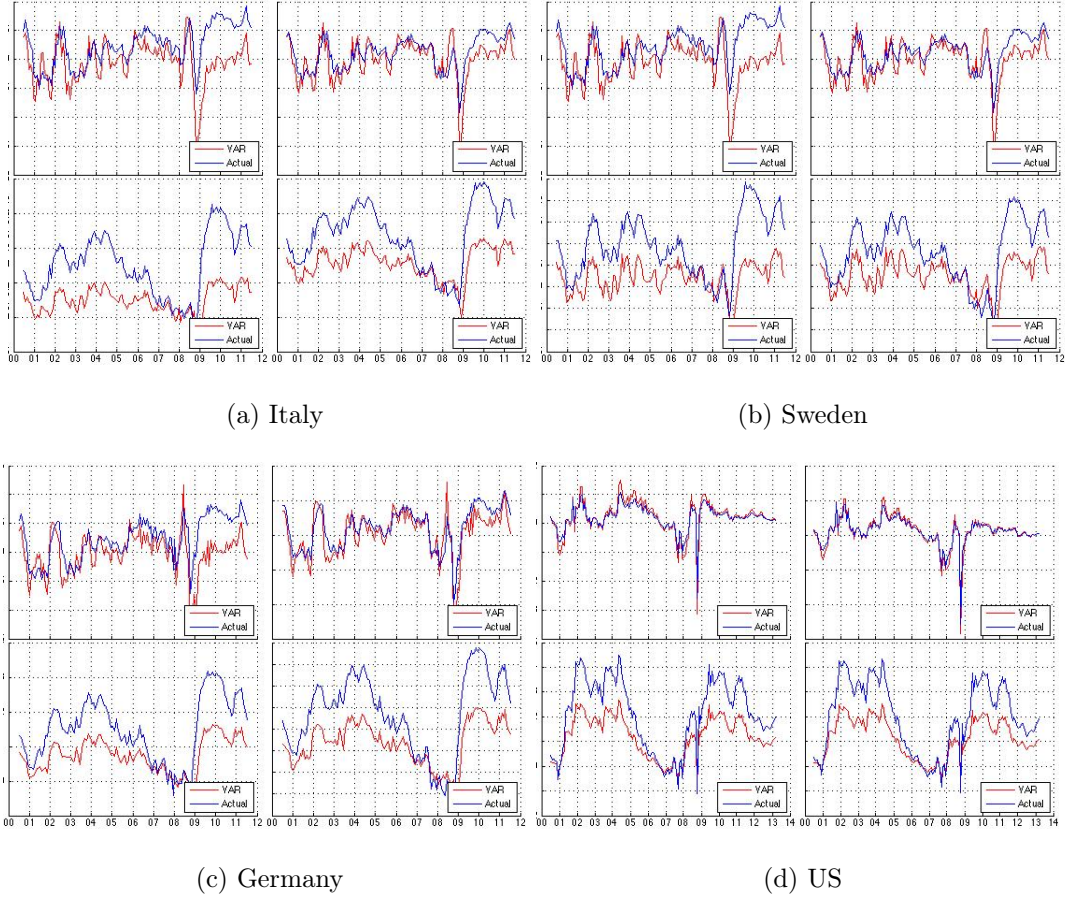


Figure 7: Theoretical vs. Actual Spread

Each subplot draws the time series respectively for the following combination of n and m (1,12) (3,12) (1,120) (3,120)

As to Swedish data, we have a sound rejection of the EH for every pairs of maturities, as most regression coefficients are significantly far from one. Lastly, the regression on US data shows that at the short end of the curve an increase in the spread is followed by a subsequent hike in short-term rates in a way that is still not consistent with the EH given that the slope coefficients are extremely high. Nonetheless, the long end of the term structure shows the same patterns found previously for the other countries.

Table 19 shows the results from the second regression in Campbell and Shiller (1991) performed on the small sample. Again, we find a relatively strong support of the EH in Italy as well as in Germany. Excluding the maturity pair (12, 24), in Italy we find coefficients in the range $0.78 - 1.36$ and $0.66 - 1.66$ in Germany. In many

cases, asymptotic inference implies that we cannot reject the null hypothesis that the coefficients are not different from one, even though for both countries the EH does not work too well on the long end of the curve. Overall, evidence supporting the EH seems weaker in Sweden and even more so in the US, where most coefficients are far away from one. Interestingly, while in Sweden the slope of the yield curve is on average bigger than the expected changes in future short-term rates, which amount to the perfect foresight spread, the opposite seems to be true in the US - the slope coefficients are under unity for Sweden and above for the US.

Table 20 contains the slope coefficients resulting from the VAR regression methodology. Once more, we deem that the EH fares relatively well in Italy and Germany for short to medium maturities. When n is lower than or equal to 12, we find that the beta coefficients of the VAR regression range from 0.89 to 1.08 for Italy, and from 0.87 to 1.09 for Germany. Albeit these coefficients are mostly significantly different from one according to asymptotic inference, they are economically close to one and suggest that EH performs well in this part of the term structure. The long-term end of the curve, however, still points to a resounding failure of the EH, as the coefficients are decisively far from one. In line with the results from the PFS regression, tests of the EH in US as well as in Sweden do not lend any support in favor of the theory since most coefficients are economically and statistically different from one.

5.3 Combined Evidence

Although it is difficult to reconcile the results from the aforementioned methodologies and samples, we try in this section to draw a few general conclusions on the validity of the Expectation Hypothesis. First, by looking at evidence from the full and reduced samples, it is obvious that the financial crisis may have caused some artificial patterns which we do not observe when only looking at the period before 2008. Hence, we advise the reader to interpret the results while bearing in mind that the last couple of years may have biased our conclusions.

Second, as opposed to Campbell and Shiller's earlier findings, the EH has at least the merit of predicting the sign of the changes in longer-term bond. For almost every couple of maturities, results from the first regression show that, whenever the spread between the long-term and short-term bond is positive, the price of the long-term bond falls over the life of the short-term bond. In other words, investors, who

hold the long-term security and are subject to an expected capital loss, are in fact compensated by a higher current yield on this security with respect to the short-term one. Exceptions to this statement are generally found when n is equal to ten years, as in this case the slope coefficients from the first regression are negative. As to the performance of the theory according to this first test, we can note how, when n is between 12 and 24 months and m between 1 and 3, we have the best results both in the sample and the subsample, as the coefficients are not statistically far from one. All in all, when considering results for all countries, Germany and Italy seem to be the ones where the EH works best in the abovementioned range of maturities. In the Swedish dataset, while the full sample regression is promising, the outcome in the subsample is quite disappointing as we cannot see any pattern in favor of the EH. As to the US, we cannot find any significant support in favor of the EH. Nonetheless, it is striking to notice the stark difference between Campbell and Shiller's results and ours, as the sign and magnitude of the regression coefficients differ quite dramatically in the two samples.

With respect to our second test of the EH, namely the perfect foresight spread regression, we find once again the best support of the EH for Italy and Germany, considering both the full and small samples, in the previously mentioned range of maturities. Sweden and the US present a more contrasting evidence, as the coefficients are further away from one. However, we cannot help but notice how the slope coefficients in this regression are generally bigger than the ones found in Campbell and Shiller (1991), which are mostly closer to zero and sometimes even negative. Our findings are in line with previous studies on some European countries that show similar numbers (Cuthbertson and Bredin, 2000; Boero and Torricelli, 1997). It is also interesting to see how the US have the largest slope coefficients, which means that the realized changes in short-term rates are bigger than the ones expected by market participants.

Finally, the evidence from the VAR regression generally confirms what we have found with the PFS regression with exceptions on the long-term part of the yield curve, since the samples used in the regression tend to sizeably differ for large n . Conversely, a comparison of the historical behaviors of the two time series reveals quite surprising results. In Italy and Germany, intermediate maturities, which show good results according to our previous metrics, do not constitute evidence in favor of the EH, as correlation coefficients and standard deviation ratios are not that close to one. On the other hand, this study yields far better results for Sweden and especially the US, whose

correlation coefficients are close to one across the board and whose volatility ratios are around unity at least for intermediate values of n . As noted before, a visual inspection of Figure 7 confirms that the VAR and actual spread move well together in the US when n is not too large. Overall, we do not find enough evidence to validate the EH for all maturities. We do find, however, that when n is between 12 and 24 months, the EH seems to work. In the next section, we examine some of the reasons which could explain a failure of the EH.

6 The Economics of the EH Failure

Failures of the previous tests are generally considered to be due to either time-varying risk premia or overreaction models of the yield curve (Tzavalis and Wickens, 1997; Campbell and Shiller, 1991). We first consider some of the results that an overreaction model can imply and then compare them with evidence from our methodology. As noted by Campbell and Shiller (1991), an alternative model to equation 4.3 could be the following, where we also allow for a constant log risk premium

$$S_t^{(n,m)} = k\mathbb{E}S_t^{(n,m)*} + c \quad (6.1)$$

This model implies that, when the perfect foresight spread is regressed onto the actual spread, the slope coefficient is given by $1/k$. In addition, the correlation coefficients between the two series should be equal to one and the ratio of the standard deviations to $1/k$. We can look at the results from the VAR methodology to see if the model fits our data. It is clear that this model does not work well for either Italy or Germany. The correlation coefficients are usually far from one for every pair of maturities and the standard deviation ratios do not approach the slope coefficients, as it is implied by the above theoretical model. However, this specification seems to perform quite well in Sweden as well as in the US. The correlation coefficients between the theoretical and actual spread are usually around one for almost every pair of maturities. Besides, there is a striking correspondence between the slope coefficients from the VAR regression and the standard deviation ratios. The only difference between Sweden and the US is that the former shows evidence that implies a value of k higher than one, whereas in the latter the opposite is true. Therefore, it looks like the term spread is larger than the realized sum of the changes in future short-term rates in Sweden, whilst

it is smaller in the US. Then if the spread amounts to expectations of future interest rates, we could say that markets participants expected such changes to be bigger in Sweden (overreaction) and smaller in the US (underreaction). This is an interesting result, since Campbell and Shiller (1991) reached the opposite conclusion for the US. However, the slope coefficients are larger than one in both our sample and subsample, which suggests that this singularity is not due to the particular time window considered in our study. A possible explanation for this is perhaps that in our sample the US had the biggest swings in interest rates, which were difficult to forecast ahead of time. Visually, the US shifts quite rapidly from a period of high interest rates, the dot-com bubble, to a period of very low interest rates before the financial crisis, and then again from high interest rates during the financial crisis to historic lows nowadays. Looking at the plots from Figure 2 it is evident how such changes are somewhat outright compared to the other countries'. If we assume that investors could not completely foresee such swings, especially very much ahead into the future, and consider that the term spread should reflect the expectations of these changes, then it is possible to argue that this is the reason behind a flatter slope than the one implied by rational expectations. In other words, markets underestimated the changes in the interest rates. Economically, this makes sense, for instance, to the extent that the financial crisis and the Fed's intervention were not easy to divine. It is worth considering why this overreaction theory seems to work in the US and Sweden, and not in Italy and Germany. Loosely speaking, if we imagine that the risk premium is mainly driven by perception of the riskiness of a country and not by the likes of volatility or inflation, then we can see how countries in the Eurozone must award their investors with a premium. Neither the US nor Sweden's solvency has ever been questioned in the sample, whereas there were some doubts in the Euro countries as the ECB did not guarantee the debt of these governments. However, as easy as this argument is easy to make about Italy, it is harder to see how investors can worry about the solvency of German debt. Another hypothesis, perhaps, is that there is a consistent liquidity premium in Italy and Germany, as these countries have low debt turnover ratios compared to US and Sweden.

No matter where it comes from, but as long as there is a time-changing risk premium that biases our regressions, we cannot recover the true role of expectations. If this varies across time and is correlated with the RHS variables in the regressions, these will suffer from an omitted variable bias. In such a case, it would be interesting to look at the role played by the risk premium in the determination of current interest

rates and compare it with the ability of rational expectations to explain the shape of the term structure. Another factor that could invalidate empirical tests of the EH, in particular at the very short end of the yield curve, could be actions of central banks. For instance, it has been suggested that the Fed stabilizes short-term rates, which in turn causes these rates to move like a random walk and eliminates any predictable variation (Mankiw and Miron, 1986; Rudebusch, 1995). Interestingly, in the sample we find that the Fed’s action is not limited to the short-end of the term structure. The quantitative easing programs devised by Ben Bernanke to stimulate the economy in the US might also have made impossible for investors to forecast long-term rates, which could be a reason for the failure of the EH. Finally, a poor performance of the EH may be explained by the presence of transaction costs or market imperfections. The fact that the EH is rejected at the short end of the spectrum could be consistent with the notion that noise traders drive the market away from any equilibrium to make a profit. Conversely, a failure of the EH for large n/m could be explained by the fact that this ratio is approximately equal to the number of times that an investor has to roll over the short-term bond m to obtain the equivalent yield of the long-term bond n , which in presence of transaction costs may invalidate the EH (Bataa et al., 2006).

7 Limitations

One of the first concerns regarding our paper is about the data. Most studies focus on zero curves which are interpolated through methodologies which produce very smooth yield curves, such as, for instance, those introduced by Svensson (1994) or Nelson and Siegel (1987). If there is not a stark difference between the spot curves produced by such methods and our data, which is obtained by linear interpolation, a graphical inspection of the forward curves would probably reveal that our forward curves are moderately jagged. This may be, in principle, an important difference as many of the implications tested in this paper have as driving force the forward rates. *Ex-ante*, it is difficult to establish which kind of data is to be preferred. On the one hand, the more “artificial rates” produced by the abovementioned methods might have better theoretical properties. On the other, however, they may be further away, in comparison to the data we use, from the actual rates observed in the market.

Another problem we encounter in developing our analysis is the relative small number of observations in our samples. As a matter of fact, we only have around 140

observations for each country, apart from Sweden whose sample is slightly larger. The effect of a small sample can be noticed especially at the long-end of the term structure, where we have the smallest number of observations when we have to perform the PFS regression. As a consequence, some of the traditional statistical tests, which rely on asymptotic inference, may be badly biased in our study, as the number of observations is relatively low. Nonetheless, the size of our sample is in line with some of the previous studies, e.g. Cuthbertson and Bredin (2000) and Boero and Torricelli (1997).

Finally, as pointed out before, our sample has the disadvantage of including data during the recent financial crisis. In this period, among the others, the abnormal behaviors of market participants and the heavy market intervention of central banks and regulators might have caused some artificial patterns in the term structure, which in turn could bias our results.

Conclusion

In this thesis, we have provided some further insights on the validity of the Expectation Hypothesis. By contrasting evidence from different countries and taking into consideration a time window rarely studied in previous papers, we present interesting results regarding the behaviors of the whole term structure. In this respect, we believe our study is particularly relevant in the context of the present literature, since it considers the entirety of the yield curve and chooses not to focus only on few selected maturities as it is done almost unanimously by previous authors.

All in all, our evidence lends support in favor of the EH for just a few pairs of maturities at the center of the term structure and in particular for Italy and Germany. However, as far as Sweden and the US are concerned, our results point to a failure of the EH. We consider different explanations for the failure of the EH and find that the overreaction theory fits incredibly well both Sweden and the US, whereas we hypothesize that a time varying risk premium makes the EH fail in the case of both Italy and Germany.

Going back to the previously cited Bernanke's speech, our findings may pose a puzzle for the current course of action undertaken by central banks. For instance, in the US, as long as yields are driven by expectations, we would not expect that expansionary monetary policies serve as stimulus for the economic activity. On the contrary, in light

of our analysis, such policies, if implemented, have better chance to lead to a higher aggregated output in Germany as well as in Italy. We find this to be rather fascinating since the US is presently using monetary instruments far more aggressively than its European counterparts.

Finally, an apparent failure of the EH does not imply that the term structure does not contain valuable information regarding future short-term rates. For example, the R^2 from the forward-spot spread regression explains up to ca. 90% of the variation in the change in the short-term rate and thus suggests that the forward-spot spread should be taken into consideration by monetary policy makers. In addition, even though the regression coefficients are often different from what the EH states, they are also frequently economically and statistically different from zero. If rational expectations of future short-term rates are not the whole story behind the formation of current rates, they still are an important part of the story.

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Appendix

Table 5: Unit-root tests for $\Delta y_t^{(m)}$ in the US

	<i>m</i>							
	1	2	3	4	6	12	24	60
ADF	-2.48	-2.53	-2.50	-2.19	-2.06	-2.12	-2.60	-3.57
PP	-14.54	-14.23	-13.75	-12.92	-11.32	-10.86	-11.12	-13.21

Critical value at a 5% significant level is -2.88

Table 6: Unit-root test of Term Spread

(a) Italy: ADF t-stat

		m					
		1	2	3	4	6	12 24 60
n	2	-2.52					
	3	-2.16					
	4	-3.08	-2.72				
	6	-2.84	-3.09	-2.77			
	9	-3.36		-3.66			
	12	-3.57	-3.46	-3.18	-3.74	-3.25	
	24	-3.76	-3.46	-3.45	-3.59	-3.37	-2.50
	36	-3.36	-3.06	-2.77	-3.01	-2.54	-2.18
	48	-2.97	-2.44	-2.50	-2.33	-2.25	-1.95 -2.41
	60	-2.69	-2.45	-2.27	-2.32	-2.03	-2.35
	120	-2.10	-1.94	-1.96	-2.18	-2.20	-2.32 -2.29 -1.98

(b) Sweden: ADF t-stat

		m					
		1	2	3	4	6	12 24
n	2	-4.43					
	3	-2.70	0.00				
	4	-4.15	-5.29	0.00			
	6	-3.82	-4.91	-4.26	0.00		
	9	-4.59	0.00	-4.34	0.00	0.00	
	12	-4.18	-4.14	-4.04	-3.66	-4.03	
	24	-3.59	-3.38	-3.26	-3.69	-3.39	-2.71
	36	-3.24	-3.03	-3.34	-3.45	-3.17	-2.25 0.00
	48	-3.03	-2.82	-3.12	-3.17	-2.94	-2.08 -1.91
	60	-2.88	-2.69	-2.62	-2.98	-2.79	-2.65 0.00

(c) GERMANY: ADF t-stat

		m					
		1	2	3	4	6	12 24 60
n	2	-2.08					
	3	-2.10					
	4	-2.41	-2.39				
	6	-2.74	-2.06	-2.33			
	9	-3.26		-3.00			
	12	-3.09	-2.81	-2.89	-4.33	-3.62	
	24	-3.13	-2.96	-3.07	-3.41	-3.36	-2.85
	36	-3.56	-3.37	-2.98	-2.97	-2.86	-2.43
	48	-3.23	-3.03	-2.71	-2.63	-2.52	-2.20 -2.37
	60	-2.98	-2.46	-2.50	-2.39	-2.30	-2.07
	120	-2.50	-2.36	-2.07	-2.26	-1.94	-2.22 -2.37 -1.91

(d) US: ADF t-stat

		m					
		1	2	3	4	6	12 24 60
n	2	-3.60					
	3	-3.24					
	4	-5.16	-5.12				
	6	-4.80	-4.93	-4.79			
	9	-4.89		-4.56			
	12	-4.76	-4.53	-4.34	-4.22	-3.87	
	24	-3.46	-3.22	-3.09	-2.79	-2.57	-2.58
	36	-2.80	-2.62	-2.52	-2.27	-2.13	-2.11
	48	-2.45	-2.31	-2.24	-2.04	-1.96	-2.00 -1.96
	60	-2.68	-2.36	-2.35	-2.29	-2.29	-1.94
	120	-2.64	-2.17	-2.20	-2.19	-2.23	-2.17 -2.18 -1.60

Table 7: Forward-spot spread Regression

(a) Italy				
$f_t^{(n-12,n)}$	α	β	<i>Wald</i>	<i>R</i> ²
(12, 24)	-0,789*	1,260*	0,143	0,191
(24, 36)	-1,827***	1,721***	2,253	0,323
(36, 48)	-2,723***	2,054***	18,344	0,510
(48, 60)	-3,652***	2,300***	17,866	0,757

(b) Sweden				
$f_t^{(n-12,n)}$	α	β	<i>Wald</i>	<i>R</i> ²
(12, 24)	-1,148**	1,399**	0,552	0,284
(24, 36)	-2,448***	1,714***	4,858	0,416
(36, 48)	-2,924***	1,484***	2,984	0,450
(48, 60)	-3,176***	1,414***	1,552	0,519

(c) Germany				
$f_t^{(n-12,n)}$	α	β	<i>Wald</i>	<i>R</i> ²
(12, 24)	-0,753*	1,229*	0,130	0,201
(24, 36)	-1,800***	1,731***	2,927	0,345
(36, 48)	-2,681***	2,055***	17,919	0,518
(48, 60)	-3,690***	2,349***	19,914	0,779

(d) US				
$f_t^{(n-12,n)}$	α	β	<i>Wald</i>	<i>R</i> ²
(12, 24)	-1,090**	0,865*	0,081	0,158
(12, 36)	-2,800***	1,461***	1,462	0,393
(12, 48)	-4,370***	1,938***	15,040	0,710
(12, 60)	-4,954***	2,047***	138,256	0,895

The first two column in each table reports respectively intercept and slope coefficients from equation 5.2 in the text. The third column reports the Wald statistics which test the null hypothesis $\beta = 1$. For this test, the critical value at a 5% significance level is 3.84. The fourth column reports the r-squared of each regression. *** indicates statistical significance at 1%, ** at 5%, * at 10%

Table 8: Campbell and Shiller (1991) first regression. Italy and Sweden.

(a) Italian data

	m									
	1	2	3	4	6	12	24	60		
n	2	-0.82 (0.25)***								
	3	-0.86 (0.25)***	-0.73 (0.26)***							
	4	0.17 (0.31)	0.40 (0.56)	0.76 (0.32)**						
	6	0.22 (0.37)	0.49 (0.51)	0.80 (0.62)	0.29 (0.44)					
	9	1.61 (0.60)***	1.79 (0.62)***	1.67 (0.60)***	1.67 (0.70)**	1.56 (0.56)***				
	12	1.78 (0.84)**	1.84 (0.94)*	1.91 (1.11)*	1.62 (1.09)	1.65 (1.12)				
	24	1.42 (1.15)	1.41 (1.47)	1.35 (1.78)	1.03 (2.02)	0.98 (1.98)	1.52 (1.49)			
	36	1.08 (1.49)	1.13 (1.82)	1.05 (2.10)	0.59 (2.25)	0.53 (2.14)	0.97 (1.71)	2.35 (0.66)***		
	48	0.38 (1.60)	0.40 (1.94)	0.39 (2.21)	-0.02 (2.30)	-0.02 (2.18)	0.51 (1.72)	2.30 (0.64)***		
	60	0.09 (1.72)	0.18 (2.02)	0.19 (2.26)	-0.20 (2.32)	-0.20 (2.20)	0.17 (1.72)	2.07 (0.71)***		
	120	-1.46 (2.15)	-1.10 (2.25)	-0.92 (2.43)	-1.16 (2.54)	-1.08 (2.49)	-0.84 (1.88)	0.92 (1.02)	2.42 (1.05)**	

***p<0.01. **p<0.05. *p<0.1

(b) Swedish data

	m									
	1	2	3	4	6	12	24			
n	2	0.03 (0.51)								
	3	0.15 (0.44)**	0.07 (0.21)**							
	4	1.80 (0.42)	1.07 (0.41)**	0.55 (0.25)**						
	6	2.20 (0.83)	1.64 (0.70)	1.20 (0.53)	0.55 (0.69)					
	9	2.38 (0.84)	1.75 (0.83)	1.45 (0.73)	1.42 (0.93)	1.40 (0.73)*				
	12	1.22 (0.88)	1.20 (0.87)	1.18 (0.77)	1.28 (0.87)	1.05 (0.57)				
	24	2.01 (1.07)	1.54 (1.21)	1.30 (1.32)	1.11 (1.47)	1.14 (1.22)	1.80 (1.24)			
	36	2.00 (1.28)	1.37 (1.49)	1.12 (1.63)	0.86 (1.74)	0.96 (1.48)	1.67 (1.36)	2.56 (0.62)**		
	48	1.87 (1.43)	1.18 (1.68)	0.99 (1.82)	0.70 (1.90)	0.81 (1.65)	1.43 (1.44)	2.58 (0.48)***		
	60	1.76 (1.58)	1.01 (1.84)	0.91 (1.97)	0.60 (2.03)	0.73 (1.77)	1.22 (1.51)	2.40 (0.41)***		

***p<0.01. **p<0.05. *p<0.1

The first number is the estimated regression coefficient from equation 3.1 in the text. Hansen-Hodrick standard errors with m-1 lags are reported in parentheses. P-values from two-tailed t-test that $H_0 : \beta = 0$. Full sample has been used in the regression.

Table 9: Campbell and Shiller (1991) first regression. Germany and US.

(a) German data

	m										
	1	2	3	4	6	12	24	60			
n	2	-0.59 (0.38)									
	3	-0.70 (0.28)**	-0.60 (0.27)**								
	4	0.20 (0.31)	0.34 (0.53)	0.68 (0.29)**							
	6	0.19 (0.41)	0.42 (0.47)	0.72 (0.58)	0.28 (0.35)						
	9	1.36 (0.62)**	1.59 (0.59)**	1.48 (0.58)**	1.50 (0.68)**	1.41 (0.50)**					
	12	1.45 (0.86)*	1.57 (0.92)*	1.70 (1.11)	1.34 (1.03)	1.44 (0.98)					
	24	1.05 (1.19)	1.17 (1.55)	1.07 (1.82)	0.67 (1.91)	0.58 (1.77)	1.46 (1.36)				
	36	0.69 (1.56)	0.79 (1.92)	0.66 (2.16)	0.21 (2.14)	0.13 (1.94)	0.94 (1.57)	2.39 (0.57)***			
	48	0.14 (1.70)	0.21 (2.05)	0.11 (2.26)	-0.30 (2.20)	-0.39 (2.00)	0.51 (1.59)	2.33 (0.54)***			
	60	-0.06 (1.81)	0.00 (2.11)	-0.10 (2.30)	-0.47 (2.22)	-0.56 (2.02)	0.19 (1.58)	2.09 (0.60)***			
	120	-1.35 (2.15)	-1.08 (2.33)	-1.08 (2.49)	-1.33 (2.46)	-1.33 (2.30)	-0.77 (1.74)	0.93 (0.90)	2.40 (0.99)**		

***p<0.01. **p<0.05. *p<0.1

(b) US data

	m										
	1	2	3	4	6	12	24	60			
n	2	-0.24 (0.48)									
	3	0.09 (0.50)	-0.01 (0.59)								
	4	3.04 (0.67)***	2.22 (0.24)**	1.03 (0.16)***							
	6	2.56 (0.99)**	2.54 (0.43)**	1.83 (0.25)***	1.61 (0.46)***						
	9	2.56 (0.85)***	2.41 (0.53)**	1.92 (0.40)***	1.90 (0.51)***	1.47 (0.58)**					
	12	1.98 (0.80)**	1.98 (0.65)**	1.67 (0.55)***	1.56 (0.69)**	1.25 (0.71)*					
	24	1.04 (1.02)	0.95 (1.09)	0.79 (1.10)	0.39 (1.13)	0.25 (1.04)	0.73 (1.11)				
	36	0.22 (1.16)	0.39 (1.24)	0.23 (1.25)	-0.18 (1.21)	-0.25 (1.08)	0.47 (1.18)	1.92 (-0.39)***			
	48	-0.35 (1.28)	-0.01 (1.32)	-0.11 (1.33)	-0.50 (1.26)	-0.55 (1.12)	0.24 (1.18)	1.82 (0.04)			
	60	-0.73 (1.41)	-0.25 (1.41)	-0.32 (1.42)	-0.69 (1.33)	-0.75 (1.17)	0.05 (1.17)	1.60 (0.45)***			
	120	-1.48 (2.01)	-0.60 (2.00)	-0.70 (1.94)	-1.10 (1.76)	-1.24 (1.50)	-0.52 (1.28)	0.96 (0.85)	2.27 (0.32)***		

***p<0.01. **p<0.05. *p<0.1

The first number is the estimated regression coefficient from equation 3.1 in the text. Hansen-Hodrick standard errors with m-1 lags are reported in parentheses. P-values from two-tailed t-test that $H_0 : \beta = 0$. Full sample has been used in the regression.

Table 10: Wald Test. Italy and Sweden.

(a) Italian data

	m					
	1	2	3	4	6	12
						24
						60
n	2	78.71 (0.00)				
	3	84.52 (0.00)	48.97 (0.00)			
	4	19.56 (0.00)	18.33 (0.00)	8.84 (0.01)		
	6	46.80 (0.00)	20.07 (0.00)	7.70 (0.02)	15.44 (0.00)	
	9	15.55 (0.00)	6.28 (0.04)	2.37 (0.31)	3.62 (0.16)	2.55 (0.28)
	12	20.60 (0.00)	8.68 (0.01)	4.86 (0.09)	4.67 (0.10)	3.24 (0.20)
	24	8.18 (0.02)	5.98 (0.05)	4.44 (0.11)	4.82 (0.09)	4.56 (0.10)
	36	9.88 (0.01)	7.61 (0.02)	6.06 (0.05)	6.69 (0.04)	6.75 (0.03)
	48	9.99 (0.01)	8.04 (0.02)	6.61 (0.04)	7.44 (0.02)	7.79 (0.02)
	60	10.05 (0.01)	8.22 (0.02)	6.98 (0.03)	7.76 (0.02)	8.32 (0.02)
	120	8.57 (0.01)	8.18 (0.02)	7.70 (0.02)	8.29 (0.02)	9.42 (0.01)
						27.67 (0.00)
						9.65 (0.01)
						-1291.32 (1.00)

(b) Swedish data

	m					
	1	2	3	4	6	12
						24
n	2	21.78 (0.00)				
	3	25.40 (0.00)	34.45 (0.00)			
	4	9.51 (0.01)	38.70 (0.00)	46.12 (0.00)		
	6	21.01 (0.00)	13.65 (0.00)	6.80 (0.03)	29.46 (0.00)	
	9	16.79 (0.00)	10.52 (0.01)	6.24 (0.04)	7.82 (0.02)	5.39 (0.07)
	12	18.89 (0.00)	12.60 (0.00)	10.63 (0.00)	10.63 (0.00)	10.24 (0.01)
	24	17.00 (0.00)	12.78 (0.00)	10.62 (0.00)	10.33 (0.01)	9.79 (0.01)
	36	15.03 (0.00)	11.06 (0.00)	9.62 (0.01)	10.02 (0.01)	9.95 (0.01)
	48	13.14 (0.00)	10.22 (0.01)	8.94 (0.01)	9.52 (0.01)	9.71 (0.01)
	60	11.68 (0.00)	9.70 (0.01)	8.51 (0.01)	9.12 (0.01)	9.50 (0.01)
						10.72 (0.00)
						20.50 (0.00)
						24.17 (0.00)
						22.40 (0.00)

First number is the chi-squared statistic from a Wald test that the intercept equals zero and the slope coefficient one. P-value is reported in parentheses. The critical value at a 95% level is 5.99.

Table 11: Wald Test. Germany and US.

(a) German data

	m					
	1	2	3	4	6	12
						24
						60
n	2	55.32 (0.00)				
	3	68.28 (0.00)	43.68 (0.00)			
	4	16.13 (0.00)	17.01 (0.00)	9.49 (0.01)		
	6	47.46 (0.00)	21.47 (0.00)	19.20 (0.00)		
	9	14.89 (0.00)	6.33 (0.04)	2.26 (0.32)	2.27 (0.32)	
	12	19.05 (0.00)	9.19 (0.01)	5.57 (0.06)	3.81 (0.15)	3.20 (0.20)
	24	7.86 (0.02)	5.96 (0.05)	5.29 (0.07)	4.82 (0.09)	3.99 (0.14)
	36	9.24 (0.01)	7.43 (0.02)	6.57 (0.04)	7.13 (0.03)	6.10 (0.05)
	48	8.85 (0.01)	7.37 (0.03)	7.63 (0.02)	8.27 (0.02)	8.86 (0.01)
	60	8.63 (0.01)	7.38 (0.03)	7.78 (0.02)	8.81 (0.01)	12.01 (0.00)
	120	7.64 (0.02)	7.06 (0.03)	7.56 (0.02)	9.62 (0.01)	25.34 (0.00)
						10.22 (0.01)
						-2595.64 (1.00)

(b) US data

	m					
	1	2	3	4	6	12
						24
n	2	20.30 (0.00)				
	3	19.10 (0.00)	17.82 (0.00)			
	4	13.27 (0.00)	28.72 (0.00)	6.62 (0.04)		
	6	22.26 (0.00)	22.50 (0.00)	15.37 (0.00)	12.58 (0.00)	
	9	24.22 (0.00)	18.89 (0.00)	13.44 (0.00)	12.14 (0.00)	
	12	22.64 (0.00)	16.79 (0.00)	11.98 (0.00)	10.92 (0.00)	7.17 (0.03)
	24	17.56 (0.00)	14.84 (0.00)	12.84 (0.00)	12.66 (0.00)	7.39 (0.02)
	36	15.28 (0.00)	15.08 (0.00)	13.90 (0.00)	15.00 (0.00)	10.63 (0.00)
	48	12.41 (0.00)	13.71 (0.00)	13.49 (0.00)	15.49 (0.00)	14.79 (0.00)
	60	10.30 (0.01)	12.00 (0.00)	12.39 (0.00)	14.71 (0.00)	18.06 (0.00)
	120	5.70 (0.06)	6.77 (0.03)	7.47 (0.02)	9.10 (0.01)	15.61 (0.00)
						18.96 (0.00)
						14.67 (0.00)
						44.35 (0.00)

First number is the chi-squared statistic from a Wald test that the intercept equals zero and the slope coefficient one. P-value is reported in parentheses. The critical value at a 95% level is 5.99.

Table 12: PFS regression. Italy and Sweden

(a) Italian data

	m					
	1	2	3	4	6	12
						24
						60
2	0.09 (0.13)***					
3	0.07 (0.16)***					
4	0.51 (0.23)**	0.70 (0.28)				
6	0.55 (0.17)**	0.71 (0.27)	0.90 (0.31)			
9	0.95 (0.16)		1.26 (0.33)			
12	0.90 (0.12)	1.10 (0.26)	1.29 (0.37)	1.23 (0.38)	1.32 (0.56)	
24	1.43 (0.42)	1.58 (0.43)	1.62 (0.39)	1.57 (0.44)	1.51 (0.44)	1.26 (0.74)
36	1.58 (0.55)	1.75 (0.62)	1.80 (0.60)	1.81 (0.62)*	1.75 (0.56)	1.55 (0.49)
48	1.32 (0.36)	1.40 (0.37)	1.43 (0.36)*	1.46 (0.34)*	1.47 (0.21)*	1.59 (0.34)*
60	1.31 (0.19)	1.40 (0.21)*	1.44 (0.11)*	1.45 (0.22)*	1.45 (0.34)	1.51 (0.25)***
120	0.98 (0.02)	0.98 (0.02)	0.99 (0.01)	1.02 (0.01)	1.09 (0.02)***	0.97 (0.02)
						1.24 (0.14)*
						1.71 (0.52)

***p<0.01. **p<0.05. *p<0.1

(b) Swedish data

	m					
	1	2	3	4	6	12
						24
2	0.51 (0.26)**					
3	0.64 (0.19)					
4	1.33 (0.26)	1.04 (0.20)				
6	1.35 (0.30)	1.26 (0.26)	1.10 (0.27)*			
9	1.32 (0.24)		1.15 (0.28)			
12	1.25 (0.20)	1.19 (0.20)	1.13 (0.23)	1.18 (0.31)	1.02 (0.28)	
24	1.51 (0.33)*	1.52 (0.31)	1.52 (0.32)*	1.63 (0.44)*	1.58 (0.42)	1.40 (0.62)
36	1.44 (0.26)	1.47 (0.25)	1.48 (0.27)	1.60 (0.35)	1.60 (0.32)	1.66 (0.36)
48	1.29 (0.19)*	1.32 (0.18)*	1.30 (0.18)**	1.42 (0.22)**	1.45 (0.19)*	1.55 (0.13)
60	1.08 (0.20)***	1.15 (0.19)***	1.18 (0.20)***	1.28 (0.30)***	1.40 (0.28)*	1.61 (0.24)*

***p<0.01. **p<0.05. *p<0.1

The first number is the estimated regression coefficient from equation 3.3 in the text. Hansen-Hodrick standard errors with n-m-1 lags are reported in parentheses. P-values from two-tailed t-test that $H_0 : \beta = 1$. Full sample has been used in the regression.

Table 13: PFS regression. Germany and US

(a) German data

	m									
	1	2	3	4	6	12	24	60		
n	2	0.20 (0.19)***								
	3	0.12 (0.18)***								
	4	0.51 (0.21)**	0.67 (0.26)							
	6	0.54 (0.16)**	0.73 (0.27)							
	9	0.93 (0.15)	0.86 (0.29)							
	12	0.88 (0.10)	1.09 (0.24)	1.14 (0.35)	1.22 (0.49)					
	24	1.36 (0.39)	1.50 (0.40)	1.47 (0.40)	1.43 (0.40)	1.23 (0.68)				
	36	1.57 (0.55)	1.71 (0.61)	1.76 (0.59)	1.71 (0.55)	1.54 (0.46)				
	48	1.31 (0.34)	1.39 (0.37)	1.46 (0.35)	1.50 (0.25)*	1.62 (0.16)*	1.67 (0.27)			
	60	1.29 (0.18)	1.38 (0.20)*	1.43 (0.10)*	1.45 (0.20)*	1.48 (0.31)***	1.57 (0.23)***			
	120	0.93 (0.02)*	0.94 (0.02)**	0.97 (0.02)**	1.04 (0.03)	1.13 (0.03)***	1.30 (0.13)**	1.70 (0.50)		

***p<0.01. **p<0.05. *p<0.1

(b) US data

	m									
	1	2	3	4	6	12	24	60		
n	2	0.38 (0.24)**								
	3	0.42 (0.29)**								
	4	1.63 (0.38)*	1.61 (0.12)***							
	6	1.45 (0.25)*	1.63 (0.15)***	1.41 (0.13)***						
	9	1.48 (0.16)***	1.35 (0.17)**							
	12	1.45 (0.20)**	1.39 (0.21)*	1.32 (0.30)	1.13 (0.36)					
	24	1.48 (0.16)*	1.39 (0.19)	1.33 (0.27)	1.18 (0.38)	0.87 (0.55)				
	36	1.58 (0.23)**	1.52 (0.24)**	1.46 (0.25)*	1.41 (0.31)	1.26 (0.41)				
	48	1.77 (0.18)***	1.73 (0.19)***	1.68 (0.19)***	1.66 (0.18)***	1.56 (0.21)***	1.41 (0.02)			
	60	1.82 (0.10)***	1.80 (0.10)***	1.77 (0.10)***	1.79 (0.12)***	1.82 (0.07)***				
	120	1.23 (0.03)***	1.25 (0.04)***	1.26 (0.04)***	1.27 (0.04)***	1.30 (0.03)***	1.29 (0.02)***	1.63 (0.16)***		

***p<0.01. **p<0.05. *p<0.1

The first number is the estimated regression coefficient from equation 3.3 in the text. Hansen-Hodrick standard errors with n-m-1 lags are reported in parentheses. P-values from two-tailed t-test that $H_0 : \beta = 1$. Full sample has been used in the regression.

Table 14: VAR regression. Italy and Sweden.

(a) Italian data									
m									
	1	2	3	4	6	12	24	60	
2	0.07 (0.10)								
3	0.04 (0.07)								
4	0.46 (0.12)	0.67 (0.14)							
6	0.49 (0.10)	0.64 (0.13)	0.84 (0.12)						
9	0.80 (0.11)		1.15 (0.08)						
n									
12	0.61 (0.09)	0.76 (0.10)	0.97 (0.09)	0.84 (0.10)	1.02 (0.10)				
24	0.52 (0.06)	0.59 (0.07)	0.68 (0.06)	0.56 (0.07)	0.58 (0.07)	0.49 (0.05)			
36	0.40 (0.05)	0.46 (0.05)	0.52 (0.05)	0.39 (0.06)	0.42 (0.05)	0.40 (0.04)	0.36 (0.03)		
48	0.36 (0.04)	0.42 (0.04)	0.47 (0.04)	0.36 (0.04)	0.40 (0.04)	0.41 (0.03)	0.43 (0.02)		
60	0.35 (0.03)	0.41 (0.03)	0.45 (0.03)	0.35 (0.04)	0.39 (0.03)	0.43 (0.03)			
120	0.35 (0.02)	0.40 (0.02)	0.43 (0.02)	0.36 (0.02)	0.38 (0.02)	0.41 (0.02)	0.40 (0.01)	0.37 (0.01)	

(b) Swedish data									
m									
	1	2	3	4	6	12	24		
2	0.52 (0.04)								
3	0.63 (0.05)								
4	1.32 (0.07)	1.03 (0.10)							
6	1.35 (0.05)	1.25 (0.06)	1.11 (0.05)						
9	1.28 (0.04)		1.14 (0.04)						
n									
12	1.10 (0.04)	1.05 (0.04)	1.03 (0.04)	1.06 (0.04)	0.95 (0.05)				
24	0.82 (0.03)	0.80 (0.03)	0.81 (0.03)	0.78 (0.03)	0.77 (0.03)	0.57 (0.03)			
36	0.74 (0.02)	0.73 (0.02)	0.75 (0.02)	0.72 (0.02)	0.72 (0.02)	0.63 (0.02)			
48	0.69 (0.01)	0.69 (0.01)	0.71 (0.01)	0.68 (0.02)	0.70 (0.02)	0.63 (0.02)	0.77 (0.01)		
60	0.67 (0.01)	0.67 (0.01)	0.69 (0.01)	0.67 (0.02)	0.69 (0.01)	0.64 (0.01)			

The first number is the estimated regression coefficient from equation 3.4 in the text. Hansen-Hodrick standard errors with n-m-1 lags are reported in parentheses. P-values are not reported since most coefficients are statically different from either 0 or 1. Full sample has been used in the regression.

Table 15: VAR regression. Germany and US.

(a) German data										
m										
	1	2	3	4	6	12	24	60		
n	2	0.19 (0.11)								
	3	0.10 (0.08)								
	4	0.47 (0.12)	0.64 (0.12)							
	6	0.49 (0.10)	0.67 (0.11)	0.81 (0.08)						
	9	0.81 (0.10)	1.12 (0.06)							
	12	0.64 (0.08)	0.83 (0.08)	0.98 (0.06)	0.85 (0.08)	1.01 (0.08)				
	24	0.62 (0.04)	0.69 (0.04)	0.74 (0.04)	0.64 (0.05)	0.65 (0.06)	0.62 (0.04)			
	36	0.56 (0.03)	0.61 (0.03)	0.63 (0.03)	0.55 (0.04)	0.53 (0.04)	0.56 (0.03)			
	48	0.53 (0.02)	0.57 (0.02)	0.58 (0.03)	0.51 (0.03)	0.49 (0.03)	0.54 (0.03)	0.58 (0.02)		
	60	0.52 (0.02)	0.55 (0.02)	0.56 (0.02)	0.50 (0.03)	0.47 (0.03)	0.53 (0.02)			
	120	0.50 (0.01)	0.51 (0.01)	0.52 (0.02)	0.51 (0.02)	0.46 (0.02)	0.48 (0.02)	0.50 (0.01)	0.44 (0.01)	
(b) US data										
m										
	1	2	3	4	6	12	24			
n	2	0.38 (0.10)								
	3	0.41 (0.08)								
	4	1.61 (0.06)	1.61 (0.03)							
	6	1.43 (0.04)	1.63 (0.05)	1.42 (0.04)						
	9	1.44 (0.04)	1.35 (0.04)							
	12	1.32 (0.03)	1.29 (0.04)	1.21 (0.04)	1.23 (0.06)	1.11 (0.05)				
	24	0.91 (0.01)	0.87 (0.01)	0.83 (0.02)	0.77 (0.01)	0.66 (0.02)	0.41 (0.02)			
	36	0.73 (0.01)	0.70 (0.01)	0.66 (0.01)	0.62 (0.01)	0.55 (0.01)	0.41 (0.01)			
	48	0.65 (0.01)	0.62 (0.01)	0.60 (0.01)	0.58 (0.01)	0.55 (0.01)	0.47 (0.01)	0.53 (0.01)		
	60	0.62 (0.01)	0.60 (0.01)	0.58 (0.01)	0.58 (0.00)	0.56 (0.01)	0.51 (0.01)			
	120	0.58 (0.00)	0.57 (0.00)	0.57 (0.00)	0.59 (0.00)	0.60 (0.00)	0.60 (0.00)	0.63 (0.01)	0.45 (0.01)	

The first number is the estimated regression coefficient from equation 3.4 in the text. Hansen-Hodrick standard errors with n-m-1 lags are reported in parentheses. P-values are not reported since most coefficients are statically different from either 0 or 1. Full sample has been used in the regression.

Table 16: Time series comparison. Italy and Sweden

(a) Italian data correlation coefficient

m						
	1	2	3	4	6	12 24 60
2	0.106					
3	0.060					
4	0.438	0.612				
6	0.471	0.583	0.740			
9	0.676		0.897			
n	12	0.573	0.662	0.799	0.683	0.740
	24	0.626	0.697	0.787	0.659	0.710 0.750
	36	0.586	0.665	0.746	0.586	0.657 0.742
	48	0.622	0.705	0.770	0.623	0.706 0.813 0.872
	60	0.681	0.756	0.806	0.679	0.759 0.860
	120	0.824	0.862	0.885	0.797	0.842 0.906 0.942 0.957

(b) Swedish data correlation coefficient

m						
	1	2	3	4	6	12 24
2	0.687					
3	0.746					
4	0.943	0.929				
6	0.968	0.968	0.973			
9	0.974		0.977			
n	12	0.967	0.966	0.972	0.953	0.948
	24	0.953	0.953	0.956	0.926	0.923 0.855
	36	0.971	0.973	0.975	0.955	0.957 0.934
	48	0.978	0.981	0.982	0.963	0.967 0.953 0.981
	60	0.982	0.985	0.986	0.969	0.974 0.966

(c) Italian data standard deviation ratio

m						
	1	2	3	4	6	12 24 60
2	0.688					
3	0.697					
4	1.060	1.089				
6	1.033	1.101	1.134			
9	1.185		1.276			
n	12	1.071	1.148	1.214	1.236	1.378
	24	0.837	0.847	0.868	0.846	0.820 0.655
	36	0.678	0.687	0.702	0.674	0.641 0.539
	48	0.574	0.593	0.612	0.577	0.561 0.510 0.490
	60	0.510	0.539	0.561	0.522	0.519 0.499
	120	0.419	0.469	0.491	0.448	0.457 0.452 0.426 0.382

(d) Swedish data standard deviation ratio

m						
	1	2	3	4	6	12 24
2	0.754					
3	0.845					
4	1.399	1.109				
6	1.394	1.294	1.144			
9	1.314		1.171			
n	12	1.134	1.085	1.058	1.111	1.005
	24	0.863	0.841	0.847	0.838	0.829 0.662
	36	0.760	0.749	0.764	0.754	0.757 0.670
	48	0.706	0.701	0.719	0.709	0.722 0.658 0.783
	60	0.681	0.678	0.698	0.690	0.709 0.658

Table 17: Time series comparison. Germany and US

(a) German data correlation coefficient

	m					
	1	2	3	4	6	12 24 60
2	0.232					
3	0.126					
4	0.463	0.656				
6	0.491	0.640	0.762			
9	0.718	0.926				
n	12	0.658	0.790	0.877	0.756	0.827
	24	0.816	0.889	0.914	0.796	0.827 0.868
	36	0.858	0.913	0.923	0.793	0.814 0.886
	48	0.887	0.927	0.930	0.816	0.832 0.913 0.930
	60	0.910	0.938	0.938	0.843	0.854 0.929
	120	0.942	0.954	0.951	0.897	0.894 0.947 0.967 0.953

(b) US data correlation coefficient

	m					
	1	2	3	4	6	12 24 60
2	0.627					
3	0.736					
4	0.964	0.988				
6	0.974	0.989	0.990			
9	0.990	0.990	0.990			
n	12	0.991	0.990	0.989	0.972	0.963
	24	0.989	0.987	0.985	0.976	0.958 0.906
	36	0.991	0.990	0.989	0.983	0.971 0.943
	48	0.993	0.993	0.993	0.991	0.985 0.972 0.956
	60	0.996	0.996	0.996	0.996	0.992 0.984
	120	0.998	0.998	0.998	0.999	0.998 0.997 0.992 0.981

(c) German data standard deviation ratio

	m					
	1	2	3	4	6	12 24 60
2	0.827					
3	0.772					
4	1.016	0.974				
6	0.998	1.047	1.059			
9	1.122	1.209				
n	12	0.974	1.050	1.121	1.129	1.221
	24	0.758	0.777	0.805	0.808	0.782 0.710
	36	0.656	0.669	0.688	0.691	0.649 0.627
	48	0.601	0.614	0.627	0.629	0.588 0.596 0.623
	60	0.571	0.583	0.593	0.597	0.556 0.573
	120	0.528	0.539	0.542	0.567	0.510 0.510 0.514 0.458

(d) US data standard deviation ratio

	m					
	1	2	3	4	6	12 24
2	0.599					
3	0.554					
4	1.671	1.629				
6	1.469	1.650	1.434			
9	1.452		1.363			
n	12	1.327	1.306	1.218	1.269	1.151
	24	0.924	0.885	0.839	0.785	0.688 0.452
	36	0.736	0.703	0.672	0.631	0.569 0.439
	48	0.656	0.629	0.608	0.589	0.554 0.480 0.555
	60	0.622	0.599	0.586	0.583	0.564 0.523
	120	0.581	0.569	0.568	0.593	0.599 0.602 0.632 0.457

Table 18: Campbell and Shiller (1991) first regression. Small sample.

(a) Italy				(b) Sweden			
m				m			
1	3	12		1	3	12	
2	1.12 (0.38)***			2	0.26 (0.35)		
3	1.15 (0.40)***			3	0.74 (0.38)*		
4	1.28 (0.41)***			4	0.53 (0.43)	0.58 (0.29)**	
6	1.29 (0.49)**			6	-0.01 (0.56)	0.13 (0.39)	
9	1.43 (0.65)**			9	0.05 (0.64)	0.40 (0.60)	
12	1.61 (0.80)**			12	-0.24 (0.67)	0.20 (0.50)	
n							
24	1.21 (1.48)			24	0.02 (1.14)	-0.20 (1.16)	-0.57 (1.40)
36	0.41 (1.98)			36	-0.25 (1.73)	-1.28 (1.84)	-2.00 (2.21)
48	-0.56 (2.26)			48	-1.01 (2.24)	-2.20 (2.41)	-2.93 (2.71)
60	-1.48 (2.48)			60	-1.69 (2.71)	-2.90 (2.87)	-3.46 (3.07)
120	-4.88 (3.31)				***p<0.01. **p<0.05. *p<0.1		
***p<0.01. **p<0.05. *p<0.1							
(c) Germany				(d) US			
m				m			
1	3	12		1	3	12	
2	1.00 (0.24)***			2	2.01 (0.37)***		
3	1.25 (0.28)***			3	2.38 (0.43)***		
4	1.29 (0.29)***			4	2.59 (0.46)***	1.80 (0.38)***	
6	1.34 (0.36)***			6	2.38 (0.57)***	2.28 (0.60)***	
9	1.56 (0.49)***			9	2.11 (0.75)***	2.17 (0.86)**	
12	1.73 (0.64)***			12	1.34 (1.09)	1.60 (1.13)	
n							
24	1.82 (1.32)			24	0.28 (1.15)	-0.10 (1.58)	0.55 (2.04)
36	1.11 (1.83)			36	-0.53 (1.24)	-0.77 (1.64)	0.17 (2.19)
48	0.29 (2.13)			48	-0.90 (1.37)	-1.08 (1.71)	-0.04 (2.13)
60	-0.51 (2.33)			60	-1.08 (1.51)	-1.22 (1.80)	-0.19 (2.08)
120	-3.95 (3.26)			120	-1.30 (2.22)	-1.23 (2.32)	-0.43 (2.11)
***p<0.01. **p<0.05. *p<0.1				***p<0.01. **p<0.05. *p<0.1			

Table 19: Campbell and Shiller (1991) second regression. Small sample.

(a) Italy			
m			
	1	3	12
2	1.06 (0.19)		
3	1.10 (0.16)		
4	1.15 (0.16)		
6	1.14 (0.16)	1.17 (0.21)	
9	1.14 (0.13)	1.17 (0.21)	
n	12	1.10 (0.11)	1.14 (0.24)
	24	0.87 (0.23)	0.83 (0.25)
	36	0.90 (0.19)	1.02 (0.24)
	48	0.78 (0.17)	0.79 (0.21)
	60	0.95 (0.03)	0.98 (0.04)
***p<0.01. **p<0.05. *p<0.1			
(b) Sweden			
m			
	1	3	12
2	0.63 (0.17)**		
3	0.89 (0.17)		
4	0.87 (0.16)		
6	0.74 (0.19)	0.56 (0.19)*	
9	0.74 (0.24)	0.70 (0.27)	
n	12	0.73 (0.20)	0.72 (0.24)
	24	0.67 (0.09)	0.58 (0.19)*
	36	0.82 (0.07)	0.84 (0.10)
	48	0.80 (0.05)*	0.75 (0.06)**
	60	0.51 (0.05)***	0.46 (0.07)***
***p<0.01. **p<0.05. *p<0.1			
(c) Germany			
m			
	1	3	12
2	1.00 (0.12)		
3	1.10 (0.14)		
4	1.13 (0.14)		
6	1.11 (0.11)	1.15 (0.19)	
9	1.11 (0.12)	1.11 (0.18)	
n	12	1.06 (0.11)	1.06 (0.23)
	24	0.78 (0.20)	0.69 (0.20)
	36	0.83 (0.17)	0.93 (0.23)
	48	0.70 (0.16)*	0.66 (0.22)
	60	0.89 (0.02)***	0.90 (0.04)**
***p<0.01. **p<0.05. *p<0.1			
(d) US			
m			
	1	3	12
2	1.51 (0.19)***		
3	1.58 (0.16)***		
4	1.67 (0.15)***		
6	1.71 (0.22)***	1.64 (0.30)**	
9	1.83 (0.32)***	1.72 (0.45)*	
n	12	1.85 (0.43)**	1.67 (0.62)
	24	1.79 (0.38)	1.69 (0.48)
	36	1.67 (0.40)*	1.76 (0.45)*
	48	1.68 (0.15)***	1.65 (0.22)***
	60	1.50 (0.03)***	1.56 (0.04)***
***p<0.01. **p<0.05. *p<0.1			

