The term structure of interest rates and macro economy: Evidence from the pre- and post- crisis periods

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Abstract

In this paper we extract the factors that shape the yield curve and we relate them with macroeconomy. We examine whether the term structure can predict future economic activity by applying a range of econometric approaches both in pre- and post- crisis periods. Furthermore, we assess the strength of the yield curve forecasting power on economic activity for Eurozone. In addition, we analyze the effect of increased market risk in the term structure and economic activity whereas we evaluate the impact of monetary policy in the term structure. We find that the forecasting performance of term structure deteriorates in the post-crisis period and that credit spreads forecast better Eurozone industrial production. Also, as we find, one significant explanation for the change in predictability during pre- and post-crisis periods is due to the effect of market risk on the term structure during the post-crisis period. Finally, we argue that monetary policy determines significantly the term structure either by conventional or unconventional measures.

Keywords: Term structure, VAR, Principal component analysis, Markov switching regressions, Financial crisis, Monetary policy, Economic activity, Market volatility

JEL codes: E27, E52, E58, E42, E44

1. Introduction

The recent financial crisis has brought into attention again the relationship between the term structure and economic activity. The different shapes of the yield curve were historically deemed as an economic forecaster by researchers, investors and central authorities. More specifically, an inverted yield curve indicates an upcoming recession, a steep upward sloping yield curve shows a strong expected economic growth, and conversely, a very flat curve predicts weak growth. However, the recent financial crisis emerged issues concerning the forecasting power of the yield curve on economic activity, as many researches revealed that this relationship weakened.

During the last years, many researchers model the term structure of interest rates (yield curve) by using various specifications. A voluminous literature has been recently developed on the "affine" for term structure models and their link with economic activity. Affine Term Structure Models have gained remarkable reputation since their appearance as a core method to analyze the dynamics of short term rate and to price yields of different maturities. This category of models developed by Vacisek (1977), Cox *et al.* (1985) and Duffee (1996) under the assumption of non-arbitrage. In the above works, they derive a process for the short term rate evolution with some potential sources of uncertainty. Usually, the risk neutral process that they propose is an Ito's process. The term "affine" in the specification means that the yields in arbitrage-free models are functions of a state vector of "x" variables in a state space system (Piazzesi (2010)), and always include a constant (as opposed to linear models).

The early equilibrium models differentiated in the determination of the drift and volatility of the short rate evolution process. After these, a voluminous literature of arbitrage-free models developed in the concept of equilibrium models, i.e. a process with a drift and a volatility. In the works of Ho and Lee (1986), Hull and White (1990) and Heath *et al.* (1992)

the term structure models are assessed with market data in order to be fully consistent with the theories. They key difference of the later models compared to the previous studies is the fact that the drift in the first is time dependent. This evidence lead to the closed bond pricing formulas according to the non-arbitrage assumptions.

The key advantage of the affine class of models is that they allow us to identify both the short term evolution and to capture the risk parameters. The second fact provides to them an advantage compared to the other type of term structure models, the Nelson-Siegel models. Moreover, by applying the affine specification the computation of yields is feasible without performing different types of simulation.

The first empirical works included a yields-only framework (models that include only bond yields) for the term structure followed by studies that examine the effect of macroeconomic factors on bond yields and performed forecasts for economic activity. The affine models were applied to examine different implications of the term structure and in differentiated form. The researchers choose each time the number of observable and latent factors in setting the affine representation. Duffee (2011) for example, states that at least four factors (three latent and an observable) are needed for a proper affine model set up. The main, widely accepted in literature, latent factors that determine the shape of the yield curve are the so called level, slope and curvature (Litterman and Scheinkman, (1991)). The computation of these factors makes the approximation of the term structure feasible.

In this paper, we extract the basic relationships that dominate term structure by analyzing US data and we examine some special issues by adding more countries in the sample. First, we apply a principal component analysis for US in order to capture the main factors that shape the yield curve and we relate them to economic activity as proxied by industrial production. Second, we rely on the existing literature to develop a model to estimate the affine term structure model from which we extract the short rate evolution factors and the market risk premia. Third, we provide answers on the question about the relationship between macroeconomy and term structure. Therefore, we regress the term structure factors on industrial production in pre-crisis (1994-2006) and post-crisis (2007-2014) periods.

Our specification also considers the country interdependence effect. We use a set of seven countries US, UK, Canada, Japan, Germany, France and Italy, and we examine the contemporaneous impact of one country yield curve movements on another. Furthermore, we study of the direct effect of yield curve on economic activity defined by different regimes in a Markov procedure, taking also into account the real economic conditions contemporaneously. Also, the Markov process approximates the extent to which the yield curve can predict economic activity. Our next issue is the examination of the market volatility effect on economic activity and interest rates for post crisis period. Within this analysis we can measure the effect of market shocks that transmitted to economic activity and the yield curve in post-crisis period. Then we analyze the forecasting ability of both term spread and credit spread on economic activity for Eurozone countries before and after crisis. Especially, we estimate the impact of countries term spreads and credit spreads on industrial production for the post-crisis period in order to include both financial and debt crises. Finally, we specify the effectiveness of monetary policy on determining the movements of the term spread before and after crisis. Therefore, we regress both conventional (short rate) and unconventional (asset purchases) measures on yield curve, both for pre- and post-crises periods.

Previewing our results, we found that term structure provide significant information to industrial production at least in pre-crisis period and remained after one year. More specifically, in pre-crisis period the factors that shape the yield curve contain information about the evolution of industrial production growth for short term period (up to 12 months), however, in post-crisis period, the predictive power of yield curve over industrial production weakens. According to the Markov process results, the term structure has increased forecasting power over industrial production for most of the countries. We show also, that there exist a strong inter-relationship between countries as their term spreads affect each other over time contributing on the international transmission of shocks. We argue then, that market volatility plays significant role for the variation of the term structure and economy in post-crisis period. The results also suggest that as the term spread forecasting power declined in post crisis period, its credit equivalent strengthened its effect. For the pre-crisis period we observe significant effect on term spread by key policy rate. However, in post-crisis period main policy rate power is insignificant. Contrary, the effect of asset purchases by central bank has greater and significant explanatory power over the term spread for this period.

The rest of the paper is organized as follows: The second section is the literature review, the third section analyze the data and methodology and the fourth section is the preliminary statistics analysis. The fifth section provides principal component analysis and the sixth to the relationship between macroeconomy and term structure. In the seventh section we estimate the affine term structure model. The eighth section refers to country interdependence, the ninth to the business cycle fluctuations and the tenth to volatility parameter impact. Finally, the eleventh section includes the Eurozone crisis case study and the twelfth analyze the monetary policy effect on term spread and the thirteenth section is the conclusion.

2. Literature Review

The analysis of the affine term structure models is performed via state space specifications or DSGE models. The DSGE models use structural specifications for the state of economy where participants have different preferences towards risk. These series of models presents a production economy with constraints where the potential utility is maximized. Empirical DSGE models assess the risk aversion and inter-temporal substitution (Van Binsbergen *et al.* 2012) in the affine framework. Other researches, add consumption and investments decisions in the model in order to establish a link between affine type and DSGE set up emanating from investor's stochastic discount factor (De Graeve *et al.* 2009).

The state space framework allows us to examine the relationship between observed variables (bond yields) and a possible unobserved state which is driven by a stochastic process. This dependence takes the form of a transition equation that describes the transition of the state of nature from period t-1 to period t. The econometric approach that incorporates this time series specification is the Vector Autoregressive (VAR) process. This pattern we describe between time t-1 and time t refers to a Gaussian specification VAR(1) model. Therefore, the use of the affine specifications for the short rate and risk premium and the Gaussian framework for the state of economy constitute the affine Gaussian models.

Our procedure is based on the affine Gaussian specification that allows to incorporate both different maturity yields and macroeconomic factors. However, it is a matter of significance for the researcher the number of factors in the model setup that properly explain the whole term structure. In a seminal paper, Ang and Piazzesi (2003) proposed a combination of the above setup that describes the economic environment. They first estimate a three factor yields only model to analyze the dynamics of the term structure and extract the risk premia. Then, they add a block of inflation and output variables in a five-factor model. As they found, the macroeconomic variables affect largely the term structure, and the model performance improves as non-arbitrage restrictions are imposed. Also, their basic insight is that Taylor rule specification has also an affine form.

In a specification similar to the context of Ang and Piazzesi (2003), Bikbov and Chernov (2010) elaborate a four factor affine model where the two factors are observable (inflation, output) and the other two are unobservable (latent; level and slope). Their main result was the confirmation of the existence of a strong relationship between macroeconomic variable and bond yields after the application of different methodological approaches.

In the same framework, Kim and Orphanides (2005) elaborate a three factor affine model for treasury yields in the motivation of Ang and Piazzesi (2003) and address the issue of small samples concerning the empirical studies. They argue that data up to two decades, cannot sufficiently explain the volatility of the yield curve, mainly due to strong persistence of the interest rates. They use survey data to minimize this problem, and perform also Monte Carlo experiment as an alternative procedure. As they showed, the use of survey forecast information can be more effective than using a long sample. Duffee (2011) applied a macrofinance specification, where he estimated a total five factors, three latent (level, slope and curvature) and two observable factors (macros). In his study he added Markov dynamics in the Gaussian affine term structure model, and filtered the data to extract risk premia. His work highlighted the relatively little information that provide macroeconomic variables about the latent components of the risk premia.

Ang *et al.* (2011) and Chun (2011) estimated the effects of shifts in monetary policy using the term structure of interest rates. Ang *et al.* (2011) proposed a short rate evolution that follows a Taylor model and they pointed out that the overall yield curve response to output gap is relatively small comparing to the inflation loadings. Chun (2011) elaborated monetary policy models for monetary policy decisions. He argued that expectations about inflation, output and anticipated monetary policy actions contain important information for explaining movements of the bond yields. Moreover, he found that macroeconomic forecasts play significant role in deriving the market prices of risk. Bikbov and Chernov (2008) proposed three different regimes of monetary policy after evaluating the term structure over time. The model they applied posited regime changes in the volatility of output, inflation and short term rate shocks, emerging at least three different regimes. In this framework, Renne (2012) applied a model for Eurozone rates introducing also three different monetary policy regimes. Their results indicate that market yield curves follows the changes of the central banks rules (conventional and unconventional) and reflects their behavior.

In the same context, Li and Wei (2013) estimated an affine model that includes bond yields, supply factors and unconventional monetary policy strategy for the financial crisis period. As they showed, the number of securities held by investors and the volume of the asset purchase programs had considerable explanatory power over the yield curve. Also, as they found, the non-standard measures adopted by FED affected largely the term structure of interest rates. Table 1 summarize the theoretical term structure models, both equilibrium and arbitrage free, while Table 2 presents the paper methodologies for the empirical affine models.

[Insert Tables 2.1, 2.2]

3. Data and methodology

3.1 Data description

The dataset include interest rates and various maturities bond yields and several macroeconomic variables. More specifically, we include 1,3,6,9,12 month and 2,3,5,7,10 year US Treasury bond yields. Also, we insert 3-month and 12-month US LIBOR rates. Furthermore, we include 10-year corporate BBB bond yield, industrial production growth and stock market indices for US, UK, Germany (GM), France (FR), Italy (IT), Canada (CA) and Japan (JP). In the case of US the dataset contains inflation rate as it is measured by the growth of natural logarithm of CPI index. The term spread is defined by the spread between 10- year and 3-month Treasury bond rates, the credit spread is constructed by the difference between 10-year corporate BBB rate and 3-month treasury rate, and LIBOR spread is calculated by the spread between 12-month and 3-month LIBOR rates. The industrial production growth is created by the natural logarithm of monthly change in industrial production index. Also, the dataset embodies central banks' short term policy rates, such as Fed Funds rate (FFR) for US, SONIA for UK, EONIA for Eurozone and others. In addition, the dataset involves stock market indices for high capitalization firms for all countries. We use monthly frequency data from March 1994 to March 2014. The data are obtained from *FRED* economic database and *Datastream*.

3.2 Model setup

The affine term structure models make functional assumptions which lead to pricing formulas. These assumptions are the function that describes the evolution of the short term rate and the process *"x"* that defines the movements of the state variables under risk-neutral measure. The term affine refers both to short term rate and to process x', which has also an affine drift and variance.

The short (one period) rate evolution process is given by

$$r_{t,1} = \delta_0 + \delta_1' x_t \tag{2.1}$$

where $r_{t,1}$ is the short term (one period) rate and it is determined by the state vector x′ that includes both observable and unobservable factors. The long term rates are formed under the expectations hypothesis. More specifically, if the n-period rate is $r_{t,n}$ at time t ,the expectations theory states that long-term interest rate is the average of the current period interest rate and the expected, as at time t, the future period interest rate is

$$r_{t,n} = (1/n)\sum_{j=1}^{n} E_t r_{t+j-1,1} + (1/n)\sum_{j=1}^{n} tp_{j,t} \tag{2.2}$$

where tp is the term premium component.

The model combines both observable and unobservable (latent) variables. Therefore, the state vector x' captures the state of economy. The specification kernel assumes that the observed series r_t depends on the state of economy x' which is driven by a stochastic process. According to Lutkepohl (2005), the relation between r and x is described by the observation equation

$$r_t = H_t x_t + u_t \tag{2.3}$$

The state vector is generated as

$$x_t = F_{t-1} x_{t-1} + w_{t-1} \tag{2.4}$$

which is the transition equation, that describes the transition of the state of nature from period *t-1* to period *t.* Since the latent factors follows AR(1) process (Ang, Piazzesi, 2003), the state space specification can be transformed into a VAR(1) model:

$$x_t = \mu + \Phi x_{t-1} + \varepsilon_t \tag{2.5}$$

where Φ' is a K×K vector of parameters, x′ is the K-dimension vector of endogenous observable and latent variables.

According to Duffee (2002), we assume the existence of a stochastic discount factor

$$M_{t+1} = \exp\left(-r_t - \frac{1}{2}\Lambda_t' \Lambda_t - \Lambda_t' \varepsilon_t\right) \tag{2.6}$$

that is the price kernel where r_t is defined by equation (1). We can use this kernel to price any asset. Parameters Λ_t are the time-varying prices of risk which follow an affine specification

$$\Lambda_t = \lambda_0 + \lambda_1 x_t \tag{2.7}$$

These time varying risk parameters explain the variability of instantaneous expected excess holding period return on a n-period bond over a short term interest rate r_t . Therefore, the term premium (tp) is formed as

$$tp_{t,n} = E_t(R_{t+n}) - r_t = -B_n' \Sigma \Lambda_t \tag{2.8}$$

where R_{t+n} is the holding period return of a n-period bond, B_n is a (K×1) vector of valued functions and Σ is a (K × K) diagonal matrix which consists of volatility parameters in its diagonal. This excess return is measured as the term premium for holding a high maturity bond over a short time period.

From the equation of short term rate evolution (2.1), together with state vector dynamics (2.4) and the pricing kernel (2.6), we can construct a Gaussian K-factor model with K_1 observable and K_2 unobservable factors. By applying the specification of Duffie and Kan (1996) and Dai and Singleton (2000), the price of a n-period zero coupon bond P_t can be estimated by rehearsing on the no-arbitrage bond-pricing equation

$$P_{t,n} = E_t\left[M_{t+1}P_{t+1,n-1}\right]$$

with terminal condition $P_{t,n}$=1. As the bond prices are exponential functions of the state variables the price of a bond pricing formula is given as

$$P_{t,n} = \exp(\bar{A}_n + \bar{B}_n' x_t) \tag{2.9}$$

where A_n is a scalar function and and B_n is a (k×1) vector of valued functions as mentioned. The continuously compounded yield ($y_{t,n}$) on the n-period zero coupon bond is

$$y_{t,n} = -\frac{\log p_t^n}{n} = A_n + B_n' x_t \tag{2.10}$$

where coefficients A, B can be computed recursively

$$A_0 = 0,\ A_1 = -\delta_0,\ A_{n+1} = -\delta_0 + A_n + B_n'(\mu - \Sigma\lambda_0) + \frac{1}{2}B_n'\Sigma\Sigma' B_n$$

$$B_0 = 0,\ B_1 = -\delta_1,\ B_{n+1}' = -\delta_1 + B_n'(\Phi - \Sigma\lambda_1)$$

We can transform equation (9) by taking logarithms

$$y_{t,n} = -\frac{1}{n}\log P_{t,t+n} = -\frac{1}{n}\left(A_n + B_n' X_t\right) \tag{2.11}$$

where n is the maturity of a specific zero-coupon bond. In the affine specification, equation (2.11) is the measurement equation and equation (6) is the state equation.

4. Preliminary Statistics analysis

4.1 Descriptive statistics and Correlations

Table 2.3 shows some descriptive statistics for main monetary policy rates, the industrial production, the term spreads and the credit spreads. Then, we report correlations between term spreads and between credit spreads.

As regards to the key monetary policy rates, we point out higher mean values for SONIA, FFR and Canada central bank rate. In the case of Japan, the rate value is low due to the increased period of deflation. Also, the standard deviation for Japan rate is the lowest among other rates. The skewness of FFR, EONIA and SONIA rates are negative and for Japan and Canada are positive, indicating more aggressive stance by the US, Eurozone and UK monetary policy authorities. All countries have positive industrial production growth, except for Italy, which has negative mean value due to the decline in financial and debt crises. Also, we observe higher standard deviation for Germany IP growth and augmented kurtosis for Japan. With respect to term spreads, we show the highest mean value for Italy, with 1.96, accompanied by the highest standard deviation, as during crises periods the Italy long term year bond rate increased sharply. In the case of credit spreads we point out that US has increased mean value (4.01) compared to other spreads. Also, in Eurozone, the highest mean value is observed in France (3.08). In these countries we also find the maximum standard deviation. In contrast, Table 4.1 exhibits that Japan has the lowest mean value (1.1).

We observe that Canada has positive correlation with all term spreads but mainly with the US (71%) and less with Italy and Japan (22% and 26%). France has also positive correlation with other term spreads that vary between 55% (US) and 69% (UK). Germany has significant positive correlation with Canada, France, Japan and UK term spreads whereas its spread has low correlation with Italy and US spreads (20% and 28%). Italy has significant positive relationship with other spreads except for Germany (20%), and especially with Japan where the correlation is negative (-36%). UK has significant correlation with all spreads apart from Japan where the spreads are uncorrelated (8%). US spread has insignificant correlation with Germany and negative with Japan (-27%). In the case of credit spreads, the correlations are increased compared to term spreads, indicating a stronger linear relationship between them. The correlations are significant and above 80% for most the countries. We remark that Japan credit spread has the lower correlation with other spreads. Also, we observe nearly perfect positive correlation between spreads in Eurozone countries, indicating high country interdependence.

[Insert Table 2.3]

4.2 Unit root tests results

We next proceed with the unit root tests for all variables in order to examine if they are stationary or not. The tests are the Augmented Dickey-Fuller (ADF). We used 6 lags maximum based on the Akaike information criterion. The steps for these tests are: first, each variable is tested for a unit root in their level and, second, if found non-stationary, their first difference is taken so as to become stationary.

The basic ADF test has the following representation:

$$\Delta X_t = \gamma_0 + \gamma_1 T + \beta X_{t-1} + \sum_{i=1}^{m} a_i \Delta X_{t-1} + \varepsilon_t$$

where $\Delta X_{t-1} = X_{t-1} - X_{t-2}$.

We report the unit root tests results in Table 2.4. The results from the ADF test showed that all variables for all countries are non-stationary in their levels. However, when taking their first differences the unit root hypothesis was rejected.

[Insert Table 2.4]

5. Principal component analysis

With respect to the analysis of the behavior of the term structure over time we use the Principal Components Analysis (PCA) proposed by Litterman and Scheinkman (1991). This approach has some potential advantages mainly in the cases where there is a large number of variables that seemingly are correlated by dimension reduction. The use of PCA can overcome the problem of data overfitting (that is created by high dimensionality) that reduce the degrees of freedom as it enables us to summarize all the information contained in the term structure into a small number of factors. Hence, we can address the problem of multicollinearity that arises due to existence of bond yields of different maturities that are usually highly correlated (they are driven by common sources-factors). Also, under PCA method we are able to contain some information about what drives the dynamics of zero-coupon bond yields.

Since the work of Litterman and Scheinkman (1991), several authors have recognized the importance of identifying the common factors that determine the term-structure of interest rates. Principal component analysis describes the behavior of correlated variables in terms of a small number of uncorrelated variables called principal components. We follow the specification of Espada *et al.*, and we denote by y' the matrix of observations for each maturity over time, where the columns include different bond yields, while the rows indicate different points during the time period. Firstly we estimate the variance-covariance matrix of the zero-coupon bond yields:

$$\Theta = cov(y)$$

where Θ is a square symmetric matrix of dimension n × n and n is the number of yields. The diagonal values of Θ matrix are the variances of the bond yields, while the other elements refer to the covariances between yields of various maturities. We state that Θ' is a positive definite matrix since it does not exist any identical linear combination of one yield to another. Therefore, the Θ' matrix has an entire set of n specific and absolute positive eigenvalues, and there exists an orthogonal matrix Ω including the eigenvectors of Θ,

$$\Theta = \Omega \Lambda \Omega'$$

where Λ is the n × n diagonal matrix of eigenvalues of Σ' and Ω' is the analogous n × n matrix of eigenvectors. Also, the orthogonal matrix Ω satisfies the condition $\Omega' = \Omega^{-1}$. The principal components (pc) of the yield curve at time t are defines as follows:

$$pc_t = \Omega'(y_t - \bar{y}) \qquad (2.12)$$

where pc is the principal component, y_t is a k×1 dimension vector that contains the n different yields at time t and $\bar{y}$ is the sample mean of the yields. Our Principal Component analysis is based on a set of different yields spanning in the range between three months and ten years. According to PCA estimates presented in Table 2.5, the term structure variation is explained at 99.75% by two principal components. The first factor explains the largest part of this variation (96.45%), while the second factor explains the remaining part (3.3%).

[Insert Table 2.5]

The first principal component can be interpreted as a "level" factor. In the literature (Ang and Piazessi (2003)), this factor explains the parallel shifts in the term structure. The second principal component is referred as the "slope" factor in literature, and determines the slope of the yield curve. The literature use some alternative generally acceptable measures for the level and slope of term structure when factors extracting is not applicable; we call them Factor A and Factor B. We found that the "level" factor has almost perfect positive correlation with Factor A that is the average of three month, two year and ten year rates (99%), Also, the second principal component, also called “slope”, has high positive correlation with the Factor B, that is the difference between ten year rate and three month rate; the term spread (79%). As the two principal component factors determine the variation of the whole term structure, we can rely on the proxy measures to forecast yield curve movements.

In Figure 2.1 we show that the information of the level factor remains as the number of months increase, the maximum information for the curvature factor is given nearly at the medium of the period and then gradually decays and the information contained on the slope factor increases as the time to maturity also increases.

[Insert Figure 2.1]

6. The link between the term structure and economy

6.1 Term structure and industrial production

Recent literature suggests that there is a close relationship between term structure factors and macroeconomic variables. According to this, we can use the term structure of interest rates in order to perform forecasts for economic activity. We build a framework in which we relate a key economic determinant, such as industrial production and the factors that define the shape of the yield curve for US. The empirical analysis is based on a linear regression model where the dependent variable is the industrial production growth (defined as the logarithmic monthly change) and the explanatory variables are the three factors (obtained by principal component analysis) that explain mostly the yield curve[1].

We target to the evaluation of the forecasting power of the term structure on industrial production both in pre- and post-crisis periods. For this reason, we split the sample into the

[1] We use three principal components as yield curve factors, against two that we found by running the PCA. According to Ang and Piazzesi (2003) the factors that mostly explains the variation in term structure are three; level, slope and curvature.

so-called pre-crisis period (1994-2006) and post- crisis period (2007-2014). More specifically, we examine whether the predictive power of the yield curve has changes between the two main periods. The estimators are captured by running standard robust OLS regressions for different time horizons up to twelve months ahead. The variables we apply are tested for stationarity to avoid the spurious regression phenomenon, and the standard errors are corrected for heteroskedasticity and autocorrelation according to Newey-West formulae:

$$\Delta_n ip_{t,n} = \alpha_0 + \beta_1 level_{t,n} + \beta_2 slope_{t,n} + \beta_3 curvature_{t,n} + \varepsilon_{t,n} \quad (2.13)$$

As we observe, from the results in Table 2.6, in the pre-crisis period both the level and slope factors had significant forecasting power on industrial production. More specifically, the results show that these two factors affect significantly the future variation of industrial production in the short term (up to six months), while their impact on industrial production after 12 months is insignificant. This evidence confirms the theory which suggests that term spread has a strong predictive ability on output, at least at the short end. As it was expected, the curvature factor does not provide any information for industrial production movements for all time horizons. Recall that according to principal component analysis, only two factors can explain the variation of the term structure, and the third factor (curvature) is insignificant.

Contrary, in the post-crisis period, we observe that the level factor retains its significance on expected industrial production growth except for three months coefficient. The slope factor does not provide any significant information for future industrial production up to three months ahead. However, after six and twelve months the slope factor becomes significant. However, its effect is negative for future output and counter-intuitive, indicating a significant distortion of slope factor as a predictor of total output. Also, the curvature factor continues to give no information for future industrial production movements.

The results show that we need only two factors to explain term structure movements, and these factors can predict future industrial production movements. We also find, that level factor in both periods is significant and has positive effect for future industrial production. The slope factor in pre-crisis period is significant and positive related to expected industrial production (in accordance with literature), indicating its strong predictive power for future economic conditions. However, in the post-crisis period, the slope factor becomes insignificant in the short-term (up to three months). The slope factor effect on expected industrial production changed to significant but negative after six months. The results suggest that, in the post-crisis, the term structure relationship with economic activity as they are expressed by the factors and industrial production respectively have substantially changed.

[Insert Table 2.6]

We continue on the examination of the relationship between the constructed term spread (10-year rate minus 3-month rate) and other spreads and the industrial production before and after crisis. The target is to evaluate the performance of the term spread to predict output growth and to compare it with other spreads. The alternative spreads we apply are the credit spread (10- year corporate BBB yield minus 3-month treasury rate) and the LIBOR spread (12-month LIBOR rate minus 3-month LIBOR rate). Due to credit risk premia sharp increase during the financial crisis period, the credit spread can become a proper measure for industrial production forecasts. Also, the LIBOR spread is a generally acceptable proxy spread for market participants against term spread. The analysis is performed using robust OLS regressions for forecasting period up to twelve months. By definition, the dependent variable is the industrial production growth and the explanatory variables are the term spread (*tsp*), the credit spread (*crsp*) and the LIBOR spread (*libsp*). The analysis is conducted in first differences to ensure stationarity.

$$\Delta_n ip_{t,n} = \alpha_0 + \beta_1 crsp_{t,n} + \beta_2 tsp_{t,n} + \beta_3 libsp_{t,n} + \varepsilon_{t,n} \quad (2.14)$$

The results in Table 2.7 show that in the pre-crisis period, the term spread has significant forecasting power on industrial production for only short term, up to two months ahead. The credit spread importantly influence the industrial production at only two months forward. However, the LIBOR spread does not have any impact on industrial production for the pre-crisis period. So, we argue that in pre-crisis period the only reliable information emanates from term spread and for short term horizon. In the post-crisis period, the forecasting power of the term spread is significant for only two months ahead. The predictive power of LIBOR spread to industrial production is significant for one month. Furthermore, we observe that the impact of credit spread to future values of industrial production is significant up to six months. The estimation coefficients are significant with a negative sign which indicates that an increase in credit spread forecasts a sharp decline in industrial production. According to the results, in post crisis period the credit spread is stronger forecaster than the term spread.

[Insert Table 2.7]

6.2 Term structure factors and economic measures

In the recent term structure literature, the level factor has been closely related with measures of inflation expectations. In order to evaluate their relationship, we define a long-run inflation compensation measure and we correlate it with the first principal component (level) both in the pre- and post-crisis periods. Therefore, we use as instrument the spread between 10-year yields on nominal and inflation-indexed securities as in the work of Rudebusch and Wu (2004).

In Table 2.8 we present the linear correlation coefficients. The first principal component appears to be closely related to expected inflation in the pre-crisis period. The correlation between level factor and long-run inflation compensation reaches 0.65, thus confirming the existence of a strong relationship between the level factor and the expected inflation. In addition, Dewachter and Lyrio (2006) proved the association of inflation and level factor by using different methodological approach. However, during the post-crisis period, we observe a breakdown in this relationship since their linkage weakens as the level factor with inflation compensation are nearly uncorrelated (0.10).

According to Piazzesi (2005) the slope of the yield curve is closely associated with the cyclical responses of the economy, and therefore, the slope factor should be linked to the movements of the central bank's rate. The results suggest that the correlation between the second principal component (slope) and the federal funds rate in pre-crisis period is -0.52, and indicates that the yield curve slope is connected to the central bank dynamics. More specifically, during expansionary monetary policy periods (accompanied by low interest rates) the slope factor increases. This evidence is consistent with the countercyclical response of yield curve, as the slope becomes flatter when an economic downturn is expected, whereas, at the time when the yield curve is downward sloped, there exists economic growth. This evidence is consistent with the findings of Ang and Piazzesi (2003) and Rudebusch and Wu (2004). However, during the post-crisis period, we found that slope and federal funds rate become uncorrelated, as the federal funds rate remained stable nearly zero in order to stimulate the economy, and there was no further response by the yield curve slope.

[Insert Table 2.8]

7. Estimation of the term structure model

We follow a specification similar to Ang and Piazessi in order to estimate the parameters of the model for US. Firstly, we estimate the factor dynamics of the equation (2.5) by an unrestricted VAR(1) model and then we apply regression for short term rate rule (2.1) by ordinary least squares method. Secondly, we compute the risk premium parameters given the estimates of equation (2.5) by the differencing observed yields and term premium estimates.

The empirical estimation results are closed to those found in literature. In Panel A of Table 2.9 we estimate the parameters of the model ("Φ") for latent (level, slope) and macroeconomic (industrial production, inflation) variables. The autocorrelations for latent variables are significant and very high indicating increased persistence. In Panel B of Table 2.9, the parameters describe the short rate evolution (equation 2.1, where x΄ is the set of macroeconomic and latent variables). The coefficient related to level factor is positive as one would expect, as the increased level indicate signs of economic overheating, and central banks respond by increasing short term rates. The effect of the slope factor is negative as the steep yield curve includes low short term rate. The coefficients corresponding to the industrial production growth and the inflation rate are positive due to the monetary policy rule which is followed by FED.

[Insert Table 2.9]

The risk premiums are captured from excess holding bond returns. The application of this approach avoids the disadvantages we face when we estimate a model with many factors using the maximum likelihood one step procedure, in which both yields and factors are highly persistent. The model we estimate contains observable and unobservable factors. The observable factors are macroeconomic variables, i.e. industrial production and inflation and the unobservable factors derived from yields and constitutes of the level and slope factors.

As we have already pointed out in equation (2.2), the *n*-period yield can be written as the average of expected future nominal short-rates plus an additional term *(tp)*, which we refer to interchangeably as a yield risk premium or term premium:

$$y_{t,n} = \underbrace{\frac{1}{n} E_t \left(y_{t,1} + y_{t,2} + \ldots + y_{t+n-1} \right)}_{\text{expectations component}} + \underbrace{tp_{t,n}}_{\text{yield risk premium}} \tag{2.15}$$

Recalling equation (2.8), the price of risk is defined as the expected values of the excess holding period returns and they are characterized by time variation. These values can be captured with the assumption of no arbitrage and under the expectations hypothesis, the risk premia are assumed to be constant. In Panel B of Table 2.9, we report the variable parameters when we regress macroeconomic and latent factors on risk premia. Their coefficients corresponding to inflation and industrial production are significant, implying that macro factors drive the time variation in risk premia. The negative signs of industrial production and inflation coefficients indicate that bond risk premia are highly counter-cyclical, as reported by many studies. For example, negative industrial production shocks lead to risk premia increase, a result that is reflected by the Figure 2.2, where the risk premia rose during the two last US recession periods. Also, the risk premia parameters are significant for both latent factors (level and slope). As a result, the risk premia that linked with unobservable factors are priced in the bond market.

In Figure 2.2 we show the contemporaneous risk premia for US term structure. As we can easily observe, during the two US recession periods (2001 and 2007-09), the risk premia reached peak values above 2 percent. The result is consistent with theory suggesting that the risk premia soared during crisis periods.

[Insert Figure 2.2]

8. The country interdependence and term structure

We further analyze the impact of foreign term spreads movements to domestic term spread and central bank rate. The countries we select are the US, UK, Germany, France, Italy, Canada and Japan. The most appropriate specification is setting up VAR models that allows us to examine the term spreads and central bank rates as endogenous factors. For this reason, we constructed alternative VAR models with the same structure that combines different countries term spreads. Each one includes countries central bank rates and their spreads. The spreads we apply are the *term spread*, i.e. the difference between ten year bond rate and three month treasury rate and the *credit spread*, i.e. the difference between 10-year corporate BBB rate and 3-month treasury rate. We apply VAR with two lags as the Akaike information criterion indicates.

The analysis of different VAR models revealed that the relationship between all spread and key policy rates is negative. Also, the vast majority of spreads have positive effect on other countries spreads, indicating increased country interdependence. The graphical representation of the impulse response functions are presented in Figure 2.3.

The panel A reports the VAR impulse responses for US and UK. The impact of a unit volatility shock by fed funds and SONIA rates affects negatively both USA and UK term spreads. The key policy rate movements imposes the same direction changes of the short term rate of the yield curve, so the spread declines after the positive shock by main rates. Also, the responses of key rates to innovations from term spreads are negative, as an expected steep yields curve reheats inflationary pressures. An active monetary policy responds by lowering the short term rate. Panel B shows the VAR figures for US, UK and Canada. The positive shocks by key monetary rates have negative impact on the term spreads for each country as in the previous VAR model. The effect is similar when the shocks form term spreads are imposed on main rates. In addition, we remark that positive innovation from each country term spreads has also positive impact on other countries term spreads, indicating increased interdependence between these countries.

Panel C refers to a VAR model with Germany, France and Italy. The positive innovations from EONIA rate have negative impact on euro zone term spreads. On the other side, the impact of a unit volatility shock by euro zone term spreads have negative effect on EONIA rate. Furthermore, the positive shocks implemented by term spreads have positive impact on other countries term spreads. This result indicates interdependence among euro zone countries. Only the impact of Italy term spread to France and Germany becomes negative before converge. Panel D reports the results form impulse responses for a VAR model that involves US, Germany and Japan. We found that positive innovations from Japan term spread have positive effect on both Germany and US yield spreads and vice versa. However, a unit volatility shock by US term spread has negative impact on Germany term spread. Contrary, a shock by Germany term spread has positive effect on US term spread.

Panel E shows the impact of shocks in a VAR system that involves Japan, Germany and Canada. The results show that shocks implemented by term spreads have positive effects on other countries term spreads. However, positive innovations from Japan term spread have negative effect on Canada term spread. Panel F illustrates the impulse responses figures in a VAR model with UK and Germany. We remark that positive shocks from Germany term spread have negative impact on UK term spread. However, positive innovations from UK spread have also positive effect on Germany term spread. This result reveals the spillover effect from Germany to UK, but not from UK to Germany.

Panel G reports the figures form VAR models by implementing credit spreads instead of term spreads. In the first VAR model with US and Germany, the positive innovations from EONIA and fed funds rate have negative impact on the credit spreads and vice versa. This is a result that coincides with the VAR models that included term spreads. The credit booms urges central banks to cut their rates, in order to restore the liquidity. We also found positive impact on innovations by each credit spread to other, as in the case of term spreads. The second VAR model includes US and Japan. In this case we confirmed the positive relationship of shocks between countries credit spreads. The third VAR model included Germany, France and Italy, with Germany exogenous variables. The impact of credit spreads on EONIA rate is negative, as we have seen so far. Also, the most innovations of credit spreads indicated positive effects on other countries credit spreads. However, in case of Germany, a positive shock by Germany credit spread have negative effect on France and Italy credit spread.

[Insert Figure 2.3]

9. The yield curve and business cycles fluctuations

We analyze the predictive power of the term structure over the business cycles. We estimate a Markov switching autoregressive model for the business cycles of each country. Under the Markov switching approach, the possible outcomes are restricted into *"m"* states (regimes) of the world. This specification is built on the assumption that movements of a specific variables are determined by a Markov process. According to the Markov property, the variable value at time *t* depends only on the state at time *t-1* (first order Markov process). As a result, there is not any path dependence in process of a variable evolution, however, the variable can swifts from one regime to another (transition). The stability of each state depends on the transition probabilities of the model.

Our proxy is the industrial production index estimated as a logarithmic year over year change and we select also as a switching regressor the term spread in order to examine its forecasting power for each regime. The parameters of estimation switch according to a Markov chain process that consists of two regime states. We choose two states so as to capture the economic states: growth or recession. The recession state has lower (negative) mean value than the expansionary and a much higher volatility (leverage effect). Hence, our decision is determined by these properties. We observe that the expected duration for the growth state in all countries is higher than the recession regime as long as its state dependence. The analysis focus on the predictability power of term spread on economic growth within the industrial production contemporaneously.

The model we apply in the Markov regression is

$$ip_t = \beta_0 + \beta_1 termspread_t + \varepsilon_{it} \quad (2.16)$$

The analysis is performed for US, UK, Canada, Japan, Germany, France and Italy. We applied also alternative models for industrial production with short term rates and other spreads and macros as explanatory variables but the best fit is performed by the model above. However, our model does not fit adequately in the case of Japan where the model has weak predictive power on recessions and in the case of Italy where we transform the model to include credit spread as it is evident that the country's economy was influenced by increased credit volatility during financial and debt crisis periods. We establish recession periods according to NBER definition for recessions (i.e. two consecutive quarters with negative GDP growth). We estimate the percent change in real GDP for countries for a year ago and we construct a dummy variable where 1 is the recession period and 0 is the expansionary period. As our data are monthly we do the proper transformation.

The results show that the financial crisis period of 2007-2009 was predicted by the model with term spread for all countries. In the case of Japan some recessionary periods during the 1994-2014 period had not predicted by the model, as well as in case of Germany. The US model forecasting power is the stronger compared to other countries. In the case of Italy, the term spread model did not performed well as the Italian economy continued to be on recession after 2010 due to debt crisis and the model did not predicted it. For this reason, we estimate a model including also the credit spread. The results showed that the corrected model for Italy performed effectively. For the graphical representation of the recession regimes we apply smoothed probabilities as they are estimated using the entire sample.

According to the results, in Canada, the recession period is the second state where the mean value is less than first state and the volatility is higher. The transition matrix shows considerable state dependence for both regimes, mainly for the expansionary regime (1). Furthermore, for the second state, we see low transition probability from the first to the second regime. In addition, the expected duration of the first state is considerable higher (72 months) than the second regime (7 months). We observe also, increased positive correlation between regime 2 and recession (0.61), indicating that the model performed well. As we show in Table 2.10 and depict in Figure 2.4, the recession period in 2008 is forecasted by the model.

[Insert Table 2.10, Figure 2.4]

In the case of Japan, Table 2.11, we define state two as the recession regime (as it has lower mean and increased volatility) and the regime one as the expansionary. The transition results show also state dependence for the expansionary regime, as it is nearly 99% possible that the expansionary regime will be maintained the next period. The second state is less persistent and its expected duration is below the first regime (82%). The expected duration for the growth regime is 87 months and for the recession regime is 5 months. As we observed, the correlation between contraction regime (2) and recession is low, as the recession of 1998-1999 and 2001 did not predicted by the model.

[Insert Table 2.11, Figure 2.5]

In the case of US, Table 2.12, we define the second regime as the growth state with the first one as the recession. Second regime is more state dependent than first, but both of them has increased dependence. The expected duration of the growth state is nearly 48 months with

8 months for the first. We remark low probability of the transition between state two to state one. The correlation between recession dummy and regime 1 (contraction) is very high, indicating that the model applies correctly. The Figure 2.6 show that the two recession periods are effectively forecasted by the model.

[Insert Table 2.12, Figure 2.6]

As regards to UK, Table 2.13, the state with higher mean value and lower volatility indicating economic growth is the first regime, while the second one is the recession regime. As the transition probabilities show, the persistence of the first state is nearly perfect, while the second regime appears lower state dependence. Also, the duration for the expansionary period is considerably higher (130.5 months) than in the recessionary period (6 months). Furthermore, we observe increased correlation between recession dummy and contraction regime (71%) as the model predicts correctly the economic conditions.

[Insert Table 2.13, Figure 2.7]

The results suggest that in the case of Germany, Table 2.14, the first state refers to the expansionary period (higher mean value) whereas the second one as the recession. The transition probability matrix shows increased probability for state dependence in the second expansionary regime as long as higher expected duration. The contractionary regime has increased transition probability to state 1. The correlation between recession dummy and regime 1 is relatively low.

[Insert Table 2.14, Figure 2.8]

The Markov switching regression in the case of France, Table 2.15, defines the first state as the growth regime with the second one as the recession. The expected regime duration is nearly to 99%. Also, we remark a significant state dependence for this regime, while the second regime (contraction) has low state dependence and increased transition probability.

The correlation between regime 2 and recession dummy is 62%, indicating increased predictability by the model, as also presented in figure.

[Insert Table 2.15, Figure 2.9]

In the case of Italy, Table 16, we change the model by adding the lag of the credit spread. So the models becomes

$$ip_t = \beta_0 + \beta_1 termspread_{t-1} + \beta_2 creditspread_{t-1} + \varepsilon_{it} \tag{2.17}$$

The recession period is the second regime, while the first regime is the growth state. Both states have very high state dependence as the transition matrix shows, and the growth state (regime 2) has the higher expected duration. The correlation between recession dummy and contraction regime is increased confirming the forecasting power of the model. If we apply the benchmark Markov model in Italy, we observe that the last recessionary period is not predicted by the model.

[Insert Table 2.16, Figure 2.10]

10. Market volatility, contagion and the term structure

In this section, we examine the market contagion effect on the term spread, industrial production and the main policy rates during the post-crisis period (2007-2014). Therefore, we estimate firstly, the volatility of stock market indices by applying a GARCH(1,1) model of the form

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \tag{2.18}$$

where ε_{t-1} is the ARCH term and σ_{t-1} is the GARCH term.

Second, we develop VAR models for each country in order to study the effects of market volatility shocks to country's specific variables. The GARCH structure and the optimal lag length for the VAR models are determined according to Akaike information criterion.

The volatility parameters emanate from major stock market indices that include high capitalization firms. More specifically, we use the SP500 for US, the FTSE100 for UK, the DAX30 for Germany, the CAC40 for France, the Nikkei225 for Japan and the TSX60 for Canada. We extract the relationship between market volatility and industrial production activity by performing a simple correlation analysis. Summarizing the results for all countries we show that shocks from market volatility variable have negative impact on industrial production and monetary policy rates, as the increased volatile periods are associated with crisis periods and showdown in economic growth. Also, the correlation between recession periods and market volatility variable is always positive and the strength of their relationship depends on country (Table 2.17). Moreover, the results are associated with the leverage effect that is the tendency of volatility to rise more following a large price fall rather than following a price increase of the same magnitude. Contrary, the impact of volatility on yield curve is characterized as positive due to the countercyclical effects.

[Insert Table 2.17]

The results in Figure 2.11 show that in the case of Japan and Germany, the impact of market volatility shocks are positive for industrial production and monetary policy rates and negative for term spread. This result is opposite to that it was expected as the analysis indicates lowered forecasting power by the term spread on the economic activity. This evidence is consistent with the Markov switching regression results of the previous section, where Japan and Germany term spreads provide little information for industrial production movements. The specific country results are presented below. Also in the case of Germany and Japan, the correlation analysis in Table 2.17 show that the volatility variable and industrial production have positive correlation and the relationship between recessionary periods and increased market volatility periods are negative. This evidence is counterintuitive but consistent with the VAR and Markov switching regressions results.

In the case of Canada, one unit volatility shock by TSX60 index has negative effect on industrial production growth as the increased volatile periods in stock markets usually concur with recessionary periods. The response of Canadian key policy rate after an innovation from market volatility is negative, due to the fact that monetary policy authorities try to stabilize the economic conditions by lowering interest rates. The effect of market volatility shock to term spread is positive. The reason is that increased volatility lowers short term rates and the yield curve becomes steeper. Furthermore, the highly volatile periods in stock market usually turn up when there is a dampening in economic growth. In case of the term spread, we observe that it has countercyclical response as at the time of recession it forecasts growth for the next period.

In the case of Japan, the impact of one unit volatility shock to the selected variables creates a mixture of responses. As a result, we have no clear insight on the impact of stock market on the evolution of the industrial production, short term rate and the term spread. The effect of market volatility on the industrial production and key policy rates is positive at the beginning, but then (after five months) becomes negative before converging to zero. We also observed that the recessionary periods and market volatility index are uncorrelated. The responses of the term spread to innovations from market volatility are also unclear as they are positive in the first two months, then turn to be negative and after seven months become positive again.

In the case of US the responses of industrial production growth and FED funds rate due to shocks from SP500 index are negative and remained below zero for all the period. This result is consistent to what it was expected. Furthermore, the responses of the term spread after a unit volatility shock by stock market volatility are negative at the beginning but becomes positive after three months and converges to zero. The reactions of the term spread to market volatility changes are due to the effect of the recent financial crisis. it is evident, that the financial crisis distorted the US yield curve and this is reflected on the responses of the term spread.

As regards to UK, the reactions of industrial production as well as SONIA rate after a shock by market volatility are negative and remain below zero until convergence. The results suggest that high volatility in UK stock market has negative repercussions on economic activity and induces the Bank of England to follow expansionary monetary policy. Contrary, the responses of the term spread to unit volatility shock by FTSE index are positive, as the short term rate declines consistently with the reduction in main monetary policy rate.

In the Eurozone we observe some significant differences with respect to the impact of market volatility on several variables. More specifically, in the case of Germany, the effect of market volatility shock creates a mixture of the industrial production responses. At the beginning, the responses are negative, then turn to positive and following the fourth period become temporarily negative again. Therefore, the results imply that there is no clear relationship between the DAX30 index and the industrial production growth. The impact of market volatility to term spread is negative as in the case of Germany, the downward yield curve coincides with periods with increased volatility. Furthermore, the responses of EONIA rate due to a shock in market volatility are positive and counterintuitive.

As regards to France, the responses of industrial production and EONIA rate to shocks from CAC40 index volatility are negative and they are consistent with the intuition previously developed. In addition, the reactions of the term spread to innovations from market volatility are positive and as it was expected due to countercyclical movements. Finally, in the case of

Italy, the responses of the industrial production are negative as well as the reactions of the EONIA rate. This result confirm the negative relationship between economic activity and stock market index movements. However, we point out some differences about the impact of term spread to market volatility shocks as these are negative at the beginning of the period and then become positive and converges to zero.

[Insert Figure 2.11]

11. Eurozone financial and debt crises and the term structure

We continue by studying the impact of the term structure on economic activity during both financial crisis (2007-2009) and debt crisis (2010-2012) periods. We define these crisis periods by creating a dummy that equals 1 for the period 2007-2014 and 0 for the period 1994-2007. We construct a model with industrial production as the dependent variable and term spread, credit spread in contemporaneous form and two interaction terms as the explanatory variables. The variables are mean centered to avoid the multicollinearity issues due to the inclusion of interaction terms.

The interest on this analysis is focused on whether economic fluctuations could be predicted by both term and credit spreads in this period. Therefore, we add credit spread in the sample due to the increased market risk during crisis periods. The effect of the market risk premia is captured by adding credit spread as an explanatory variable. The two interaction terms, one for each spread show us the effect of the specific variable on industrial production during crisis periods. Our approach relies on a robust OLS regression that includes constant terms. The error terms are corrected for autocorrelation and heteroskedasticity according to Newey-West method. The model has the following form:

$$ip_t = \alpha_0 + \beta_1 ts_t + \beta_2 crsp_t + \beta_3 ts_t \times crisis + \beta_4 cs_t \times crisis + \varepsilon_t \tag{2.19}$$

where ts, cs are abbreviations for term spread and credit spread respectively, and crisis is the dummy that determines both financial and debt crises.

The results in Table 2.18 show a significant impact of crisis interaction terms on industrial production activity. In the post crisis period, the effect of term spread on industrial production is positive and significant for all three countries. The credit spread is important only for France and Italy in post crisis period due to the larger effect of financial and debt crises.

[Insert Table 2.18]

More specifically, in the case of Germany, the effect of the term spread is insignificant for the pre-crisis period (when the dummy=0). This result is consistent with the analysis of Markov switching regimes, where the predictability of Germany recessions by the term spread is weak. The credit spread has significant negative impact on industrial production in the pre-crisis period as we expected. The term spread interaction term is however significant and positive, indicating a remarkable impact of term spread on industrial production for only post crisis period. Contrary, the credit spread in post crisis period is negative but insignificant due to the low market risk premia effect on economic activity. Hence, the results confirm that the debt crisis did not affect Germany while the financial crisis influenced the economy at a minor degree.

As regards to France, the results show significant positive and negative effect by term spread and credit spread respectively on industrial production for the pre-crisis period. Moreover, as the interaction terms indicate, the significant effect of the spreads remain during the crisis period. The impact of the term spread is positive again as yield curve increases when anticipating industrial production growth. In the case of France, the significance of the credit spread on industrial production indicates that market turmoil emanating from financial and debt crises affected largely the economic activity.

In the case of Italy, the results show that the term spread in pre-crisis period was negatively affected the industrial production whereas the credit spread had positive impact on it. These results are opposite to what it was expected, suggesting that both spreads had no consistent predictive power on the economic activity. The interaction terms underline the significant effect that both the term and the credit spreads have on the industrial production. The sign for the term spread is positive and that for the credit spread is negative as it was expected, indicating increased predictive power in crisis periods. In the case of Italy, the results confirm the Markov regression results for Italian industrial production response on both spreads.

12. The monetary policy and the yield curve in pre- and post-crisis periods

Finally, in this section we analyze the impact of the monetary policy instruments on the US term spread both in the pre- and post-crisis periods. The traditional monetary policy instrument by which the FED conduct the monetary policy is the funds rate. We use also the ratio of asset purchases to total FED assets as a proxy for the unconventional monetary policy strategy that was followed by the FED during the financial crisis period. For the pre-crisis period we take into consideration only the short term policy rate, the FED funds rate. For the post-crisis period we evaluate the effect of the asset purchase program conducted by FED as part of the quantitative easing measures, on the term spread and finally the joint effect of the FED funds rate and asset purchases program on the term spread.

Due to the economic downturn during the recent financial crisis period, the FED was forced to make a series of large-scale asset purchases, which lasted until October 2014. The FED purchased in the secondary market a large number of longer-term securities issued by the government and Mortgage Backed Securities issued or guaranteed by government-sponsored enterprises. The FED interventions reduced the supply of securities in the market, resulting in the increase in their prices and thus in a decline in their yields. Therefore, the FED injected the necessary liquidity in financial markets, the exchange rate of dollar reduced (domestic underprice) and in parallel, the central bank managed to retain the inflation control. Furthermore, the investors responded to lower yields by acquiring assets with higher yields such as private sector securities. Therefore, both investors' and FED's direct purchases of private sector securities increased their prices and reduced their yields. Consequently, the effect of the FED actions was the reduction in yields of longer-term securities, and as a result to ameliorate the economic conditions.

Given that the FED funds rate has been effectively equal to zero during the financial crisis period, the effect of non-conventional measures on economy within their impact on term spread provide an evaluation measure for the monetary policy during this period. More specifically, the FED funds rate was a representative measure for short term rates evolution, while the management of the supply of securities used as a tool by FED to handle the long term interest rates. As a result these two measures explain the whole monetary policy stance before and during the crisis. The motivation we follow includes three models; one for pre-crisis period and the other two for the post-crisis period. We analyze the contemporaneous impact of monetary policy instruments on term spread by the use of robust OLS regressions. The general model has the form:

$$tsp_t = \beta_0 + \beta_1 ffr_t + \beta_2 assets_t + \varepsilon_t \tag{2.20}$$

where tsp is the term spread, assets are the asset purchases, the parameter β_2 is zero for the pre-crisis period in model I, the parameter $\beta_1$is zero in model II, and model III has the above complete form.

[Insert Table 2.19]

The results in Table 2.19 show that in the pre-crisis period (model I) the effect of the key policy rate on the term spread is significant and negative as one would expect. The increase in the short term rate induces short term treasury rates to rise, and thus urging the yield curve to become flatter. In the post-crisis period we examine the effect of unconventional measure (model II) and both conventional and unconventional measures (model III). We find that the impact of increased asset purchases by the FED on the term spread is significant and negative in both models. These results imply a flatter yield curve after an increase on the asset purchases.

The intuition behind this evidence is that as we earlier pointed out, the FED unconventional monetary policy strategy implemented by large long term asset purchases reduced long term yields, including ten years bond rate for our spread. The reduction of long term interest rates induced by FED, performed in order to give the signal of sustained low rates in future, as a way to boost the economic activity. We argue that this strategy was effective as the term spread declined by 2.3 percent according to the model. Also, during the post-crisis period the impact of fed funds rate is negative but insignificant for the term spread as the rate remained effectively zero for an extended period after the financial crisis outbreak and there was no real impact on economic activity.

Relying on the results above, we state that standard policy measures affected term spread before crisis significantly, however in the aftermath of the financial crisis there exists a break in their relationship. Contrary, the effect of large asset purchases was significant in reducing the term spread, indicating higher effectiveness and explanatory power by the unconventional monetary tools.

13. Conclusion

In this paper, we develop a Gaussian affine term structure model with a vector of macroeconomic variables. We are interested in extracting the factors that shape the yield curve and explain the whole term structure and review the relationship between macroeconomic variables and yields that exist in literature. We found that the two factors that explain the term structure (level and slope) have significant effect on the industrial production in the pre-crisis period. Contrary, in the post-crisis period the forecasting ability of the level remains significant, whereas the forecasting power of the slope factor weakens. We then estimate the affine term structure model in which we include a vector of US bond yields and macroeconomic factors.

Furthermore, we study the interrelationship between countries' term structure and their level of interdependence. Our findings show that countries' term spreads have a positive impact on other countries' term spreads, indicating a high degree of spillover effects. In addition, we focus on the examination of the relationship between term spread and economic activity both in pre- and post-crisis periods. We developed a model with industrial production as the dependent variable and the term spread as the explanatory variable. Then we applied a Markov switching regime regression that gives us the economic regimes for each country and the predictability of term structure on each regime. The estimated Markov regressions lead to the conclusion that two regimes exist for the economic activity (expansionary-contractionary) as well as different degree of correlation between regimes and the term structure.

Given that the recent financial crisis influenced negatively all countries we focused on the impact of market volatility on the term structure and economic activity. The market risk premia distorted the forecasting ability of the term structure, and as we found, the volatility factor (market risk proxy) affected significantly several key policy rates, term spreads and industrial production in the post-crisis period. Then we applied a case study for the Eurozone, for the period that covers both the recent financial and the debt crises, and we assessed the impact of the term spread and the credit spread on economic activity. The results suggested that during the Eurozone debt crisis the role of credit spread in predicting economic activity highlighted. We found significant post crisis effect for the term spread on industrial production for the Eurozone countries. In the case of Italy and France, the credit spread had also significant impact on industrial production for the post-crisis period.

Finally, we examined the effect of the monetary policy instruments on term structure before and after crisis. In the pre-crisis period we took into consideration only short term policy rate, whereas in post-crisis period we assessed also the effect of non-conventional measures (asset purchases). As our analysis showed, in the pre-crisis period the policy rate worked effectively since it had negative effect on the term spread, while in post crisis period its effect is insignificant. However, the non-standard policy tool has negative and significant impact on the spread.

Table 2.1 Theoretical term structure models (equilibrium and arbitrage free)

Equilibrium models	
Paper	**Model**
Rendleman, Bartter (1980)	$dr = \mu r dt + \sigma r dz$ $m(r) = \mu r;\ s(r) = \sigma$ r follows geometric Brownian motion
Vasicek (1977)	$dr = a(b-r)dt + \sigma dz$ $m(r) = a(b-r);\ s(r) = \sigma$ the drift incorporates mean reversion, negative r

Cox, Ingersoll, Ross (1985)	$dr = a(b-r)dt + \sigma\sqrt{r}dz$ $m(r) = a(b-r);\ s(r) = \sigma\sqrt{r}$ Includes mean reversion, non-negative r
Chan et al. (1992)	$dr = a(b-r)dt + \sigma r^a dz$ $m(r) = a(b-r);\ s(r) = \sigma r^a$ use constant elasticity of variance assumption, mean reversion
Duffie, Kan (1993)	$dr = a(b-r)dt + \sqrt{\sigma_0 + \sigma_1 r}dz$ $m(r) = a(b-r);\ s(r) = \sqrt{\sigma_0 + \sigma_1 r}$ affine type models
Arbitrage-free models	
Paper	**Model**
Ho, Lee (1986)	$dr = \theta(t)dt + \sigma dz$ $m(r) = \theta(t);\ s(r) = \sigma$ Independent of r, allows negative drift, bond valuation
Hull, White (1990)	$dr = [\theta(t) - ar]dt + \sigma dz$ $m(r) = [\theta(t) - ar];\ s(r) = \sigma$ incorporates mean reversion, time varying drift, allows negative drift, bond valuation
Heath, Jarrow, Morton (1992)	$\Delta f(t,T) = a(t,T)\Delta + \sigma(t,T)\Delta z$ $m(r) = a(t,T);\ s(r) = \sigma(t,T)$ Forward rate evolution
Black, Karasinki (1991)	$d\ln r = [\theta(t) - a(t)\ln(r)]dt + \sigma(t)dz$ $m(r) = [\theta(t) - a(t)\ln(r)];\ s(r) = \sigma(t)$ r is lognormal, non-negative

Table 2.2 Methodological evolution of empirical affine models

Paper	Methodological approach
Piazzesi (2001), Bikbov, Chernov (2008)	Insert different monetary policy regimes in the term structure analysis
Ang, Piazzesi (2003)	3-factor (yields-only) term structure model and 5-factor model with macroeconomic variables
De Graeve et al. (2009), Van Binsbergen et al. (2012)	Affine model with DSGE specification

Lu, Wu (2009), Ang et al. (2011), Chun (2011)	Analyze the role of monetary policy rules (Taylor, McCallum) in the affine term structure
Cochrane, Piazzesi (2005), Dewachter, et al. (2014)	Effect of the risk premia in interest rates
Christensen, Lopez, Rudebusch (2008), Renne (2012), Li, Wei (2013)	The effect of monetary policy at the financial crisis in the term structure
Bikbov, Chernov (2010)	4-factor model with macroeconomic variables
Duffee (2011)	5-factor model both yields only and by macro variables
Kim, Orphanides (2005)	3-factor model with survey data, Monte Carlo simulations
Jardet et al. (2013)	Insert cointegration in the affine set up

Table 2.3 Correlations and descriptive statistics

Term Spreads

	CA	FR	GM	IT	JP	UK	US
CA	1						
FR	0.65	1					
GM	0.64	0.62	1				
IT	0.22	0.65	0.2	1			
JP	0.26	0.03	0.51	-0.36	1		
UK	0.63	0.69	0.54	0.71	0.08	1	

US	0.71	0.55	0.28	0.55	-0.27	0.65	1

Credit Spreads

	CA	FR	GM	IT	JP	UK	US
CA	1						
FR	0.87	1					
GM	0.85	0.97	1				
IT	0.9	0.97	0.96	1			
JP	0.63	0.65	0.64	0.72	1		
UK	0.91	0.9	0.9	0.92	0.7	1	
US	0.96	0.83	0.77	0.87	0.6	0.87	1

Main rates

	FFR	EONIA	SONIA	CBRATE_CA	CBRATE_JP
Mean	3.05	2.26	3.75	3.19	0.44
Std. Dev.	2.3	1.51	2.36	1.85	0.38
Skewness	-0.08	-0.03	-0.33	0.19	2.19
Kurtosis	1.34	1.74	1.73	2.27	8.19

Industrial Production

	CA	FR	GM	IT	JP	UK	US
Mean	0.11	0.01	0.05	-0.03	0.03	0	0.17
Std. Dev.	0.97	1.28	8.74	1.31	2.18	1.04	0.68
Skewness	-0.16	-0.24	0.14	-0.47	-3.21	-0.75	-1.82
Kurtosis	3.82	4.48	2.46	4.1	24.97	8.47	12.05

Term Spread

	CA	FR	GM	IT	JP	UK	US
Mean	1.65	1.71	1.39	1.96	1.44	0.75	1.72
Std. Dev.	1.06	0.88	0.95	1.38	0.62	1.48	1.16
Skewness	0.18	-0.27	-0.38	0.42	0.95	0.14	-0.05
Kurtosis	1.95	2.16	2.67	2.30	3.23	1.98	1.86

Credit Spread

	CA	FR	GM	IT	JP	UK	US
Mean	2.96	3.08	2.72	2.89	1.10	1.59	4.01
Std. Dev.	1.33	1.68	1.43	1.52	0.69	1.07	1.86
Skewness	0.49	1.16	1.01	1.37	2.36	1.15	0.79
Kurtosis	3.30	4.06	4.09	5.00	8.25	4.85	4.32

Table 2.4 Unit root tests

Variables	US	UK	GM	FR	IT	CA	JP
main rate	-2.10	-2.77	-1.31	-1.31	-1.31	-1.83	-2.05
Δmain rate	*-5.81**	*-5.83**	*-7.62**	*-7.62**	*-7.62**	*-6.95**	*-8.32**
IP	-1.91	-0.95	-1.15	-1.59	-1.47	-1.29	-1.18
ΔIP	*-5.16**	*-20.60**	*-6.92**	*-7.93**	*-7.05**	*-7.65**	*-7.12**
3mrate	-2.12	-2.81	-1.55	-1.79	-1.71	-1.94	-1.01
Δ3mrate	*-5.48**	*-6.02**	*-10.75**	*-12.57**	*-16.09**	*-10.11**	*-6.09**
10yrrate	-1.77	-2.69	-1.31	-2.05	-1.68	-1.95	-1.87

Δ10yrrate	*-6.13**	*-6.62**	*-8.30**	*6.96**	*-6.45**	*-6.68**	*-5.86**
10yrBBBrate	-1.25	-0.98	-1.58	-1.88	-1.12	-0.76	-0.95
Δ10yrBBBrate	*-5.26**	*-6.25**	*-5.89**	*-7.32**	*-5.23**	*-5.12**	*-6.03**
Treasury rates	US	Treasury rates	US				
1m	-1.91	2yr	-1.68				
Δ1m	*-8.93**	*Δ2yr*	*-6.21**				
3m	-2.12	3yr	-1.55				
Δ3m	*-5.48**	*Δ3yr*	*-7.21**				
6m	-1.75	5yr	-1.78				
Δ6m	*-6.69**	*Δ5yr*	*-5.81**				
9m	-1.42	7yr	-2.23				
Δ9m	*-5.19**	*Δ7yr*	*-9.54**				
12m	-1.78	10yr	-1.77				
Δ12m	*-6.77**	*Δ10yr*	*-6.13**				

Note: The table presents the results from Augmented Dickey-Fuller tests. The 1% critical values for stationarity are -3.46 for ADF test and (*) indicates significance at the 99% confidence level. The results for each variable are presented both in levels and first differences (Δ). IP is the industrial production growth, 3mrate is the 3-month Treasury bond rate, 10yrrate is the 10-year Treasury bond rate and 10yrBBBrate is the 10-year corporate BBB bond rate.

Table 2.5 Summary statistics of principal components

Factors	pc1	pc2
Mean	0	0
Maximum	5.25	1.09
Minimum	-4.45	-1.01
Std. Dev.	2.78	0.52
Skewness	-0.09	0.1
Kurtosis	1.65	2.05
	Correlation Coefficients	
Factor A	0.99	
Factor B		0.79

Note: The table presents the descriptive statistics, mean, maximum and minimum values, standard deviation (Std.Dev.), skewness and kyrtosis for the two principal components (pc1, pc2) as captured from PCA. Also table sho the correlation coefficients of Factor A (average of 3-month, 2-year and 10-year bond rates) and Factor B (10-year bond rate minus 3-month bond rate) with pc1 and pc2 respectively.

Figure 2.1 Loadings coefficients of the principal component factors

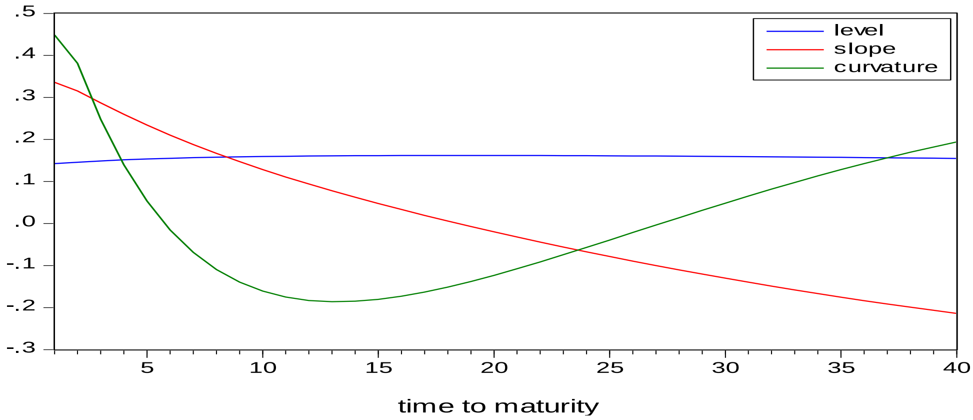


Table 2.6 Results of equation 2.13 in pre- and post- crisis periods

PRE-CRISIS						POST CRISIS				
	n=1	n=2	n=3	n=6	n=12	n=1	n=2	n=3	n=6	n=12
Level	0.240*** (0.06)	0.218*** (0.06)	0.162*** (0.06)	0.188*** (0.07)	0.157 (0.09)	1.097** (0.49)	1.293** (0.54)	0.759 (0.64)	1.494** (0.64)	1.853** (0.75)
Slope	0.408*** (0.15)	0.581*** (0.17)	0.371** (0.18)	0.472*** (0.16)	0.317 (0.25)	-1.222 (0.75)	-1.44 (0.84)	-1.003 (0.79)	-2.247** (0.88)	-2.069** (0.93)
Curvature	0.948 (0.56)	0.337 (0.6)	-0.235 (0.49)	0.017 (0.47)	0.451 (0.59)	-0.043 (0.87)	2.021 (1.1)	1.294 (1.07)	1.273 (0.9)	1.962 (1.49)
Constant	0.140*** (0.05)	0.132** (0.05)	0.127** (0.05)	0.125** (0.05)	0.105 (0.06)	0.106 (0.1)	0.123 (0.1)	0.084 (0.12)	0.149 (0.11)	0.205** (0.1)
Adj-R^2	0.089	0.081	0.061	0.067	0.033	0.078	0.114	0.042	0.15	0.21

Note: The level, slope and curvature variables are estimated in first differences in order to be stationary. n denotes the number of periods (months) ahead. (***) indicates significance at 1%, (**) at 5% and (*) at 10%. Standard errors are in parentheses. These are corrected for heteroskedasticity and forward-looking moving average serially correlated errors based on Newey-West method.

Table 2.7 Results of equation 2.14 in pre- and post- crisis periods

PRE CRISIS						POST CRISIS				
	n=1	n=2	n=3	n=6	n=12	n=1	n=2	n=3	n=6	n=12
Term spread	0.472** (0.21)	0.466** (0.21)	-0.358 (0.21)	-0.141 (0.25)	0.172 (0.26)	0.605 (0.45)	0.437** (0.20)	0.289 (0.34)	0.016 (0.22)	0.058 (0.34)
Credit spread	0.139 (0.19)	-0.453** (0.20)	0.219 (0.20)	0.085 (0.28)	-0.068 (0.20)	-0.597*** -0.18	-1.118*** (0.16)	-0.728*** (0.20)	-0.695*** (0.23)	-0.485 (0.31)
LIBOR spread	0.157 (0.25)	0.202 (0.30)	0.399 (0.28)	-0.358 (0.31)	-0.065 (0.38)	-1.294** -0.59	-0.676 (0.43)	-0.348 (0.69)	-0.372 (0.57)	-0.165 (0.76)
Constant	0.195*** (0.05)	0.190*** (0.05)	0.193*** (0.05)	0.183*** (0.05)	0.155*** (0.05)	0.029 -0.1	0.051 (0.08)	0.042 (0.10)	0.043 (0.10)	0.042 (0.11)
Adj-R^2	0.037	0.048	0.017	0.029	0.005	0.148	0.306	0.125	0.143	0.062

Note: The term, credit and LIBOR spreads are estimated in first differences in order to be stationary. n denotes the number of periods (months) ahead. (***) indicates significance at 1%, (**) at 5% and (*) at 10%. Standard errors are in parentheses. These are corrected for heteroskedasticity and forward-looking moving average serially correlated errors based on Newey-West method.

Table 2.8 Correlations between term structure factors and economic measures

PRE CRISIS			POST CRISIS		
	Level	Infl.Comp.		Level	Infl.Comp.
Level	1		Level	1	
Infl.Comp.	0.635	1	Infl.Comp.	0.104	1

PRE CRISIS			POST CRISIS		
	Slope	FFR		Slope	FFR
Slope	1		Slope	1	
FFR	-0.519	1	FFR	0.052	1

Note: FFR is the FED funds rate, slope and level are the two principal components, and Infl.Comp. is the spread between 10-year nominal bond rate and 10-year inflation linked bond rate for US.

Table 2.9 Term structure model estimation results

	Estimated parameters Φ				μ
L_t	0.990*** (0.008)	-0.002 (0.004)	0.021 (0.015)	0.004 (0.007)	0.001
S_t	-0.055 (0.042)	0.924*** (0.023)	0.107 (0.081)	-0.037 (0.041)	0.007
IP_t	0.067** (0.029)	-0.015 (0.015)	0.199*** (0.016)	0.012 (0.030)	0.399
$Infl_t$	0.148** (0.055)	0.055** (0.031)	0.281 (0.122)	0.458*** (0.027)	0.201

Short rate parameters (δ_{1}) for latent and observable factors

Level	Slope	IP	Inflation
0.771***	-0.962***	0.460**	0.701*
(0.02)	(0.27)	(0.208)	(0.405)

Risk premia parameters

Level	Slope	IP	Inflation
-0.056***	0.929***	-0.061**	-0.081**
(0.005)	(0.031)	(0.025)	(0.035)

Notes: (***), (**) and (*) indicates significance at 1%, 5% and 10% respectively. Table reports the parameter estimates and standard errors (in parentheses) from estimation model, short rate equation and risk premia. The model is $X_t = \mu + \Phi X_{t-1} + \varepsilon_t$. X contains a lag of industrial production and inflation as well as the latent variables. Thee short rate equation is given by $r_t = \delta_0 + \delta_1 X_t$, and the market prices of risk are defined as $\Lambda_t = \Lambda_0 + \Lambda_1 X_t$

Figure 2.2 Time variation in yield risk premia

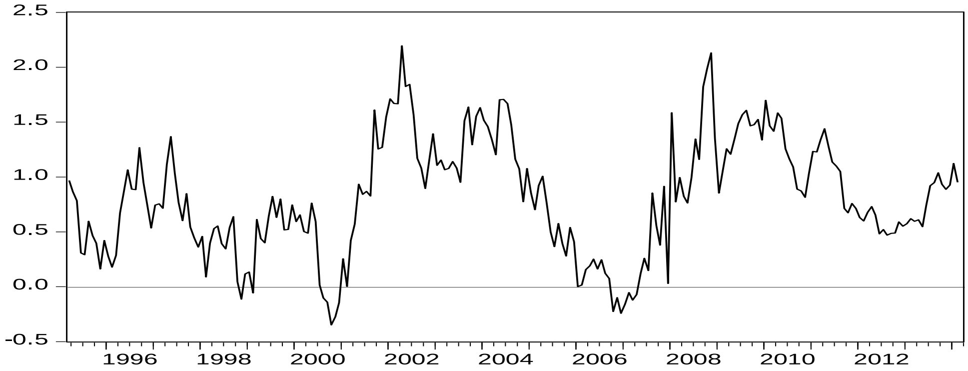
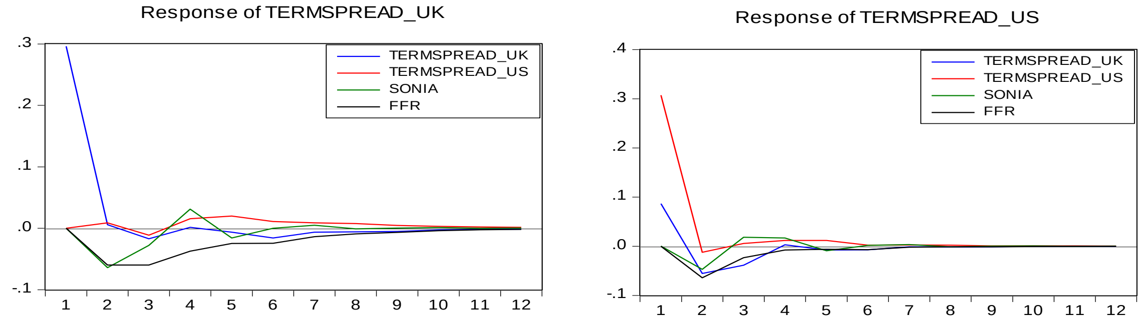
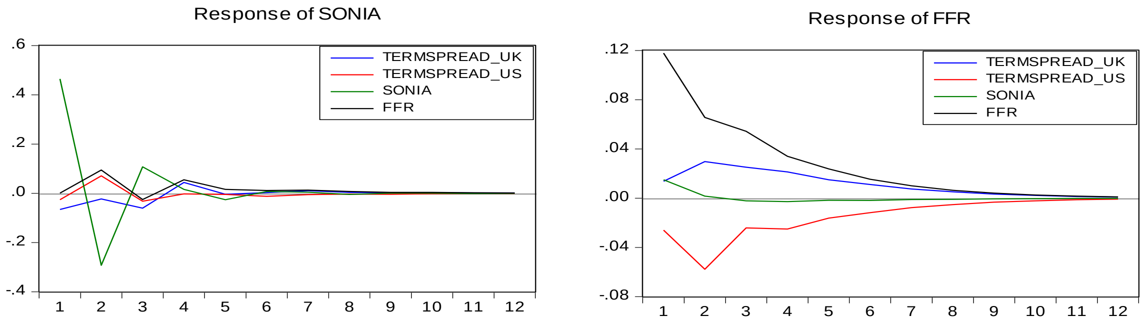


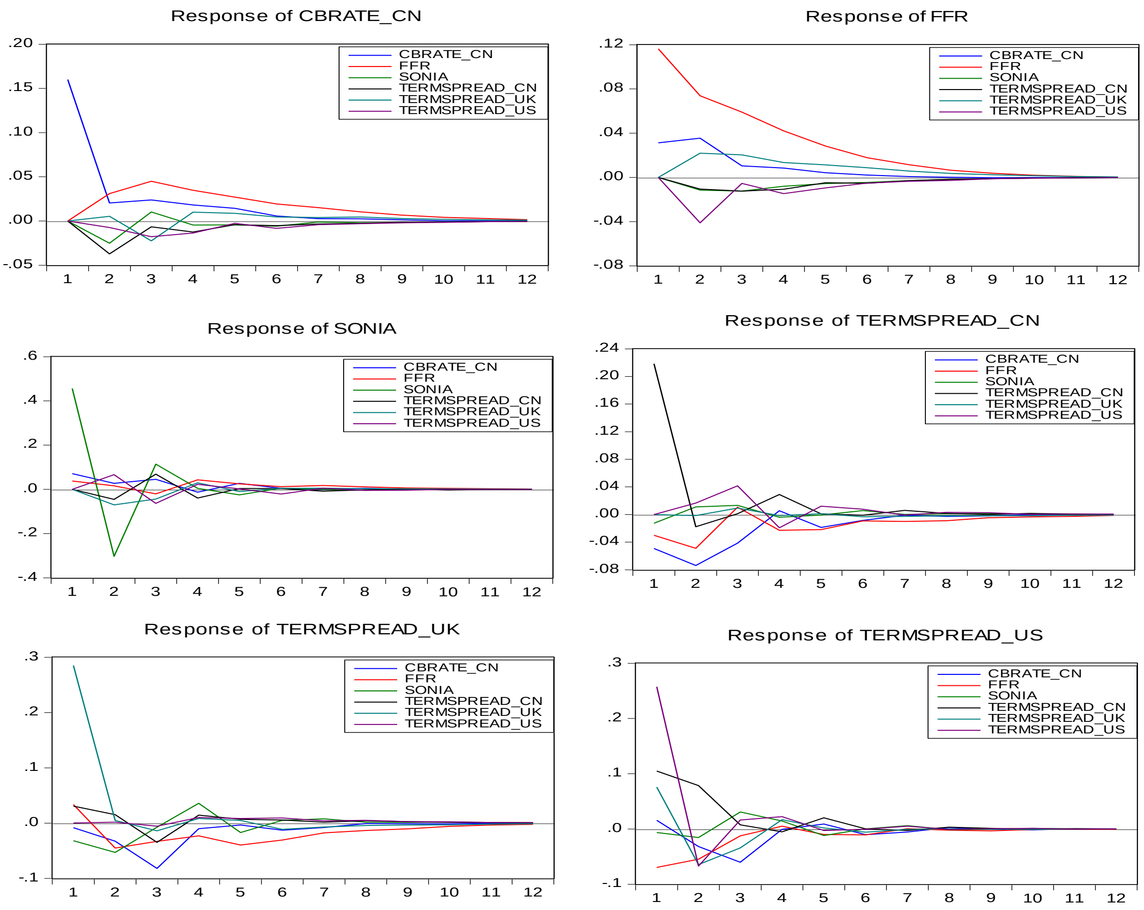
Figure 2.3 Impulse response graphs of the VAR models

Panel A. US-UK

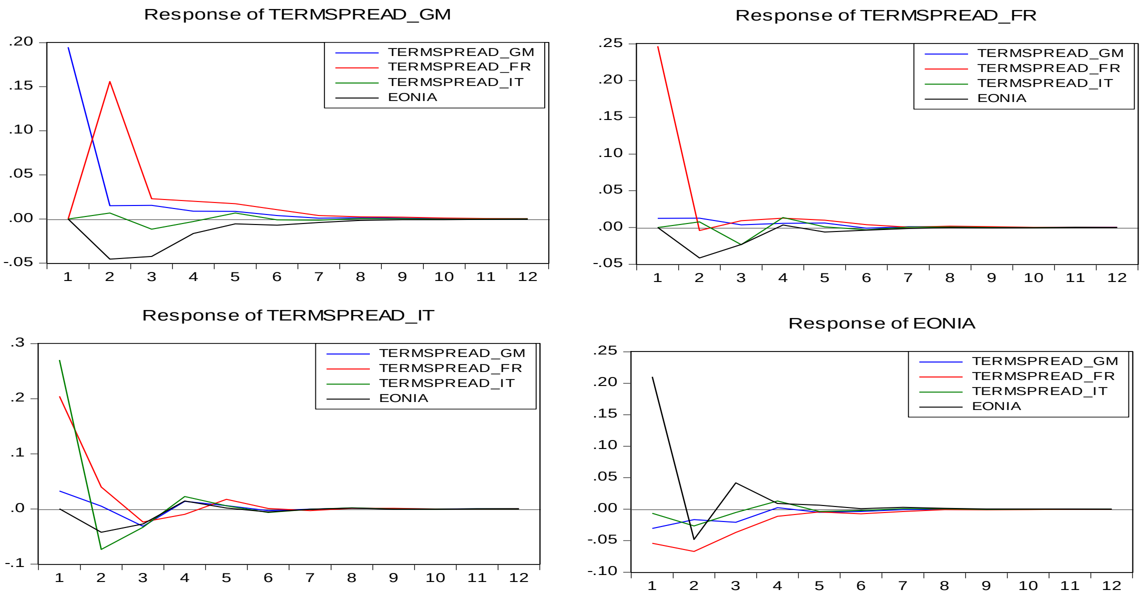




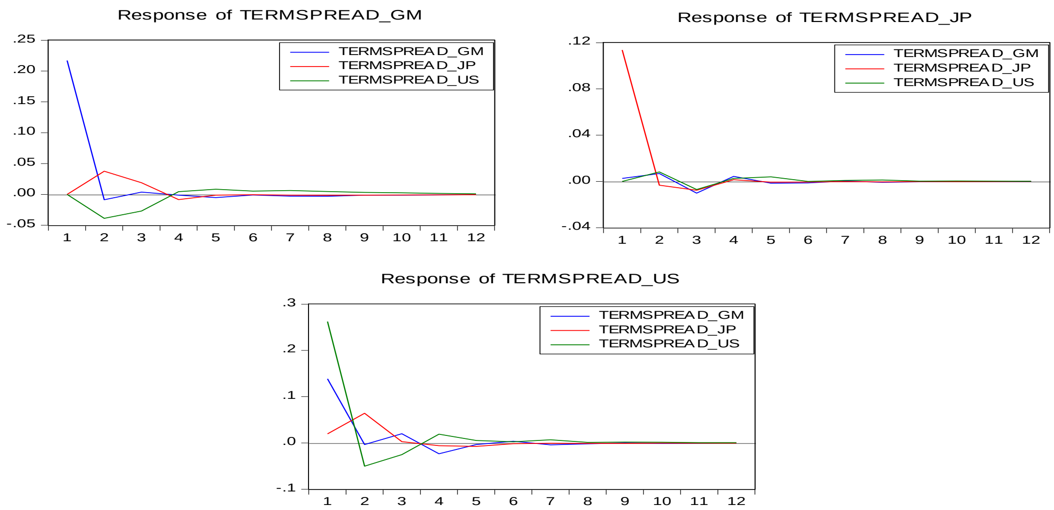
Panel B. US-UK-CN



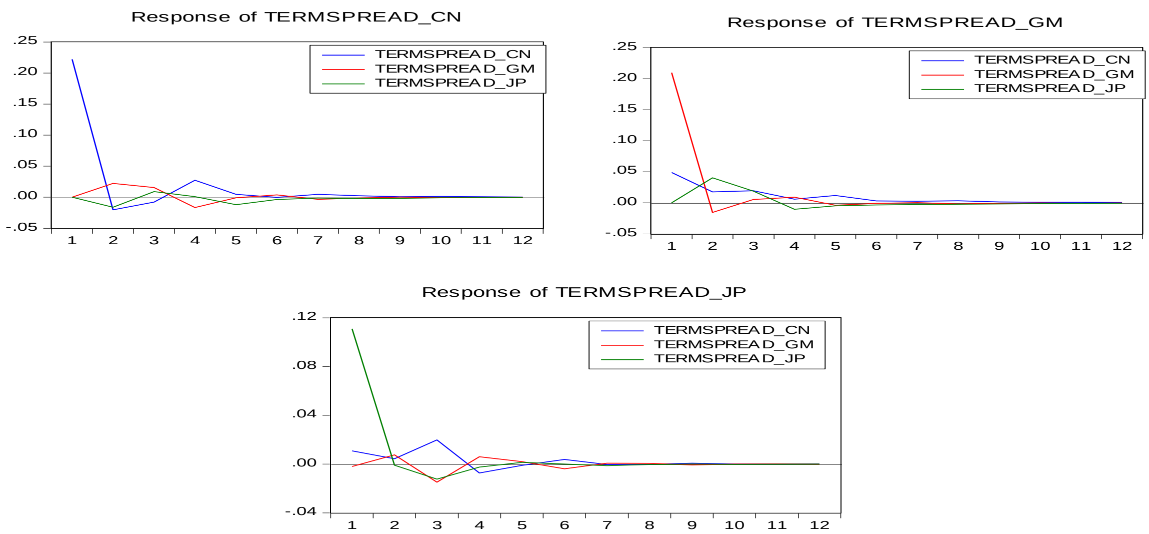
Panel C. Germany-France-Italy



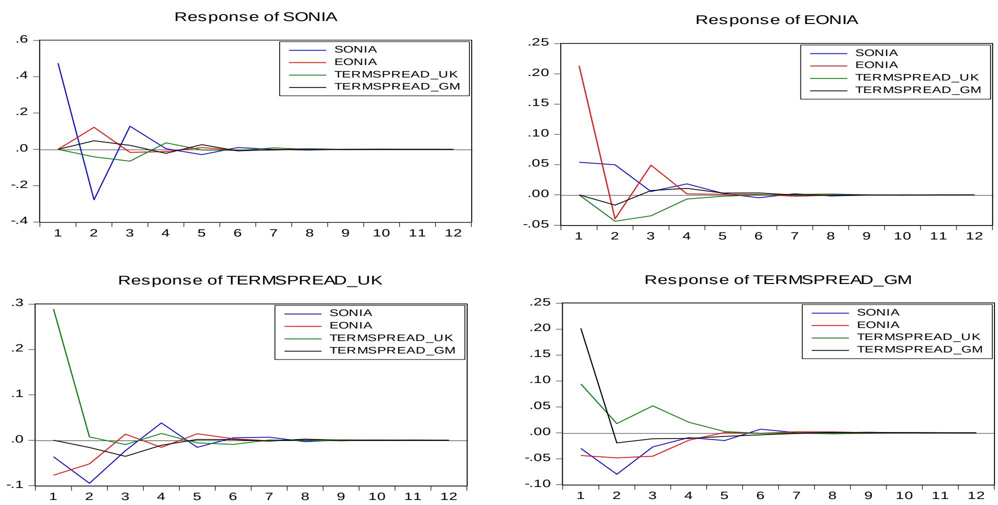
Panel D. US-GM-JP



PANEL E. Japan-Canada-Germany



Panel F. UK-GM



Panel G. Credit spreads

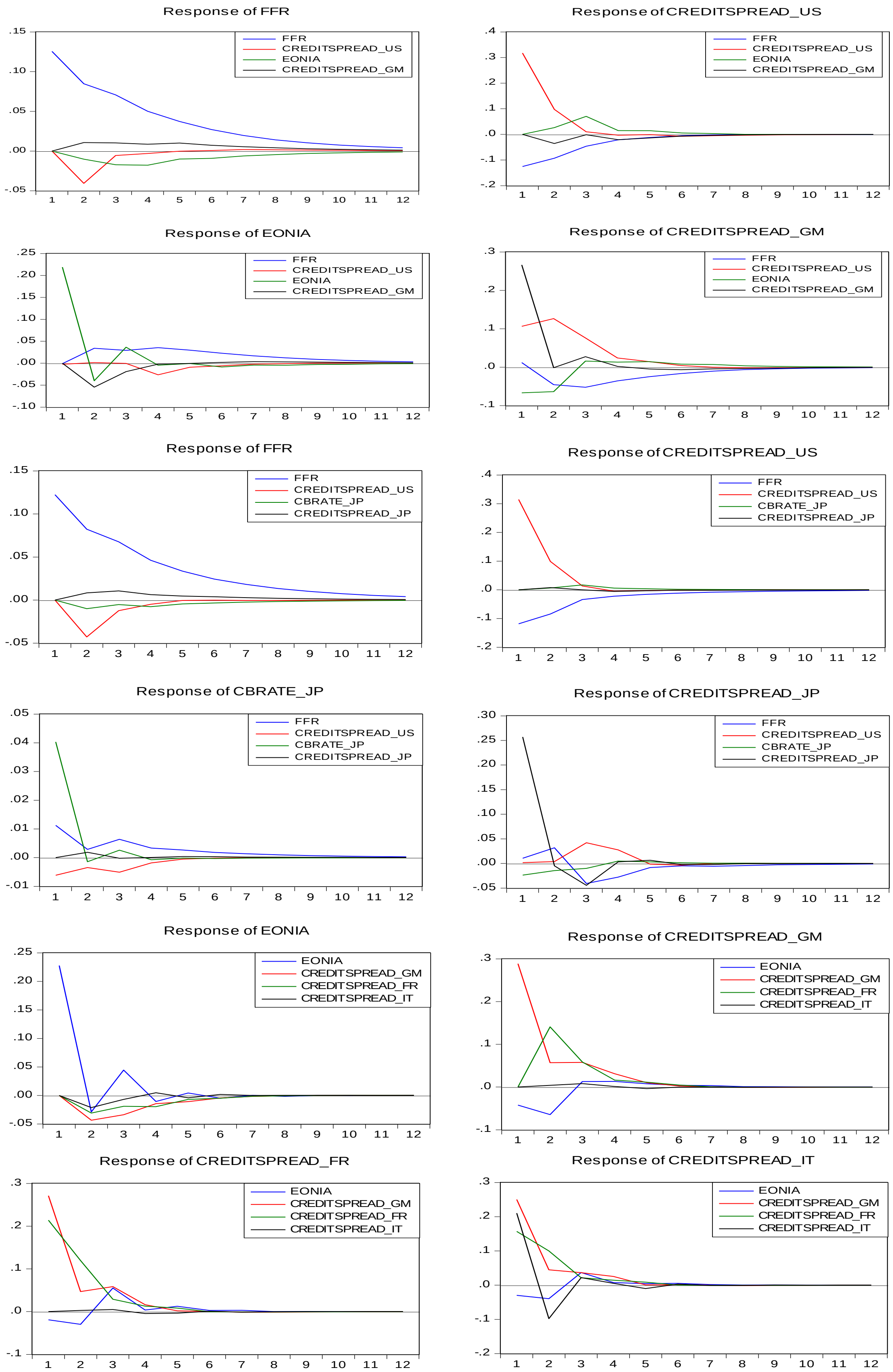


Table 2.10 Markov switching regression results for Canada

Constant transition probabilities			Constant expected durations	
	1	2	1	2
1	0.986	0.013	72.84	7.835
2	0.127	0.872		

	Regime 2	Recession
Regime 2	1	
Recession	0.612	1

Figure 2.4 Canada-Markov recession regime probabilities and actual recession periods

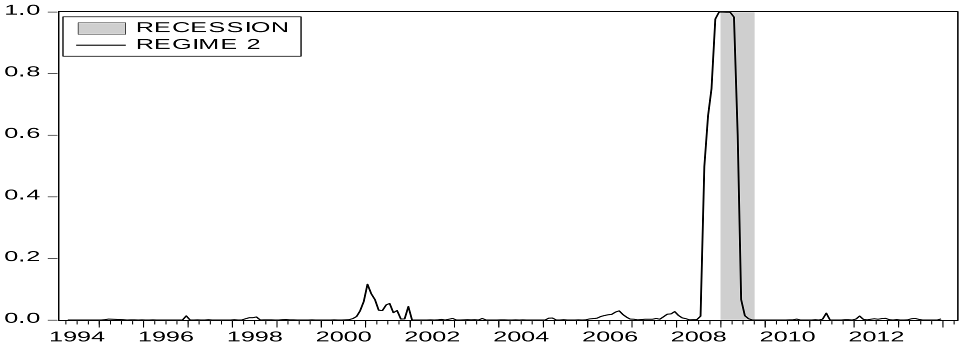


Table 2.11 Markov switching regression results for Japan

Constant transition probabilities			Constant expected durations	
	1	2	1	2
1	0.988	0.011	87.77	5.71
2	0.175	0.824		

	Regime 2	Recession
Regime 2	1	
Recession	0.412	1

Figure 2.5 Japan-Markov recession regime probabilities and actual recession periods

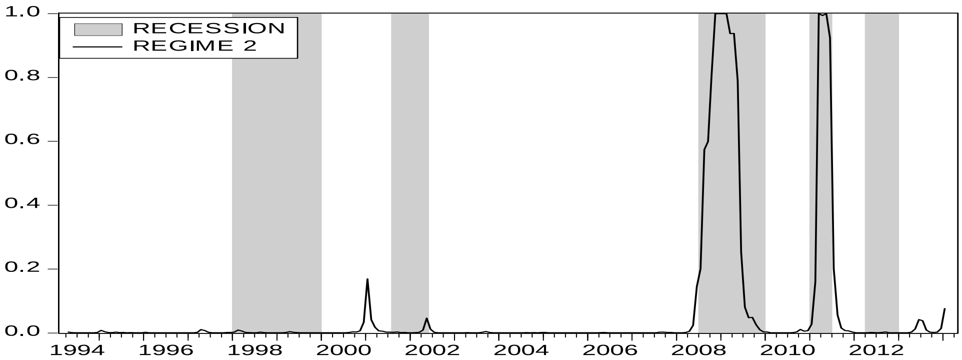


Table 2.12 Markov switching regression results for US

Constant transition probabilities	Constant expected durations

	1	2		1	2
1	0.874	0.126		7.938	47.731
2	0.021	0.981			

	Regime 1	Recession
Regime 1	1	
Recession	0.836	1

Figure 2.6 US-Markov recession regime probabilities and actual recession periods

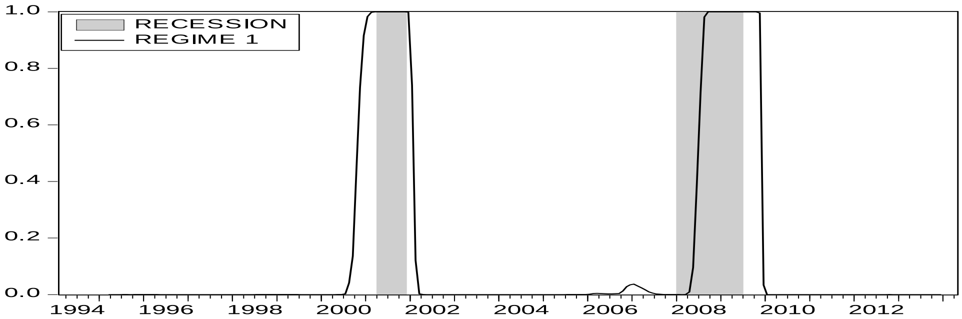


Table 2.13 Markov switching regression results for UK

Constant transition probabilities				Constant expected durations	
	1	2		1	2
1	0.992	0.007		130.522	6.035
2	0.165	0.834			

	Regime 2	Recession
Regime 2	1	
Recession	0.714	1

Figure 2.7 UK- Markov recession regime probabilities and actual recession periods

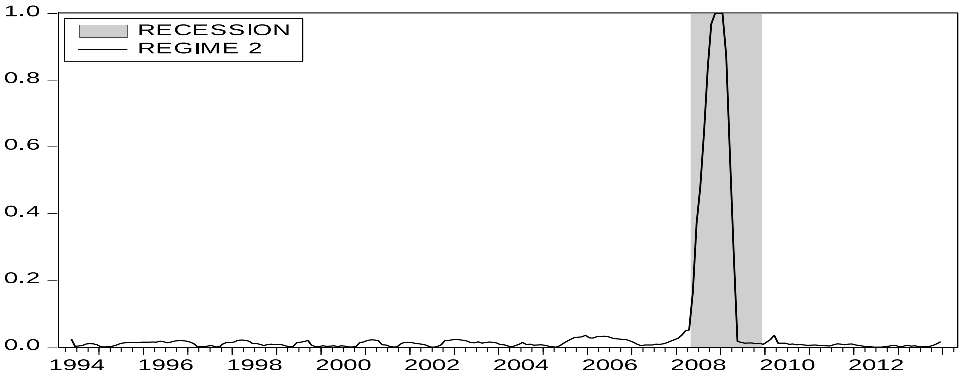


Table 2.14 Markov switching regression results for Germany

Constant transition probabilities				Constant expected durations	
	1	2		1	2

1	0.774	0.232		4.581	237.152
2	0.004	0.997			

	Regime 1	Recession
Regime 1	1	
Recession	0.401	1

Figure 2.8 Markov recession regime probabilities and actual recession periods

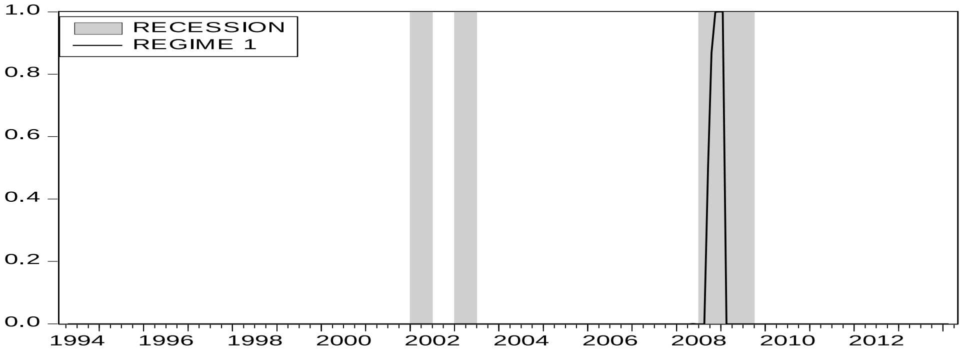


Table 2.15 Markov switching regression results for France

Constant transition probabilities				Constant expected durations	
	1	2		1	2
1	0.985	0.015		67.275	2.796
2	0.357	0.643			

	Regime 2	Recession
Regime 2	1	
Recession	0.626	1

Figure 2.9 France-Markov recession regime probabilities and actual recession periods

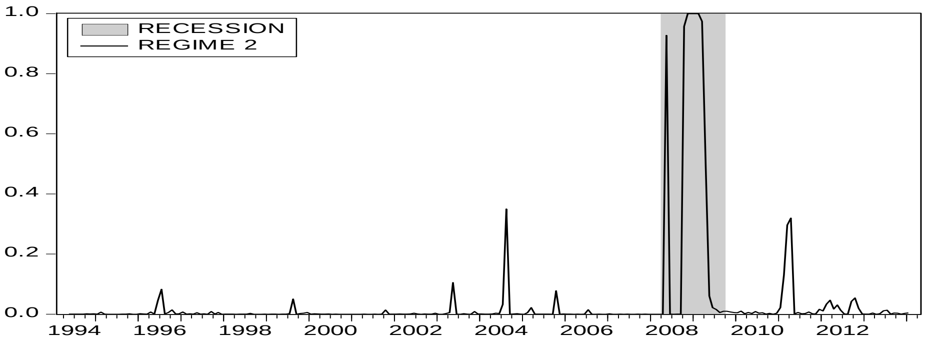


Table 2.16 Markov switching regression results for Italy

Constant transition probabilities				Constant expected durations	
	1	2		1	2
1	0.926	0.074		13.623	46.981

2	0.022	0.978

	Regime 1	Recession
Regime 1	1	
Recession	0.650	1

Figure 2.10 Italy-Markov recession regime probabilities and actual recession periods

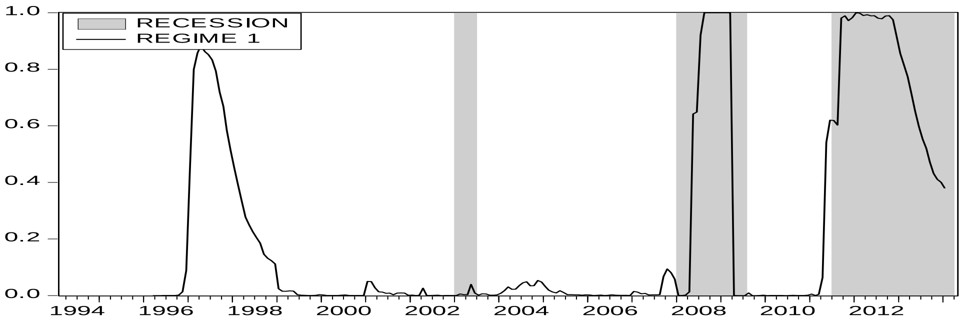
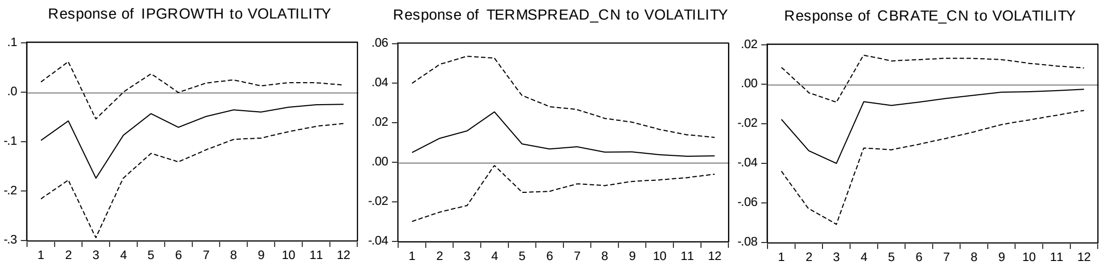
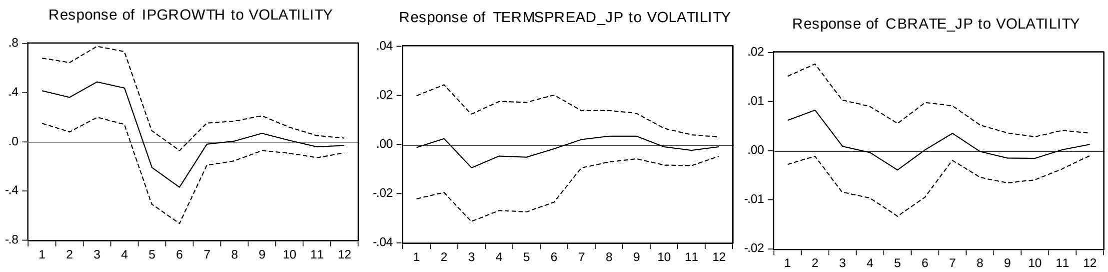


Figure 2.11 GIRFs results for market volatility effect on economy

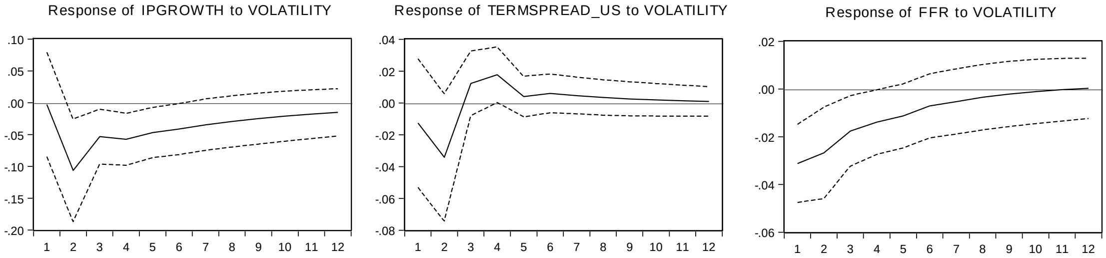
Panel A. Canada



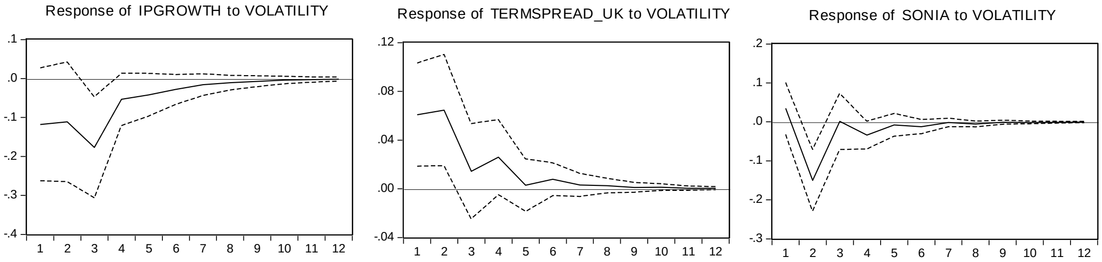
Panel B. Japan



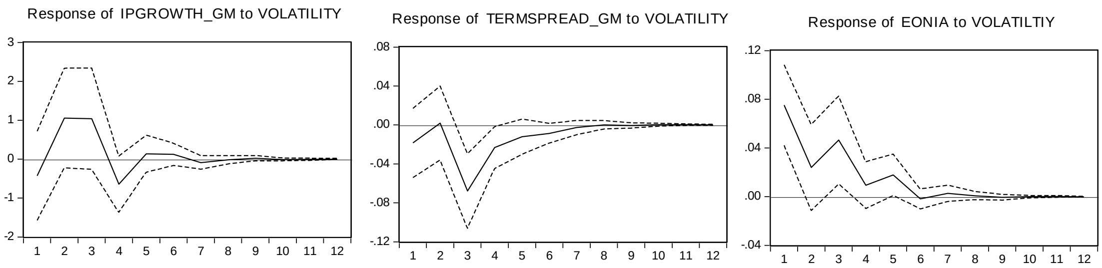
Panel C. US



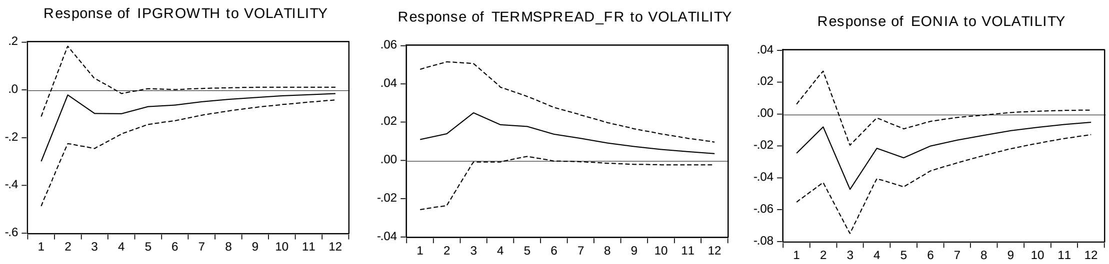
Panel D. UK



Panel E. Germany



Panel F. France



Panel G. Italy

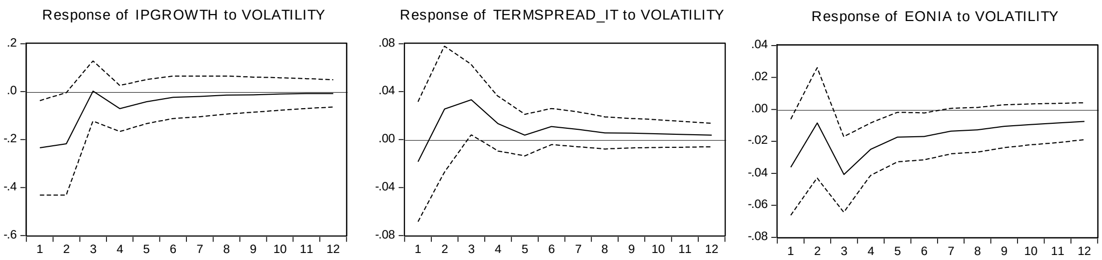


Table 2.17 Correlation for market volatility, industrial production and recession periods

	IP_CA	IP_FR	IP_GM	IP_IT	IP_JP	IP_UK	IP_US
VOL_CA	**-0.526**	-0.471	-0.155	-0.487	-0.404	-0.458	-0.533
VOL_FR	-0.328	**-0.372**	-0.096	-0.393	-0.331	-0.319	-0.313
VOL_GM	0.169	0.001	**0.011**	0.037	0.044	0.026	-0.029
VOL_IT	-0.251	-0.224	-0.066	**-0.455**	-0.181	-0.196	-0.154
VOL_JP	-0.035	-0.081	0.033	-0.093	**-0.042**	-0.089	-0.226
VOL_UK	-0.278	-0.412	-0.124	-0.395	-0.335	**-0.398**	-0.334
VOL_US	-0.391	-0.231	-0.096	-0.276	-0.211	-0.253	**-0.428**

	REC_CA	REC_FR	REC_GM	REC_IT	REC_JP	REC_UK	REC_US
VOL_CA	**0.464**	0.646	0.686	0.385	0.351	0.609	0.623
VOL_FR	0.196	**0.334**	0.365	0.293	0.118	0.302	0.360
VOL_GM	-0.495	-0.165	**-0.278**	0.140	-0.338	-0.255	0.035
VOL_IT	0.439	0.308	0.407	**0.358**	0.385	0.346	0.132
VOL_JP	-0.334	0.128	-0.037	0.136	**-0.213**	0.031	0.364
VOL_UK	0.080	0.372	0.389	0.184	0.106	**0.341**	0.388
VOL_US	0.681	0.661	0.751	0.092	0.519	0.697	**0.509**

Note: IP is the industrial production growth, VOL is the proxy for market volatility and REC is the recession period for each country. The bold values indicate correlation coefficients between variables for each country.

Table 2.18 Eurozone countries in financial and debt crises

	Germany	France	Italy
Term spread	-0.302 (0.32)	0.831** (0.33)	-2.340*** (0.37)
Credit spread	-4.073*** (0.54)	-1.884*** (0.33)	0.482** (0.19)
TS×Crisis	3.795*** (0.9)	3.398*** (0.67)	3.816*** (0.57)
CS×Crisis	-0.373 (0.42)	-1.788*** (0.38)	-3.975*** (0.5)
Constant	11.253*** (0.93)	4.668*** (0.61)	3.402*** (0.48)
Adj-R^2	0.421	0.529	0.447

Note: The term spread and the credit spread are estimated in first differences in order to be stationary. The dependent variable is the industrial production growth. TS×Crisis denotes the interaction term of term spread and crisis dummy and CS×Crisis indicates the interaction term of credit spread with crisis dummy. (***) indicates significance at 1%, (**) at 5% and (*) at 10% level. Standard errors are in parentheses. These are corrected for heteroskedasticity and forward-looking moving average serially correlated errors based on Newey-West method.

Table 2.19 Estimation results for the monetary policy and the term structure

	I	II	III
FFR	-0.537***		-0.11
	(0.02)		(0.13)
Securities		-2.211**	-2.331**
		(0.01)	(0.02)
Constant	3.613***	2.436***	2.373***
	(0.09)	(0.09)	(0.12)
Adj-R^2	0.125	0.143	0.154

Note:(***) indicates significance at 1%, (**) at 5% and (*) at 10%. The dependent variable is the industrial production growth. Standard errors are in parentheses. These are corrected for heteroskedasticity and forward-looking moving average serially correlated errors based on Newey-West method.

Model I is $tsp_t = \beta_0 + \beta_1 ffr_t + \varepsilon_t$ for 1994-2007 period.

Model II is $tsp_t = \beta_0 + \beta_1 securities_t + \varepsilon_t$ for 2007-2014 period

Model III is $tsp_t = \beta_0 + \beta_1 ffr_t + \beta_2 securities_t + \varepsilon_t$ for 2007-2014 period

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