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Economics from the Nova School of Business and Economics.

THE EFFECT OF MACROECONOMIC VARIABLES ON GOVERNMENT BOND YIELDS
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AN ANALYSIS FOR THE EUROPEAN GOVERNMENT BOND MARKET

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Abstract: This work project examines the effect of certain macroeconomic variables on the yield of government bonds. By using time series data on the weighted average of government bond yields for the 27 member states of the European Union, this research employs a Vector Error Correction Model (VECM) to uncover both short- and long-term relationships. Variables under considerations are inflation, money supply, the market interest -, the exchange - and the unemployment rate. An impulse response functions and forecast error variance decomposition analysis concludes the work to examine the significance and persistence of these effects over time.

Keywords: government bond yields; macroeconomic variables; vector error correction model; impulse response functions; forecast error variance decomposition

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I. Introduction

Government bonds are a fundamental component of the financial system, functioning as an instrument for public funding, a tool for monetary policy and a low risk asset for investors seeking portfolio diversification. Reflecting their importance, 83.4% of the general government gross debt across the member states of the European Union (EU) was composed of government bonds in the first quarter of 2024. This results in a government bonds-to-gross domestic product (GDP) ratio of 68.4% (Eurostat 2024). As a public financing instrument, sovereign bonds enable governments to fund i.e. infrastructure projects, social programs or defence without the need of immediate taxation. Moreover, government bonds play a critical role in monetary policy, allowing central banks to control money supply and manage interest rates. From the investor's perspective, government bonds are often seen as safe-haven investments during periods of economic uncertainty and market volatility, particularly in economically stable countries such as Germany. Therefore, understanding the dynamics of government bond yields is crucial not only for policymakers in shaping budgetary decisions and formulating economic policies, but also for investors seeking to optimize returns from their investment portfolios.

Following this relevance of government bonds for the European Union member states, it is important to understand how the yields of government bonds are affected by macroeconomic conditions. Existing literature in determining the yield of governments bonds identifies credit risk, global risk aversion and liquidity risk as the key drivers. In addition to these drivers, the research reveals that government bond yields are also affected by a broader set of macroeconomic variables. In order to analyse the dynamic interrelationship between macroeconomic conditions and government bond yields, the Vector Error Correction Model is commonly used. The approach allows to analyse the effect of macroeconomic indicators such as inflation, exchange rate or market interest rate in both the short- and long-run. This work

project builds upon the existing literature, by employing a Vector Error Correction Model to analyse the effect of inflation, money supply, the interest rate, the exchange rate and the unemployment rate on European government bond yields. Previous studies primarily analyse the interrelationships between macroeconomic variables and government bond yields in developing countries. In contrast, this research examines these dynamics using time series data on the weighted average of government bond yields for the 27 member states of the European Union. The analysis begins with standard unit root tests on the time series data, followed by the identification of cointegration among the government bond yield variable and the macroeconomic indicators. A Vector Error Correction Model is subsequently developed, concluding with an analysis of impulse response functions and forecast error variance decomposition. The analysis reveals dynamic interrelationships between the five macroeconomic variables and the yield of government bonds in both the short- and the long-run. Analysing the short-run relationships, through a Granger causality assessment, shows that inflation, money supply, the market interest rate, the exchange rate and the unemployment rate, jointly Granger cause government bond yields. However, only inflation Granger causes the yield of government bonds individually. In the long-run, the impulse response functions indicate significant effects on the yield of government bonds through shocks in inflation and the exchange rate. The forecast error variance decomposition supports this by showing that in the long-run around 35% and 15% of the variance in the errors of the government bond yield variable can be explained by inflation and the exchange rate respectively (36 months ahead). This work project concludes by comparing the results of the analysis for the weighted average government bond yields with three single-country analyses, which use the same methodological approach. The findings reveal that inflation consistently affects government bond yields across the examined countries, Portugal, Italy and Germany. However, variations in the effect of the other variables highlight disparities among these European Union member states.

The rest of this work is structured as follows. Section II. reviews the existing literature, with a particular focus on Vector Error Correction Models explaining macroeconomic conditions affecting government bond yields. Section III. describes the data used in this work, before section IV. outlines the research methodology. In section V. the econometric results are presented. The last section gives a brief conclusion of the work project.

II. Literature Review

The existing literature focusses on determining the yields of government bonds and analysing the effect of additional macroeconomic indicators on government bond yields. While both areas are intertwined, as macroeconomic indicators can be part of the broader determinants of bond yields, they represent different perspectives. The former body of literature typically seeks to understand how government bond yields are set, either through market mechanisms, government policy, or other factors. It often involves models that aim to predict or calculate bond yields based on various inputs, such as the demand for bonds, risk premiums, or fiscal conditions of a government. These research works are more focused on the structural and fundamental drivers of bond yields. The latter type of research investigates how additional macroeconomic variables influence bond yields. While using multivariate time series data models, the focus is on understanding the dynamic relationship between bond yields and the broader economy, particularly how shifts in macroeconomic conditions affect the yield on government bonds.

The literature determining the yield of government bonds, like (Afonso, Arghyrou and Kontonikas 2012), (Poghosyan 2014) or (Pinho and Barradas 2021), follow either a single-country or panel data approach. By using a panel data set of ten countries of the European Economic and Monetary Union, (Afonso, Arghyrou and Kontonikas 2012) assess the

determinants of long-term government bond yields for three different periods. The results revealed that different time periods lead to different main drivers for the yield of government bonds. This might be intuitive as changing macroeconomic conditions affect the results, however it allows (Pinho and Barradas 2021) to categorize, in their single-country research work for Portugal, the risk into three different key drivers: credit risk, global risk aversion and liquidity risk.

Firstly, investors seek a credit risk premium that relies mainly on the likelihood of the bond issuer defaulting. Higher credit risk prompts investors to demand increased yields as compensation. Generally, a government's credit risk is reflected by fiscal indicators like debt-to-GDP and deficit-to-GDP ratios, with higher ratios signalling a greater default risk (Klepsch and Wollmershäuser 2011). In addition to government debt, (Poghosyan 2014) identifies potential output growth as the second core credit risk driver of long-term government bond yields. From a theoretical point of view the impact of output growth on the yield of government bonds is ambiguous. On the one hand, the combination of the Ramsey optimal growth model and households with constant preferences, leads to a positive relation between output growth and a government bond yield (Poghosyan 2014; Laubach 2009). On the other hand, one can argue that an improved macroeconomic performance leads to improved debt servicing capabilities of the respective government in the future, leading to lower government bond yields (Cantor and Frank 1996). This ambiguity is also reflected in empirical research. A positive relation between macroeconomic performance and government bond yields was observed by (Poghosyan 2014) and (Pinho and Barradas 2021). (Afonso, Arghyrou and Kontonikas 2012) in contrast observed an increase of government bond yields following a slowdown in output growth.

Government debt, identified as the other core driver of the long-run government bond yields, determines the yield of government bonds through the crowding-out effect and the

default risk premium. The default risk premium influences the yield, as it represents the probability that a government may not be able to repay its debt obligations. The crowding-out effect describes limited private investments due to a fiscal expansion. Therefore, both effects lead to a positive relationship between government debt and the yield of government bonds (Pinho and Barradas 2021). Ambiguous empirical results can also be observed for this determinant of the yield of government bonds, (Poghosyan 2014) or (Laubach 2009) observed that an increase in government debt is followed by an increase of government bond yields; (Pinho and Barradas 2021) observed an inverse relationship.

Secondly, (Klepsch and Wollmershäuser 2011) and (Pinho and Barradas 2021) add global risk aversion as the second key driver of government bond yields. Global risk aversion characterizes investors disposition toward risk exposure, particularly under conditions of heightened market uncertainty. This construct is frequently quantified through proxy measures like corporate bond spreads, which represent the yield differential between long-term corporate and government bonds. In the existing literature, these spreads are operationalized in various ways, often based on the ratings of corporate bonds, such as BBB or AAA. Generally, an expanded spread indicates a diminished risk tolerance among investors. Equity market volatility serves as an alternative measure, as higher volatility levels typically reflect elevated market uncertainty and an intensified risk-averse stance within the investor base. Empirical results show that this risk driver has a negative effect on government bond yields (Pinho and Barradas 2021).

Thirdly, the last key driver is the liquidity risk. In the government bond market, it reflects to the market's capacity to absorb transactions without significant price fluctuations, thus capturing the potential for capital losses when assets are liquidated early or traded in

smaller markets. Empirical research frequently utilizes bid-ask spreads or transaction volumes as proxies for liquidity, with larger, more active markets generally associated with lower liquidity risk and, consequently, reduced yield premiums. To compensate the risk of holding less liquid assets, investors typically require a liquidity premium, particularly under unfavourable market conditions (Pinho and Barradas 2021; Klepsch and Wollmershäuser 2011). This premium diminishes in markets with sufficient trading volume, allowing assets to be exchanged with minimal price disruption, while elevated transaction costs lead investors to demand higher yields (Haugh, Ollivaud and Turner 2009).

In regards of the second type of research, which focus on analysing the dynamic relationship between additional macroeconomic indicators and government bond yields, various research uses multivariate time series data models like the Vector Autoregressive model (VAR) or, depending on the existence of a long-term relationship, the Vector Error Correction Model (VECM). Effects of macroeconomic indicators on the yield of government bonds in Indonesia are examined by (Rahmatika 2019) and (Sihombing, Santoso and Hariyanti 2023). In both studies the effect is analysed by employing time series data in a VECM, as cointegration and therefore a long-term relationship exists. The same empirical approach is chosen by (Meyer and Hassan 2020) to analyse the impact of macroeconomic conditions on government bond yields in South Africa. Frequently assessed factors are the aforementioned three key drivers credit risk, global risk aversion or liquidity risk. However, in addition to these key drivers, the credit risk driver is analysed in further dimensions as i.e. the exchange rate, inflation rate, market interest rate, labour conditions or money supply (Pinho and Barradas 2021).

Empirical results indicate that the exchange rate (respective country's US Dollar exchange rate) impacts government bond yields in parallel, meaning a decrease in the exchange rate leads to a decrease in the yield of government bonds. This can be explained by the fact that

the decrease is followed by higher export than import values, leading to a lower deficit and therefore a decrease in the risk premium. However, in the long term, a depreciation may lead to greater uncertainty, as costs of imports and foreign debt increase a country's financial risk, which ultimately leads to rising government bond yields (Rahmatika 2019). Economic theory in regards of the effect of inflation on government bond yields suggests that an increase in inflation leads to higher government bond yields due to higher uncertainty, less demand for government bonds and an embedded inflation premium. This positive relationship is empirically confirmed by (Meyer and Hassan 2020), (Pinho and Barradas 2021) and (Sihombing, Santoso and Hariyanti 2023). Empirical results for the market interest rate and its effect on government bond yields indicate ambiguous results (Rahmatika 2019; Meyer and Hassan 2020; Sihombing, Santoso and Hariyanti 2023). Labour conditions is a less commonly used macroeconomic indicator for government bond yields. However, (Pinho and Barradas 2021) reveals that an increase in labour productivity leads to a negative effect on government bond yields, explained by a greater economic robustness leading to less uncertainty and a smaller risk premium. (Rahmatika 2019) assesses in its research work the effect of an increase in the money supply, which from a theoretical point of view, enhances liquidity by increasing the purchasing power of investors which subsequently lowers yields on government bonds. The empirical results support this economic reasoning (Rahmatika 2019).

Existing literature in analysing the effect of macroeconomic variables on government bonds is mainly focusing on developing countries. Therefore, this work project aims to conduct an empirical analysis of the effect of macroeconomic indicators on government bond yields in Europe. For this purpose, time series data of the weighted average of government bond yields for the 27 members of the European Union, provided by Eurostat, is used. The work project focusses on the following five macroeconomic indicators and their effect on government bond

yields: inflation, money supply, European Central Bank (ECB) interest rate, Euro/Dollar exchange rate and the unemployment rate. The Vector Error Correction Model approach is used to analyse both, short- and long-run relationships. This work is aimed to serve governments and fiscal policy makers for the management of their borrowing costs, central banks in anticipating market reactions and institutional and private investors for the construction of an optimal portfolio.

III. Data

This research uses monthly data from January 2002 to June 2024. A large time period allows to capture effects properly through sufficient observations (270). As this work examines the effect of macroeconomic conditions on European government bond yields, the variable of interest is the government bond yield in the Euro area. The macroeconomic indicators include the inflation, the money supply, the interest rate, the Euro-Dollar exchange rate, the unemployment rate, the consumer spending growth rate and the growth rate for industrial production. The data is sourced from the Eurostat database, the ECB data portal and the St. Louis Federal Reserve Economic Data (FRED) statistics database.

The variable for European government bond yields ("*GBY*") is derived from the Maastricht Treaty EMU convergence criterion time series which refers to long-term government bond-yields of the 27 European Union member states. The time series reflects harmonised long-term (residual maturity of around 10 years) borrowing costs for central governments of the member states, making it highly suitable for tracking changes and trends in sovereign debt markets over time. The time series data is expressed in percentages per annum provided by Eurostat. Inflation ("*HICP*") is reflected by the Harmonised Consumer Price Index in the Euro area and represents the increase in the overall price level of goods and services. This

time series data is expressed as annual percentage rate of change and provided by the European Central Bank. The Money Supply ("*M2S*") in the Euro area is captured by the M2 monetary aggregate. This monetary aggregate includes the sum of currency in circulation, overnight -, two-year maturity - and at notice of up to three months redeemable deposits. Sourced from the ECB Data Portal, it reflects the liquidity available in the economy in millions of dollars. In order to capture the monthly developments of the European Central Bank interest rate ("*ECBIR*"), the ECB deposit facility rate provide by the St. Louis FRED statistics database is considered. Being a key tool of the ECB's monetary policy, expressed as an annual percentage rate, the ECB interest rate reflects the overnight rate at which banks can deposit excess cash reserves with the ECB. The Euro-Dollar exchange rate ("*EXR*") is expressed in US Dollars and sourced from Eurostat, providing information about the value of the Euro relative to the US Dollar. Measuring the percentage of the population in the labour force that is unemployed, the unemployment rate variable ("*UNEMP*"), sourced from Eurostat, provides an indicator of the labour market health. The consumer spending growth rate variable ("*RETRSA*") is derived from the retail trade growth rates time series, provided by Eurostat. Also sourced by Eurostat is the industrial production growth rate variable ("*GRINDPRO*"), reflected by the industry growth rates time series.

The three single-country analyses in this research employ the same methodology. Therefore, the respective specific country data is obtained from the same data source as the European weighted average data and marked with the prefixes "POR-", "ITA-" and "GER-" for Portugal, Italy and Germany respectively.

IV. Methodology

The econometric approach is based on a vector autoregressive (VAR) analysis, which is used to analyse long-term multivariate data. Because this work project wants to analyse the

effect of multiple macroeconomic indicators on the yield of government bonds, a VAR framework is particularly suited for this analysis as it allows for a simultaneous examination of the dynamic relationships among these time series variables. However, while analysing the relationship between the macroeconomic variables and the government bond yields, strict specifications for the VAR model are required to avoid spurious regressions. In addition to this, the VAR analysis follows additional steps to capture short- and long-term relationships and to interpretate these properly. Therefore, this work's methodology is divided into six steps: stationarity assessment, set-up of the VAR and testing for cointegration, Vector Error Correction Model (VECM), Granger causality, impulse response analysis, and forecast error variance decomposition.

In a first step a stationarity assessment is conducted. Checking for stationarity in a time series is crucial for various reasons. Firstly, it affects the persistence of shocks and in the case of a non-stationary time series the effect of a shock will be infinite. Secondly, using non-stationary data can lead to misleading, or spurious, results. Regressing two stationary time series one on the other, which are independently generated, should lead to an insignificant slope coefficient, indicated by a t-ratio close to zero and a low R-squared value. However, when two variables have a trend, hence are non-stationary, a regression can lead to a high R-squared value even if they are entirely unrelated. Thirdly, standard assumptions, like the t-ratios or f-statistic, will not follow their respective distributions and therefore undertaking hypothesis testing is not possible (Brooks 2014). This research tests each variable's time series for stationarity by the Augmented Dicky-Fuller (ADF) test, to avoid these difficulties coming with the use of non-stationary time series data. The null-hypothesis of having non-stationary time series data is rejected if the ADF test statistic is smaller than the critical value of the 5% confidence level.

Depending on the order of integration coming from the Augmented Dicky-Fuller test, the VAR model is constructed either in levels or in first difference. In addition to this, it is also

crucial to examine the existence of cointegration within the VAR framework, as cointegration indicates whether different time series data move together, meaning they share the same stochastic trend. Cointegration is also interpreted as the existence of a long-term relationship, as cointegrating variables can deviate from their short-run relationship, but in the long-run they will come back to their usual pattern. By using first difference models, hence a VAR modelled in first difference following the results of the stationarity assessment, the long-run information will be lost. Therefore, the existence of cointegration is important to examine. This research uses the Johansen test to examine the existence of cointegration between the variables, more specifically by considering the maximum-eigenvalue statistic. This statistic is tested sequentially for each rank of cointegration, assessing whether the cointegrating rank is less than or equal to a given number (Stock and Watson 2020).

In order to account for long-run relationships between macroeconomic variables and government bond yields, a Vector Error Correction Model (VECM) is used. Based on the existing literature of a VAR approach in analysing the effect of macroeconomic variables on the yield of government bonds, this research follows the restriction of including only variables with an integration order one I (1) in its VECM analysis (Harris and Sollis 2003; Pinho and Barradas 2021). The VECM approach avoids the issue where first-difference terms cancel out in the context of long-run relationships. It does so by incorporating both first-differenced terms and lagged levels of cointegrated variables, thus preserving the long-run equilibrium while modelling short-run dynamics. The general form of the VECM used is:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t$$

(1)

Where Y_t represents a vector including all variables introduced into the model. For this research work this leads to the vector including the government bond yield variable and all macroeconomic variables that are integrated of order one. The Δ stands for differencing the

vector/variables, as the VECM represents a combination of first-differenced terms and lagged levels of cointegrated variables. The parameter Π can be interpreted as the long-run coefficient matrix and is defined by the product of matrices α (adjustment parameters) and β (cointegrating vectors). The combination of the variables vector in levels and the cointegrating vectors (βY_{t-1}) is commonly referred to as the error correction term, also often represented by ECT_{t-1} . Its coefficient is a crucial parameter within a VECM analysis, because it indicates the speed at which the model adjusts back to its long-run equilibrium. Short-run dynamics are captured in the second part of the equation $\sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i}$. The matrix Γ_i includes the coefficients for the short-term effect of the i^{th} lagged differenced variables. p represents the number of lags. Finally, ε_t represents a vector of white noise error terms (Brooks 2014; Andrei and Andrei 2015).

For the interpretation of the effects of the macroeconomic variables on government bond yields and therefore the interpretation of the VECM, three features are used: Granger causality analysis, impulse response functions and forecast error variance decomposition. Conducting a Granger causality analysis to understand whether the past values of one variable can predict the current values of another variable, helps identifying the existence and direction of causality between the variables considered. More specifically, this research is interested whether the respective macroeconomic variables Granger cause the yield of government bonds (Stock and Watson 2020). However, Granger causality indicates a predictive relationship based on past values but it does not imply that one variable directly causes changes in another. In addition to this (Brooks 2014, p. 336) also emphasises that "*F-test results will not, by construction, be able to explain the sign of the relationship or how long these effects require to take place*". An impulse response and a forecast error variance decomposition enables to gather this information and therefore are used in this work project to analyse the effects of macroeconomic variables on government bond yields in more detail.

An impulse Response Analysis provides valuable insights into the temporal responses of economic variables to shocks in other variables, offering a dynamic view of their relationships. By employing orthogonalized impulse responses - which control for contemporaneous correlations among variables - it becomes possible to isolate and better interpret causal effects without interference from simultaneous shocks. In this research, positive shocks in the respective macroeconomic variables and the subsequent responses of the government bond yield variable in both, the short- and long-run, are analysed. The forecast error variance decomposition will complement the impulse response functions by indicating the proportion of variations in the dependent variables errors attributable to shocks originating within the variables themselves and arising from shocks in the macroeconomic variables.

V. Econometric Results

In order to avoid infinite effects of shocks, spurious regressions and implausible standard assumptions, a stationarity assessment is conducted to identify the order of integration of all variables considered. Therefore, this work uses the ADF test and rejects the null hypothesis of non-stationarity if the test statistic is smaller than the critical value of the 5% confidence level.

Variable	Levels		First Difference	
	ADF-Statistic	Result	ADF-Statistic	Result
GBY	-1,835	non-stationary	-6,747	stationary
HICP	-2,638	non-stationary	-4,996	stationary
UNEMP	-1,183	non-stationary	-9,159	stationary
ECBIR	-1,776	non-stationary	-5,220	stationary
M2S	-1,489	non-stationary	-4,797	stationary
EXR	-2,740	non-stationary	-10,204	stationary
RETRSA	-5,684	stationary	-11,100	stationary
GRINDPRO	-4,755	stationary	-4,352	stationary

Table 1: Results of the Stationarity Assessment

Table 1 shows the result of this assessment and indicates that six variables, including the variable of interest (GBY), are non-stationary in levels and stationary in first difference, leading to an integration order of one. The two variables consumer spending growth rate and industrial production growth rate are integrated of order zero. Following these results and in order to avoid the aforementioned problems related to non-stationary time series data, a VAR model in first differences should be constructed. However, this might lead to a loss of information on the long-run relationship of the variables. Based on the existing literature and in order to analyse the dynamic interrelationship between macroeconomic indicators and the yield of government bonds in both, the short- and long-run, this research uses the VECM approach. Therefore, it only includes variables with an integration order of one. The variables consumer spending growth rate and industrial production growth rate are not further considered. In order to examine if a long-run relationship exists, the Johansen Cointegration test is conducted. The underlying VAR model is represented by:

$$Y_t = \sum_{i=1}^5 \beta_i Y_{t-i} + \varepsilon_t \quad (2)$$

Where Y_t contains the government bond yield variable and the five macroeconomic indicators, β_i represents a vector of the i^{th} lagged coefficients of the respective lagged variables and ε_t stands for a vector of white noise error terms.

The lag length of five lags was selected based on the information criteria (Brooks 2014). Following the results of the lag-order selection criteria (s. appendix 1), either a lag-length of two or five lags is suitable. The Final Prediction Error (FPE) and the Akaike Information Criterion (AIC) suggest five lags and stand usually for the best predictive accuracy. The Hannan-Quinn Information Criterion and the Schwarz-Bayesian Information Criterion in contrast suggest an optimal lag-length of two lags, as these criteria prioritize simpler models with fewer lags (Stock and Watson 2020). This work project uses a relatively large data set,

having monthly data from January 2002 to June 2024 leading to 270 observations and therefore accuracy is prioritized. In addition to this, a higher lag-order also avoids problems with autocorrelation (Harris and Sollis 2003).

The Johansen Cointegration test is conducted to examine whether long-run relationships between the variables exist, or a simple VAR model will be sufficient to analyse the dynamic relationships. This research uses the maximum-eigenvalue statistic and tests sequentially the rank of cointegration. The null-hypothesis of cointegration at the respectively tested rank is rejected if the test statistic is greater than the critical value of the 5% confidence level. Results in table 2 indicate two cointegrating relationships.

Rank	Eigenvalue	Max-Eigen Statistic	5% Critical Value	Prob.
None *	0,1956	57,4539	40,0776	0,0002
At most 1 *	0,1433	40,8224	33,8769	0,0063
At most 2	0,0615	16,7502	27,5843	0,6015
At most 3	0,0508	13,7787	21,1316	0,3836
At most 4	0,0320	8,5791	14,2646	0,3229
At most 5	0,0003	0,0817	3,8415	0,7750

Table 2: Results Johansen Test (Maximum-Eigenvalue Statistic)

The discovery of cointegrating relationships justifies the use of a VECM to capture the dynamic relationships among these variables. It demonstrates that, although the variables may temporarily deviate from equilibrium in the short term, they tend to return to a long-term equilibrium over time. This feature is crucial for modelling economic relationships in a way that reflects both short-term dynamics and stable long-run relationships. The results of the Johansen tests, particularly the maximum-eigenvalue statistics, offer a solid basis for moving forward with the VECM estimation. These findings not only support the theoretical basis of cointegration in economic time series but also usually help to form the specification of the VECM, ensuring it accurately represents the dynamics of macroeconomic variables over time. Based on the existing literature, this research includes only one cointegrating vector for

simplicity (Brooks 2014). Using the general form of the VECM represented by equation (1), the VECM specified in this work is represented by:

$$\Delta Y_t = c + \Pi Y_{t-1} + \sum_{i=1}^4 \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (3)$$

Where Y_t is a 6×1 vector including all variables (*GBY, HICP, UNEMP, ECBIR, M2S, EXR*). Following the simplification of having only one cointegrating vector, the matrices α (adjustment parameters) and β (cointegrating vector), unified by the long-run coefficient matrix $\Pi = \alpha\beta'$, are vectors of dimension 6×1 . Each Γ_i short-run coefficient matrix is of dimension 6×6 and ε_t is a vector of dimension 6×1 . c is a vector of constants of dimension 6×1 . These strict specifications are necessary to derive from equation (3) the single-equation representation for the research purpose of this work (Brooks 2014):

$$\Delta GBY_t = c_1 + \alpha_1 ECT_{t-1} + \sum_{i=1}^4 \Gamma_{1,i} \Delta Y_{t-i} + \varepsilon_{1,t} \quad (4)$$

Where:

- α_1 is interpreted as the speed of adjustment for GBY to deviations from its long-run equilibrium.
- ECT_{t-1} includes all long-run coefficients and the lagged variables.
- $\sum_{i=1}^4 \Gamma_{1,i} \Delta Y_{t-i}$ represents all short-run effects of the i^{th} lag of each variable.
- $\varepsilon_{1,t}$ is the innovation specific to GBY
- c_1 is the constant specific to GBY

The detailed estimation results of this VECM approach can be found in appendix 2. The results indicate an existence of significant short- and long-run dynamics between the yield of government bonds and the macroeconomic variables. The error correction coefficient α_1 of equation (4) is negative and statistically significant, indicating that deviation from the long-run

equilibrium is corrected for within the current month at a convergence speed of 5.4%. The long-run relationships must be interpreted with reversed signs, which indicate significant positive effects of inflation, the ECB interest rate and the exchange rate on government bond yields. Money supply shows a slightly negative effect on the yield of government bonds at a significance level of 1%. The unemployment rate has no significant long-run effect on government bond yields. The positive relationship between government bond yields and inflation is aligned with the findings of the existing literature and economic theory. Economic theory suggests this positive relationship by higher uncertainty, less demand for government bond yields and an embedded inflation premium. The significant positive effect of the ECB interest rate reflects the transmission of monetary policy to the government bond market. The results for the exchange rate relationship are also aligned with results from (Rahmatika 2019). Results in this research indicate a positive effect of an increase in the exchange rate, supporting economic theory that an appreciation of the Euro would lead to a higher deficit and therefore a higher government bond yield. The slightly negative effect of money supply on government bond yields follows excess of liquidity together with an excess of supply in government bonds leading to a decrease in the yield.

To validate the reliability of the VECM, it is essential to perform diagnostic tests. Therefore this research performs tests for autocorrelation, residual normality, and heteroskedasticity. These tests play a crucial role in verifying that the model is correctly specified and that the findings are robust. The test results for the Portmanteau autocorrelation test, the Jarque-Berra normality test and the White heteroskedasticity test show that the VECM suffers from non-normality and heteroskedasticity in the residuals (appendices 3-5). Concluding from these results, model interpretations should be taken with a certain caution and adjustments in the model specifications should be considered to better capture residual dynamics (i.e. inclusion/exclusion of variables). Moreover, this caution is also emphasised by

the R-Squared value for the single-equation of this research purpose, which indicates that the included macroeconomic variables explain only 30.62% of the variations in the government bond yield (s. VECM results, appendix 2).

However, in order to better understand the dynamic interrelationships, this work conducts a Granger causality analysis. A Granger causality test gives insights whether past values of one variable can predict current values of another variable and therefore can be interpreted to describe the short-run relationship between the variables (Dinç and Akdoğan 2019).

Variable	Chi-sq	df	Prob.
D(HICP)	28,7646	4	0,0000
D(M2S)	9,4177	4	0,0515
D(ECBIR)	3,0790	4	0,5450
D(EXR)	1,9515	4	0,7447
D(UNEMP)	2,7304	4	0,6039
Jointly	42,7375	20	0,0022

Table 3: Results of the Granger Causality Analysis (dependent variable=GBY)

This work tests whether the macroeconomic variables Granger cause the government bond yield. The null-hypothesis of no Granger causality is rejected if the p-value of the chi-square statistic is below the 5% confidence level. Test results are provided in table 3 and indicate that only inflation Granger causes the yield of government bonds. In contrast to this, the macroeconomic variables jointly Granger cause government bond yields.

However, as Granger causality does not reveal whether a variable directly cause changes in another variable, this research complements the Granger causality assessment by an impulse response function analysis to capture this. Moreover, this research found problems with non-normality and heteroskedasticity in the residuals. Therefore, confidence intervals within the impulse response function analysis are constructed through bootstrapping the errors. Bootstrap methods are commonly employed for this purpose, as they can provide more reliable confidence intervals in small sample contexts compared to confidence intervals derived from standard

asymptotic t-distributions. More reliable confidence intervals are achieved by resampling repeatedly the empirical sample data to obtain information of its properties (Brüggemann 2006; Brooks 2014). Following the existence of non-normality and heteroskedasticity, this research uses the Hall's studentized bootstrapping method as it also bootstraps the variances and therefore accounts for heteroskedasticity (Benkwitz, Lütkepohl and Wolters 2001).

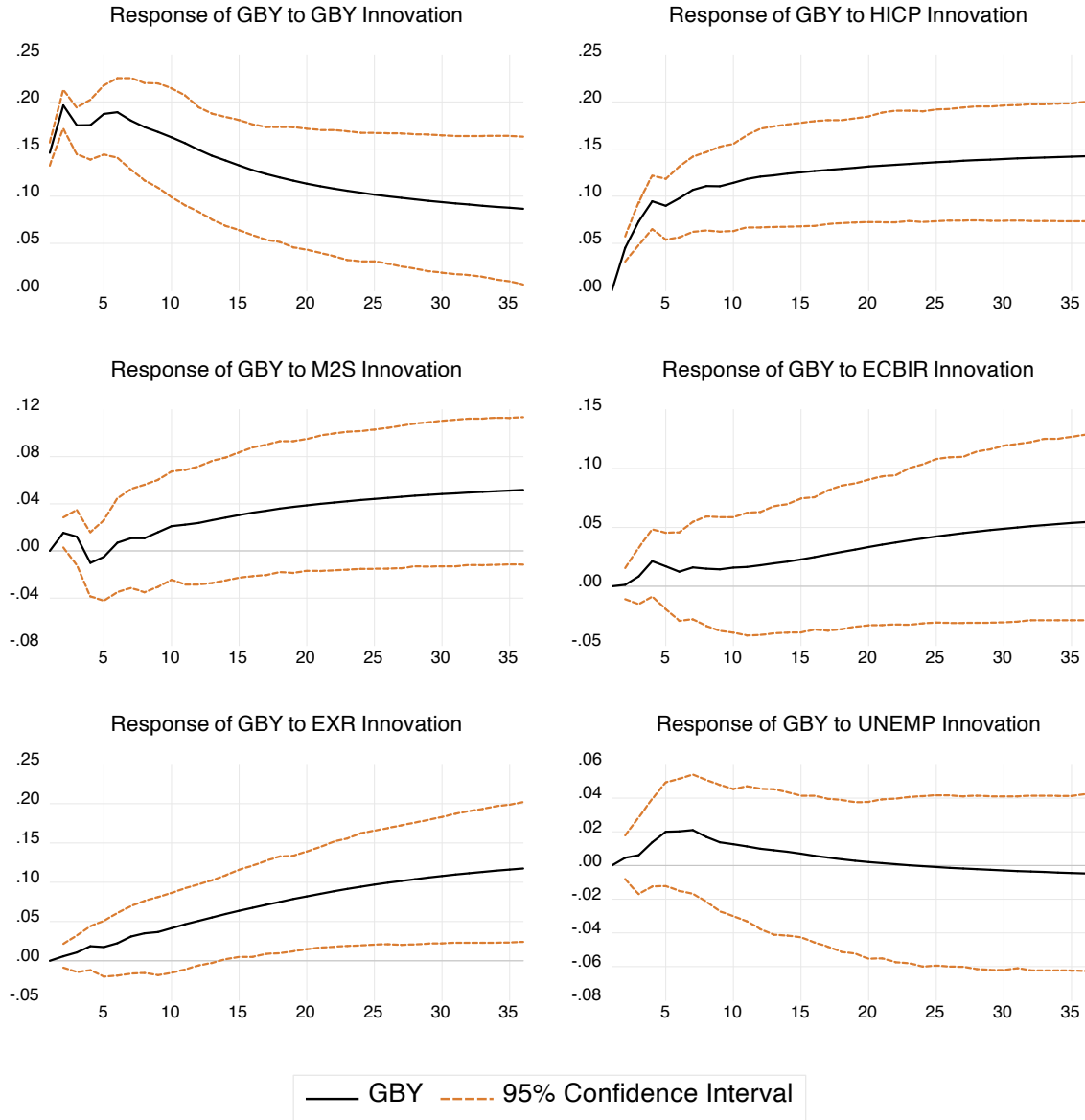


Figure 1: Impulse Response Functions

The impulse response function results in figure 1 offer insights into the effects of macroeconomic variables on government bond yields over time, that contrast with or build upon previous empirical findings and economic theory. Starting with the inflation variable (HICP),

both this analysis and the existing literature confirm a positive relationship between inflation and government bond yields. Moreover, the impulse response function results support the theoretical expectation that higher inflation leads to increased bond yields due to inflation premiums and reduced bond demand. Next, the impact of the ECB interest rate on European government bond yields, is positive, aligning with traditional expectations that higher interest rates push up bond yields by raising the cost of capital. However, the existing literature suggests ambiguous effects, which can possibly be explained by differences in central bank policies, investor expectations, or economic cycles across studies. The money supply variable shows a positive impact on bond yields in the IRF results, contradicting (Rahmatika 2019) findings that an increased money supply lowers yields by enhancing liquidity and investor purchasing power. The impulse response function's positive results might reflect inflationary concerns associated with expanded money supply, where investors anticipate potential inflation and demand higher yields. Moving on to the exchange rate, the effect in this analysis shows a positive response of government bond yields to a euro appreciation relative to the dollar. These findings are supporting the existing literature and economic theory as a strengthened currency leads to a weakened international accounts balance and subsequently a higher risk premium for the country's government bond yield. Lastly, the unemployment rate has a positive impact on the yield of government bonds in the first periods, which can be explained by more uncertainty and slow-down of the economy. Although the confidence intervals were constructed by using the Hall's studentized bootstrapping approach, the responses of government bond yields to shocks in most of the respective macroeconomic variables are not statistically different from zero at the 95% confidence level. Only responses in the yield of government bonds by their own shocks, responses by shocks in inflation and responses by shocks in the exchange rate are statistically different from zero over time.

The last step in analysing the effect of macroeconomic variables on European government bond yields is a forecast error variance decomposition. Results of the forecast error variance decomposition can be found in figure 2. This analysis examines to what extent shocks in the respective macroeconomic variables explain the variance in the errors of the government bond yield variable. The results reveal that movements in government bond yields are initially driven by their own shocks, which is a usual pattern. However, over time, inflation becomes the most significant additional macroeconomic factor. The exchange rate, the money supply and the ECB interest rate also gain importance in the long run, though to a lesser extent. The variable unemployment plays a relatively minor role in explaining the variance in the errors of the government bond yield variable.

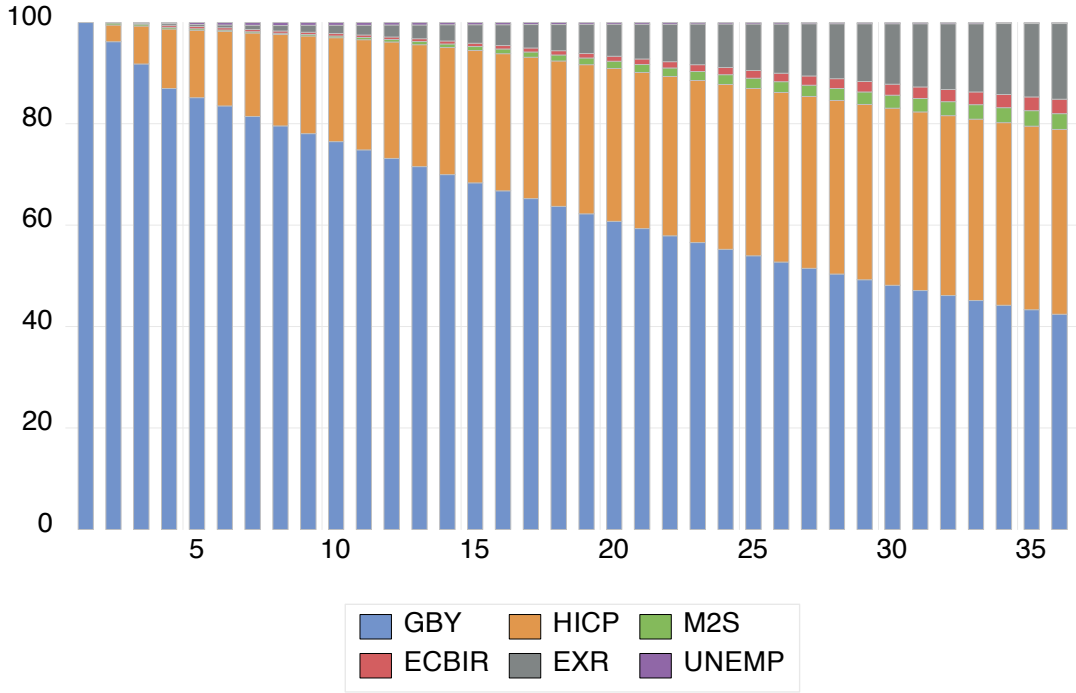


Figure 2: Forecast Error Variance Decomposition for GBY

This work project concludes its research by comparing the results of the analysis for the European weighted average government bond yield to results for three different single-country analyses, including Portugal, Italy and Germany. The scope of this comparison includes the impulse response functions and the forecast error variance decompositions. In order to be

consistent, the same methodology and variables are used. It is important to note that all three countries are part of the Economic and Monetary Union, leading to keep the data for the money supply, ECB interest rate and the exchange rate variables the same as in the analysis for the European weighted average government bond yield. Therefore, only the government bond yield, inflation, and unemployment variable and their data are country specific. The results of these impulse response functions and forecast error variance decompositions can be found in appendix 6-11. The three single-country analyses support the finding of the European weighted average government bond yield that inflation significantly affects government bond yields. In all country specific impulse response functions analyses inflation has a positive impact over time. In the case of Portugal, the responses of the government bond yield to a shock in inflation and a shock in the government bond yield itself, are the only responses that are statistically different from zero at the 95% confidence level (appendix 6). The responses in the Italian government bond yield are, in addition to the shock in itself and inflation, also statistically different from zero to shocks in the exchange rate, which is consistent with the findings of the analysis with the European weighted average government bond yield. In the long-term a shock in the money supply also affects the Italian government bond yield positively. Looking at the results for the German government bond yield, shocks in all macroeconomic variables, besides money supply, show significant positive effects on the German government bond yield over time.

These country-specific impulse response functions results are also confirmed by the forecast error variance decompositions of each country's respective government bond yield variable. This can be explained by difference in the country's credit risk profiles. In contrast to the unity in their monetary policy, fiscal policy differs from country to country, which can also explain the smaller model fit. This is indicated by the R-squared value of the countries specific

government bond yield single-equation representation in the VECM.¹ Therefore, future research work should address the aforementioned omitting variable problem by including fiscal indicators as the debt-to-GDP ratio to improve the model fit and to get more robust results.

VI. Conclusion

In this work project the important relationship between macroeconomic indicators and government bond yields was examined. By building upon the existing literature of analysing the effects of macroeconomic variables on government bond yields in mainly developing countries, this research analysed the effects of macroeconomic indicators on the yield of government bonds in the European area. The analysis reveals dynamic interrelationships between the five macroeconomic variables - inflation, money supply, market interest rate, exchange rate, unemployment rate - and government bond yields, both in the short and long run. In the short-term analysis, Granger causality tests indicate that these variables jointly Granger cause government bond yields, with inflation being the only variable that individually Granger causes government bond yields. In the long-term perspective, impulse response functions highlight significant effects on government bond yields by shocks in inflation and the exchange rate. This is further reconfirmed by the forecast error variance decomposition, which demonstrates that approximately 35% of the variance in government bond yield errors is attributable to inflation and 15% to the exchange rate over a 36-month forecasting horizon. Although that non-normality and heteroskedasticity could be addressed in the impulse response function analysis by constructing confidence intervals through the Hall's studentized bootstrapping approach, the analysis reveals only the two responses of the government bond yield variable to inflation and the exchange rate to be statistically different from zero over time.

¹ The R-squared value indicates that the included macroeconomic variables explain 21.65%, 19.90% and 25.44% of the variations in the Portuguese -, Italian -, and German government bond yield respectively.

Caution is also required due to the low R-Squared value for the single-equation of the government bond yield variable, which indicates that the included macroeconomic variables explain only 30.62% of the variations in the government bond yield. This could come from a potential misspecification of the model by omitting relevant macroeconomic variables or not capturing interactions as well as structural breaks through economic circumstances. Moreover, the strict specification to include only variables with an integration order of one reinforce these problems. Nevertheless, this study adds substantial value by revealing the existence of short- and long-run effects between the respective macroeconomic variables and government bond yields in the European area. This work expands upon existing literature by exploring the relationships using a distinct set of macroeconomic variables, specifically focusing on European government bonds. Strong effects of inflation and the exchange rate, and less powerful as well as non-significant effects of money supply, the ECB interest rate, and the unemployment rate on government bond yields are shown. Therefore, future studies should build upon the findings of this work and address problems like omitted variables, unit root specifications and capturing economic circumstances properly. In a last step of this work, the same methodology is used to examine the effect of macroeconomic variables on Portuguese, Italian and German government bond yields. The results of these single-country analyses indicate the existence of disparities between the countries. Consequently, future research should continue exploring different macroeconomic variables across different economic areas as well as different countries to provide valuable insights for multiple stakeholders. This includes assisting governments and fiscal policymakers in managing borrowing costs, enabling central banks to better anticipate market reactions, and guiding institutional and private investors in constructing optimal investment portfolios.

VII. Bibliography

- Afonso, António, Michael Arghyrou, and Alexandros Kontonikas. 2012. "The determinants of sovereign bond yield spreads in the EMU." *ISEG Economics Working Paper* No. 36.
- Andrei, Dalina Maria, and Liviu C. Andrei. 2015. "Vector error correction model in explaining the association of some macroeconomic variables in Romania." *Procedia Economics and Finance* 22 568-576.
- Benkwitz, Alexander, Helmut Lütkepohl, and Jürgen Wolters. 2001. "Comparison of bootstrap confidence intervals for impulse responses of German monetary systems." *Macroeconomic Dynamics* 81-100.
- Brooks, Chris. 2014. *Introductory Econometrics for Finance*. Cambridge: Cambridge University Press.
- Brüggemann, Ralf. 2006. "Finite sample properties of impulse response intervals in SVECMs with long-run identifying restrictions." *Sonderforschungsbereich 649: Ökonomisches Risiko*.
- Cantor, Richard, and Packer Frank. 1996. "Determinants and impact of sovereign credit ratings." *Economic policy review* 37–54.
- Dinç, Dilek Temiz, and Ece C. Akdoğan. 2019. "Renewable Energy Production, Energy Consumption and Sustainable Economic Growth in Turkey: A VECM Approach." *Sustainability* 11 (5) 1273.
- Eurostat. 2024. *Eurostat*. 22 07. Accessed 10 21, 2024. <https://ec.europa.eu/eurostat/web/products-euro-indicators/w/2-22072024-ap>.
- Harris, Richard, and Robert Sollis. 2003. *Applied Time Series Modelling and Forecasting*. Chichester: John Wiley & Sons Ltd.

- Haugh, David, Patrice Ollivaud, and David Turner. 2009. "What Drives Sovereign Risk Premiums? An Analysis of Recent Evidence from the Euro Area." *OECD Economics Department Working Papers* No. 718.
- Klepsch, Catharina, and Timo Wollmershäuser. 2011. "Yield spreads on EMU government bonds—How the financial crisis has helped investors to rediscover risk." *Intereconomics* 169-176.
- Koroleva, Ekaterina, and Maxim Kopeykin. 2022. "Understanding of Macro Factors That Affect Yield of Government Bonds." *Risks* 10, 160.
- Laubach, Thomas. 2009. "New evidence on the interest rate effects of budget deficits and debt." *Journal of the European economic Association* 858-885.
- Liu, Sheen, Jian Shi, Junbo Wang, and Chunchi Wu. 2009. "The determinants of corporate bond yields." *The Quarterly Review of Economics and Finance* 85-109.
- Meyer, D.F., and A.S. Hassan. 2020. "Analysis of the impact of exchange rate volatility on the South African Government bond market." *International Journal of Economics and Finance* 271-289.
- Pinho, André, and Ricardo Barradas. 2021. "Determinants of the portuguese government bond yields." *International Journal of Finance & Economics* 26. Jg., Nr. 2, S. 2375-2395.
- Poghosyan, Tigran. 2014. "Long-run and short-run determinants of sovereign bond yields in advanced economies." *Economic Systems* 100-114.
- Rahmatika, Nurlia. 2019. "How is the shock of the macro economics variables and world oil price effected the yield of Indonesia Government Bond Index (INDOBEXGB)?" *Media Ekonomi* 141-162.
- Sihombing, Pardomuan, Edi Santoso, and Dini Hariyanti. 2023. "Macroeconomic Variables Effect on 10-Year Tenor Government Bonds Yield." *Research of Economics and Business* 57-67.

Stock, James H., and Mark W. Watson. 2020. *Introduction to Econometrics*. Harlow: Pearson Education.

VIII. Appendix

Appendix 1: Lag-order selection for underlying VAR

Lag	FPE	AIC	HQIC	SBIC
0	1,6E+11	42,8336	42,8666	42,9157
1	1,3484	17,3261	17,5573	17,9013
2	0,5574	16,4423	16,8717*	17,5105*
3	0,5178	16,3675	16,9952	17,9288
4	0,5525	16,4304	17,2562	18,4846
5	0,5109*	16,3488*	17,3729	18,8961
6	0,5376	16,3949	17,6171	19,4351
7	0,5659	16,4394	17,8599	19,9727
8	0,5561	16,4132	18,0318	20,4395
9	0,6090	16,4925	18,3093	21,0118
10	0,6584	16,5558	18,5708	21,5682

Appendix 2: VECM results - GBY single-equation representation

Variable	Coefficient	Standard-Error	Significancy 5%
Short-Term Relationship			
Constant			
cons	0,0127	0,0191	Not significant
GBY			
LD	0,3714	0,0639	Significant
L2D	-0,2187	0,0675	Significant
L3D	0,1508	0,0670	Significant
L4D	0,0704	0,0623	Not significant
HICP			
LD	0,1352	0,0287	Significant
L2D	0,0125	0,0304	Not significant
L3D	0,0363	0,0299	Not significant
L4D	-0,0553	0,0295	Not significant
M2S			
LD	0,0000	0,0000	Not significant
L2D	0,0000	0,0000	Not significant
L3D	0,0000	0,0000	Not significant
L4D	0,0000	0,0000	Not significant
ECBIR			
LD	-0,0161	0,1146	Not significant
L2D	0,0547	0,1257	Not significant
L3D	0,1328	0,1259	Not significant
L4D	-0,1898	0,1146	Not significant

EXR				
	LD	0,1300	0,3751	Not significant
	L2D	-0,1928	0,3922	Not significant
	L3D	0,3169	0,3887	Not significant
	L4D	-0,4819	0,3766	Not significant
UNEMP				
	LD	0,0193	0,0473	Not significant
	L2D	-0,0026	0,0498	Not significant
	L3D	0,0535	0,0494	Not significant
	L4D	0,0265	0,0458	Not significant
CointEqu				
	ce1	-0,0543	0,0192	Significant
Long-term Relationship				
ce1				
	GBY	1,0000	--	--
	HICP	-0,2079	0,056	Significant
	M2S	0,0000	0,000	Significant
	ECBIR	-0,5796	0,089	Significant
	EXR	-2,2538	0,578	Significant
	UNEMP	-0,0694	0,080	Not significant
	cons	-0,3100	--	--
GBY Equation - Diagnostics				
R-squared	0,3062	Log likelihood	147,2823	
Adj. R-squared	0,2336	Akaike AIC	-0,9153	
Sum sq. resids	5,1053	Schwarz SC	-0,5641	
S.E. equation	0,1462	Mean dependent	-0,0078	
F-statistic	4,2186	S.D. dependent	0,1669	

Appendix 3: Portmanteau Autocorrelation Test

Lags	Q-Stat	Prob	Adj Q-Stat	Adj Prob	df
1	3,0604	---	3,0720	---	---
2	8,4238	---	8,4762	---	---
3	13,9804	---	14,0964	---	---
4	21,9484	---	22,1865	---	---
5	68,3940	0,3960	69,5253	0,3597	66

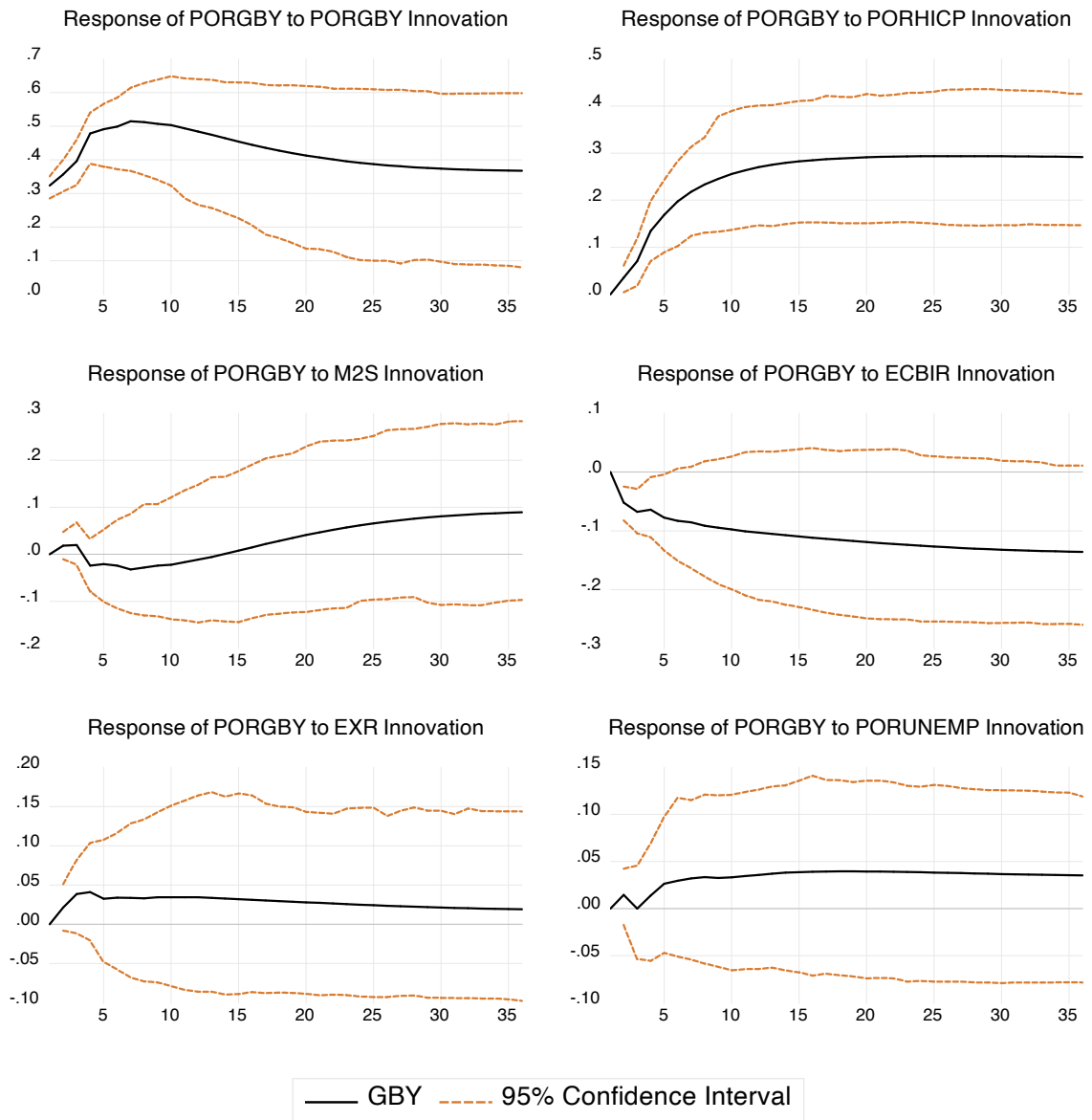
Appendix 4: Jarque-Bera Normality Test

Component	Jarque-Bera	df	Prob.
1	40,8344	2	0,0000
2	48,9201	2	0,0000
3	2158,0160	2	0,0000
4	732,9443	2	0,0000
5	15,9568	2	0,0003
6	92,6163	2	0,0000
Joint	3089,2880	12	0,0000

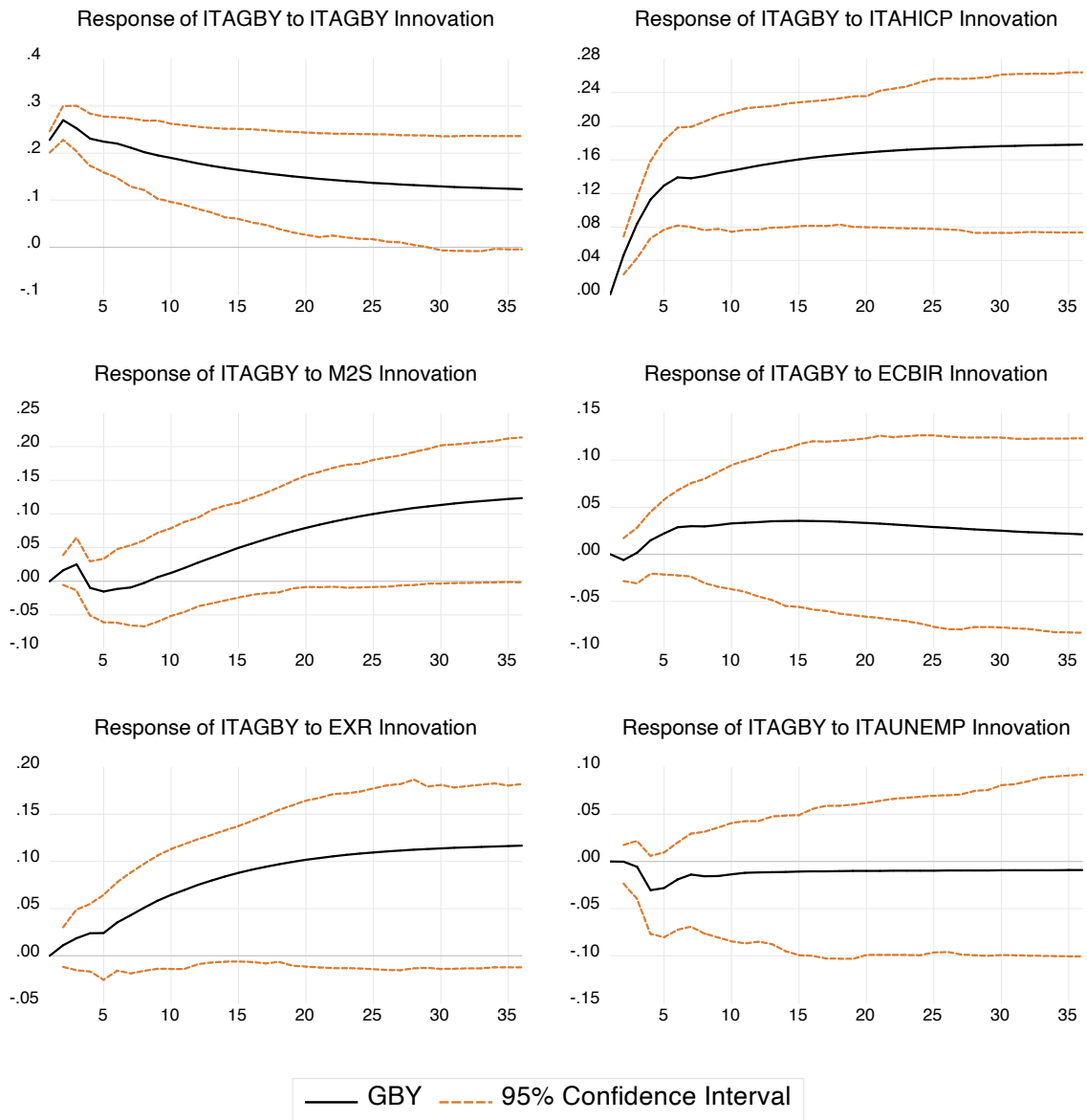
Appendix 5: White Heteroskedasticity Test

Joint test	Chi-sq	df	Prob.		
	1504,27	1050,00	0,0000		
Dependent	R-squared	F(50,214)	Prob.	Chi-sq(50)	Prob.
res1*res1	0,3353	2,1592	0,0001	88,86	0,0006
res2*res2	0,3034	1,8637	0,0013	80,39	0,0041
res3*res3	0,1666	0,8559	0,7394	44,16	0,7057
res4*res4	0,3892	2,7278	0,0000	103,15	0,0000
res5*res5	0,2327	1,2983	0,1057	61,68	0,1244
res6*res6	0,1891	0,9979	0,4854	50,10	0,4692
res2*res1	0,3319	2,1265	0,0001	87,96	0,0007
res3*res1	0,3015	1,8478	0,0015	79,91	0,0046
res3*res2	0,2764	1,6347	0,0091	73,24	0,0177
res4*res1	0,4441	3,4297	0,0000	117,99	0,0000
res4*res2	0,5039	4,3475	0,0000	133,54	0,0000
res4*res3	0,4187	3,0825	0,0000	110,95	0,0000
res5*res1	0,2970	1,6081	0,0020	78,70	0,0059
res5*res2	0,2222	1,2234	0,1669	58,88	0,1827
res5*res3	0,1704	0,8800	0,7004	45,15	0,6680
res5*res4	0,3408	2,2123	0,0000	90,30	0,0004
res6*res1	0,1814	0,9486	0,5751	48,08	0,5508
res6*res2	0,1669	0,8577	0,7364	44,24	0,7028
res6*res3	0,2363	1,3240	0,0897	62,61	0,1087
res6*res4	0,3300	2,1085	0,0001	87,46	0,0008
res6*res5	0,1649	0,8453	0,7566	43,71	0,7225

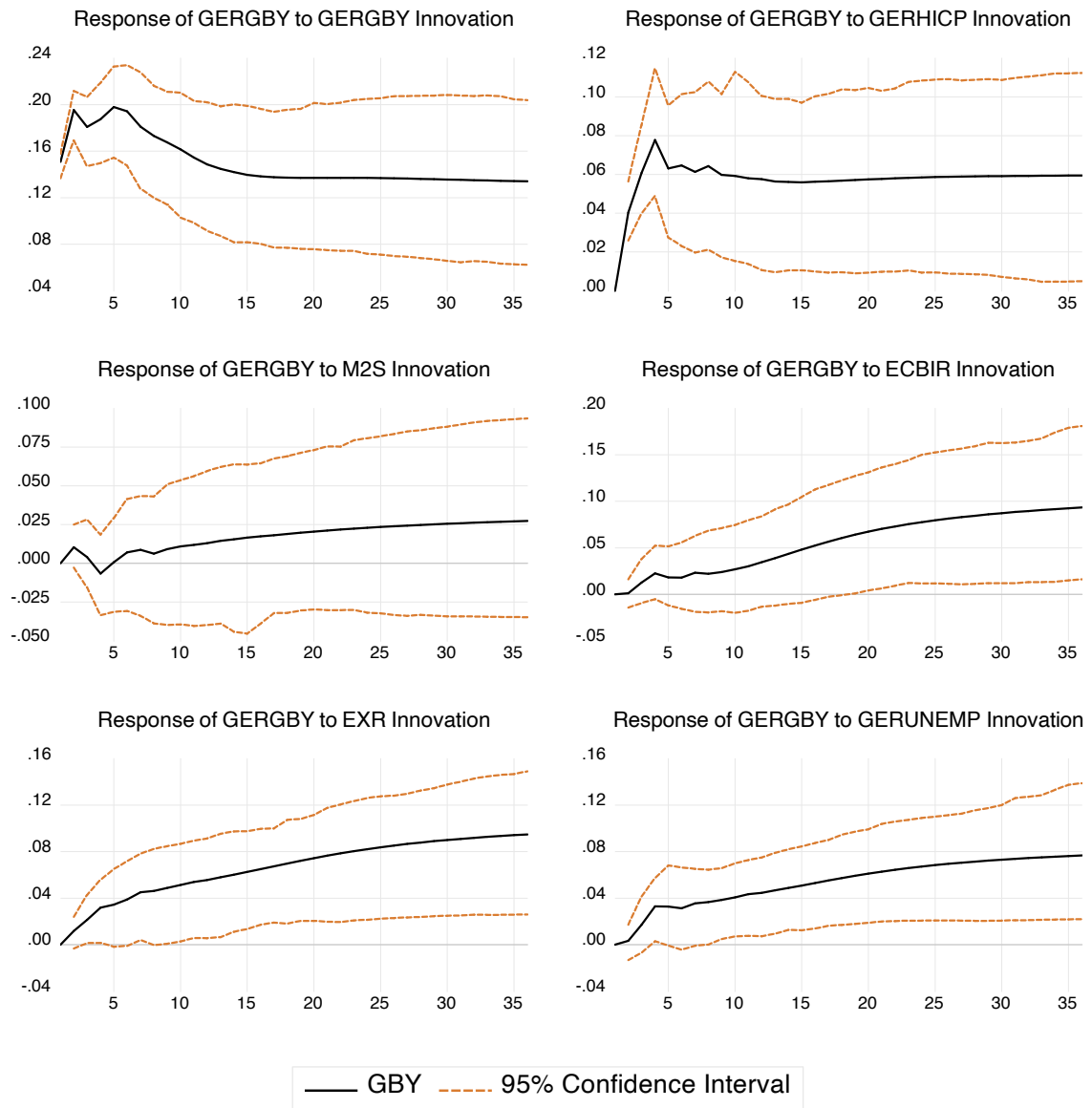
Appendix 6: Impulse Response Functions - Portuguese Government Bond Yield



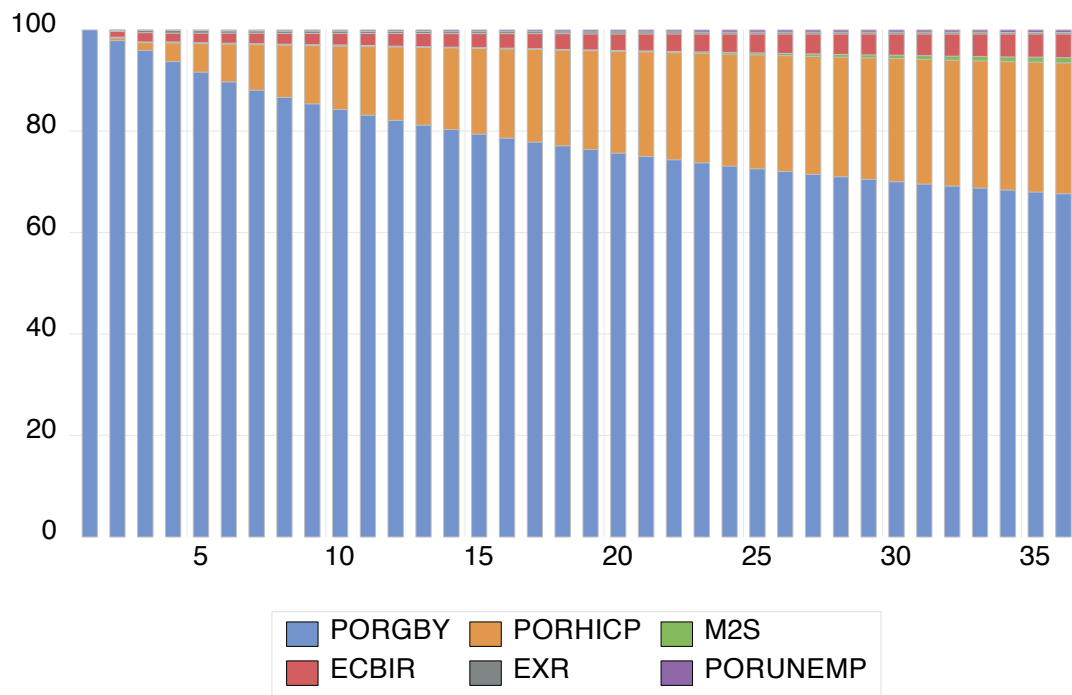
Appendix 7: Impulse Response Functions - Italian Government Bond Yield



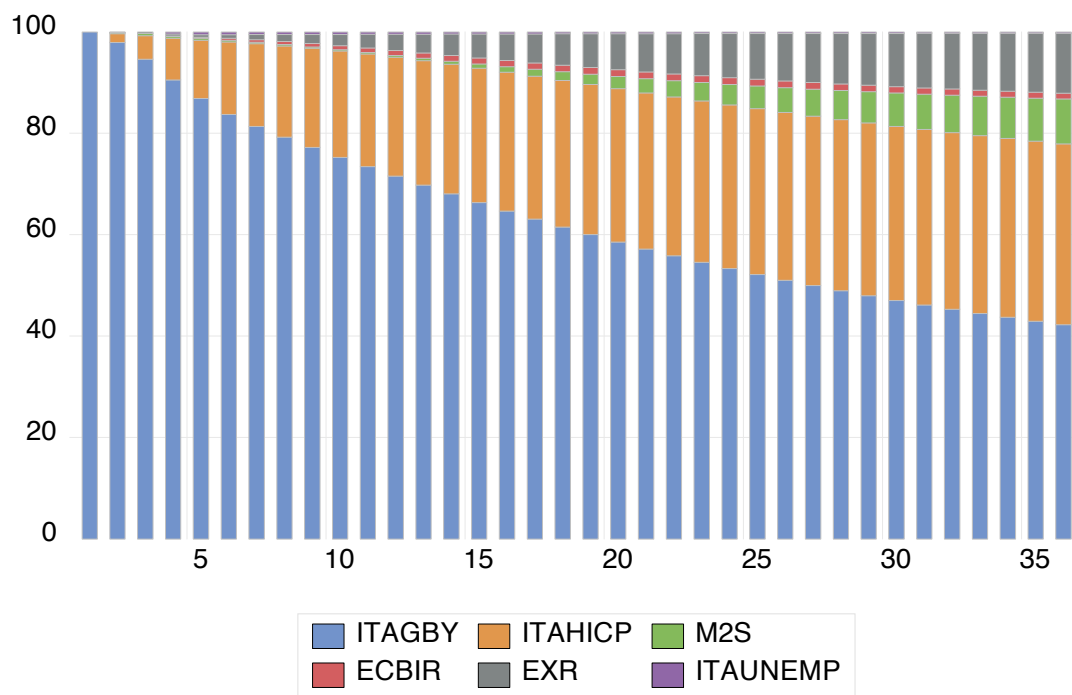
Appendix 8: Impulse Response Functions - German Government Bond Yield



Appendix 9: Forecast Error Variance Decomposition - Portuguese Government Bond Yield



Appendix 10: Forecast Error Variance Decomposition - Italian Government Bond Yield



Appendix 11: Forecast Error Variance Decomposition - German Government Bond Yield

