# Bond Supply Expectations and the Term Structure of Interest Rates

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**Abstract**

In this paper we study the impact of current and expected bond supply on Italian and German government bond yields. We find that the news on expected government bond supply affects German yields, but not Italian yields. The accuracy of news on expected supply appears to drive the result. We also estimate a Macro Term-Structure model with supply expectations for Germany and find expected supply as a driver in the time-variation of risk premium. After accounting for endogeneity, we also find the impact of current bond supply to be negligible for Italy. We also investigate the puzzle of the large amount of German bonds trading consistently below the deposit rate of the European Central Bank since 2015. We argue that this is partly caused by the expectation of a sharp contraction in the expected supply of German short-term debt. Our findings support term-structure models that account for imperfect asset substitutability and preferred-habitat investors and provide empirical evidence of the impact of supply expectations on interest rates.

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# 1 Introduction

Does forward-looking information on the amount of Government bonds drive changes in the term-structure of interest rates in Europe? According to arbitrage-free models and to the expectations hypothesis bond supply should not affect bond yields (Cox et al., 1985). However, models that consider the presence of preferred-habitat investors and imperfect substitutability between assets entail this possibility (Vayanos and Vila, 2009). To the best of our knowledge, we are the first to explore the empirical relationship between debt supply expectations derived from the Treasury and interest rates.

Our work is based on the intuition of Greenwood et al. (2015), in which expectations about future changes in supply due to expected purchases by the Central Bank affect spot and forward rates. We build on their work by constructing measures of supply expectations for two Euro Area countries (Italy and Germany) and provide support for the implications of their model. We find that news on the expected supply of government bonds influences yields, but this is true only if such news are accurate. Specifically, if accuracy is high, expected supply is considered to be more informative than current supply and the former is the only one with a price impact. If accuracy is low, only current bond supply is found to be informative and embedded in bond prices. However, after accounting for the endogeneity of such measures, we estimate the impact of current bond supply to be negligible on italian yields. We also estimate a Macro Term-Structure model (MTSM) to study how expected supply can affect interest rates when a no-arbitrage restriction is imposed on observed bond yields. We indeed find supply expectations having an impact on the time variation of risk premium. We also validate our results by employing a parametric bootstrap to compute standard errors for our maximum likelihood parameters.

Further, we also contribute to the term structure literature by offering an alternative explanation for the puzzle of government bond yields falling below the (negative) ECB rate for an extended period of time. Banks, which are among the main investors in government bonds, do not have an incentive to purchase this asset class if it yields less than the ECB deposit rate. Banks' liquidity and capital regulations[1] and local central bank interventions are offered as possible explanations for this counterintuitive behaviour of government bond yields. However, we argue that in addition to demand side effects, a downward pressure on yields may also be compounded by contractions in expected supply. Indeed, for Germany we estimate that a 1 percent decrease in the expected amount of short-term debt to GDP ratio decreases the spread between German bonds and the deposit rate of the ECB by around 10-15 basis points whenever the spread is negative.

Our findings extend a body of empirical literature that investigates the relationship between current supply (as opposed to expected supply as done in this study) and the possible channels through which it may affect interest rates. For example, Greenwood and Vayanos (2014) find that supply affects both spot rate and future returns through the risk premia. Krishnamurthy and Vissing-Jorgensen (2012) find that the overall Treasuries amount have an effect on their safety and liquidity attributes, thus driving the spread between Treasuries and corporate bonds.

While our paper is related to previous studies linking supply, unconventional monetary policies and interest rates, our main objective is the analysis of the price impact of information from bond auctions and press releases issued by Treasury departments. Specifically, we focus on Germany and Italy, two of the main European economies with a sizable and liquid bond market. The two countries feature very different policies regarding the amount of released information on future bond issuance, with the former providing detailed press releases throughout the year. We take advantage of the information provided by the German and Italian treasuries to build a new variable of expected supply. This is defined as the overall amount of debt that would be outstanding in the future if the Treasuries issued exactly the amount communicated at the time of each press release. In the case of Italian releases, when exact supply amounts are not given, we assume investors

[1] $https://www.bis.org/basel_framework/chapter/MAR/20.htm?inforce=20190101$ specifies the risk capital requirements for government bond assets for banks.

can forecast the supply that will be available in specific maturity buckets covered by the press-releases. Clearly this lowers the quality of the information that investors can derive about future issuance of Italian bonds, and we explore the resulting effects on bond prices. Germany and Italy are also two of the main benchmarks for core and peripheral European countries, respectively. This allows us to assess how supply can differently affect interest rates in two different macro-economic environments.

Our work fits within a growing strand of literature relating interest rates and fixed-income quantities. The foundations of this literature were laid by Tobin (1958, 1969), in which a shock to the stock of available assets has to change the assets' expected returns in order to restore equilibrium. Another early contribution from Modigliani and Sutch (1966) relates to the existence of preferred-habitat investors in certain segments of the yield curve. The recent influential work by Vayanos and Vila (2009) formalizes a no-arbitrage model of the yield curve in which two types of agents trade across the term-structure: preferred-habitat investors that have demand only for bonds at specific maturities and risk-averse arbitrageurs that trade along all the yield curve and render it arbitrage-free. In this setup, changes in supply impact the required rate of return requested by arbitrageurs to absorb a change in quantities and duration risk.

Our paper is also strictly related to the theoretical model developed by Greenwood et al. (2015), in which expectations about future changes in supply due to expected purchases by the Central Bank affect spot and forward rates. There is also a large body of empirical literature investigating the relationship between supply and the possible channels through which it may affect interest rates. A lot of empirical work has also been devoted to estimate the financial and macroeconomic impact of large-scale asset purchase programs (Quantitative Easing) that took place in the last decade in western economies. Most of these studies distinguish between the stock and flow effects on interest rates. Stock effects are defined as the permanent effect on yields determined by the announcement of the program implementation, while flow effects relate to the change in prices due to the actual purchases by the Central Bank. Among others, D' Amico and King (2013), Krishnamurthy and Vissing-Jorgensen (2011), Gagnon et al. (2011) and Joyce et al. (2011) estimate the impact of these programs in U.S and in the United Kingdom with an event-study approach. The literature regarding the impact of the Quantitative Easing in Europe is more limited, because the European Central Bank lagged among its peers in adopting a similar policy. However, a growing number of studies on the ECB's Asset Purchase Program (APP) have been published in the last few years (for example Altavilla et al. (2015), De Santis and Holm-Hadulla (2017) Gambetti and Musso (2017), Koijen et al. (2016), Blattner and Joyce (2016), Wieladek and Garcia Pascual (2016), Eser et al. (2019) study how the PSPP affected financial and macroeconomic variables).

Finally, our paper also fits within a vast literature regarding macro-finance models in which macroeconomic variables that are completely spanned by the yield curve are used as pricing factors in affine term-structure models that impose no-arbitrage restrictions. Among others, Smith and Taylor (2009), Ang and Piazzesi (2003), Ang et al. (2007), Rudebusch and Wu (2008) use several macro variables such as GDP and Inflation as macro factors. Related to our work, Li and Wei (2013) estimate the impact of bond supply on Interest rates in the US. However, we focus on supply expectations, rather than on the current amount of bonds available in the market.

The paper is organised as follows. Section 2 describes how we construct our measures of supply. Section 3 illustrates our identification strategy. Section 4 reports and discusses our empirical results. Section 5 shows the robustness tests we undertake to validate our findings. Section 6 concludes.

# 2 Bond Supply Measures

We download data on bond supply from the German and Italian Treasury web sites. Our sample covers the period from January 2005 to December 2017. We collect detailed information on each fixed-rate and zero-coupon government bond issued in this time period (ticker, issue date, maturity date, coupon rate, auction average price, bid-to-cover ratio and face value outstanding). In this way, we are able to reconstruct the total amount of bond supply at each point in time during our sample. For Italian bonds, we also correct the outstanding amount of each bond whenever it is modified by an exchange auction. An exchange auction happens whenever a portion of the total amount outstanding of a bond is bought back from the Treasury in exchange for another security issued in the past and with a different maturity. Usually, the objective of an exchange auction is trading a seasoned bond that is close to maturity with another one that has a longer time until redemption. We take into account exchange auctions because, even though they have a minor impact on the overall amount of government debt, they still modify both the total amount of supply and the average duration of debt.

Following Greenwood and Vayanos (2014) we construct a maturity-weighted measure of debt for each country:

$$MWD_{i,t} = \frac{\sum_{\tau=0}^{30} D_{i,t}^{\tau}\tau}{GDP_{i,t}}$$

where

$$D_{i,t}^{\tau} = Pr_{i,t}^{\tau} + C_{i,t}^{\tau}.$$

$Pr_{i,t}^{\tau}$ and $C_{i,t}^{\tau}$ are the aggregate principal and coupon payments that are due $\tau$ years from time $t$ for country $i$. We choose this as our main measure of supply because, according to Greenwood and Vayanos (2014), maturity-weighted debt-to-GDP dominates several other measures of debt when forecasting bond returns. We also compute the standard $D/GDP$ ratio, in which we only sum up principal payments and exclude coupon payments.

We also build a new measure of future expected supply for each country. To the best of our knowledge, we are the first to study the relationship between interest rates and a future expected quantity. We assume that agents incorporate all the publicly available forward-looking information in order to price assets. We define the future expected value of supply as:

$$E[MWD_{i,t+k}] = \frac{\sum_{\tau=0}^{30} E[D^{\tau}_{i,t+k}\tau | I_{i,t}]}{GDP_{i,t}}$$

where $E[D^{\tau}_{i,t+k}\tau | I_{i,t}]$ is the expected value of total principal and coupon payments due $\tau$ years from $t+k$ months ahead for country $i$ conditional on the information available at time t, $I_{i,t}$ . We build the best possible proxy for expected supply given the information known by investors at each point in time. In order to estimate this variable, we look at how each Treasury Department organises press-releases regarding their bond issuance plan. The quantity and quality of forward-looking information release by Italy and Germany is quite different.

The German Treasury issues several press releases throughout the year[2]. The first release takes place in December, when the Treasury states the issuance plans for the next calendar year with the expected notional amount of every auction for each bond. There are also communications at the end of every quarter that state changes in the upcoming auctions. Consider, for example, the press release of September 23rd 2014, in which the Treasury announced that due to lower required funding for the federal budget, the fourth quarter auctions for the 6-months and 12-months Treasury Discount Papers (announced the previous December) were cancelled.

The Italian Treasury employs a very different policy regarding press-releases on future auctions[3]. In fact, press releases are issued at the end of each quarter, and only provide an indication of the Government's intentions over the next three months. The Treasury states its intentions regarding new issues and re-openings only for bonds between 2 and

[2]All the press-releases for the German Treasury can be downloaded at `https://www.deutsche-finanzagentur.de/en/press/press-releases/`

[3]Press-releases for the Italian Treasury can be found at `http://www.dt.tesoro.it/it/debito_pubblico/emissioni_titoli_di_stato_interni/programma_trimestrale_emissione/`

10 year maturity. However, the actual face value of each bond issueis not indicated and the Treasury only communicates the minimum total amount that will be offered . Furthermore, there is no forward-guidance for auctions of short-term bonds (below 1 year maturity), bonds with maturity over 10 years and off-the run bonds. Thus, investors have full information on scheduled German bond auctions, but only partial information on scheduled italian bond auctions.

In both countries, press-releases with information on the issuance schedule for the following year are published in December. Agents though don't have any information on auctions that will take place after the end of the current calendar year and they need to wait until the new annual auction schedule is released.We use the following approach for constructing a proxy for the expected supply conditional on all the information available at time t, $E[D^{\tau}_{t+k}\tau|I_t]$.

- For Germany, $E[D^{\tau}_{t+k}\tau|I_t]$ is defined as the amount of maturity-weighted supply that would be outstanding at the end of the year, according to the information available at each point in time. So, we download every single press-release to estimate the amount of supply that would be outstanding at the end of each year if there were no changes to the Treasury's planning in the next $k$ months. Whenever a new press-release with changes to planned auctions becomes public, we adjust the measure to account for the changes in supply due to cancelled auctions, new auctions that were not announced or changes in face value offered on planned auctions. We also assume that the amount of coupon payments due in the future and starting $t + k$ months ahead will be based on market conditions that are observable at time $t$.

- For Italy, $E[D^{\tau}_{t+k}\tau|I_t]$ is computed as the amount of maturity-weighted supply that is expected to be outstanding at the end of next quarter. This relies on two assumptions. First, we assume that investors know the amount of supply that will be outstanding at the end of the quarter for bonds with maturities between 2 and 10 year. Second, since there is no information about bonds of other maturities, we assume that there will be no change in the supply of these bonds. Hence, the supply at the start of the quarter for both short-term bonds and bonds with maturity above 10 years is the best proxy for the amount that will be outstanding at the end of the quarter.

We also download the amount of government bond purchased by the European Central Bank during the Public Sector Purchase Program (PSPP) that started in March 2015. We obtain the total purchases and average remaining duration of the ECB bond holdings for both countries. We build a maturity-weighted measure of debt held by the European Central Bank as:

$$MWQE_{i,t} = \frac{\sum_{t=0}^{n} Holdings_{i,t} * \bar{M}_{i,t}}{GDP_{i,t}}$$

where $\sum_{t=0}^{n} Holdings_{i,t} * \bar{M}_{i,t}$ is the sum of all the PSPP holdings in each country $i$ multiplied by their average residual maturity.

We express our supply variables in nominal values for two reasons. First, as Greenwood and Vayanos (2014) point out, interest rate changes have a mechanical effect on the overall supply if this is expressed in market values. A decrease in bond prices would decrease maturity-weighted debt, thus creating a spurious negative relationship between yields and supply. Second, we could theoretically estimate a market value of expected debt based on interest rates observed ex-post, but those same interest rates would not be available in the market at the time in which details about future value of outstanding debt would bec available to investors.

Finally, we are interested in studying potential scarcity effects at the short-end of the German term-structure of interest rates. We define the expected amount of short-term bonds outstanding as:

$$E[STdebt_{t+k}] = \frac{\sum_{\tau=0}^{2} E[D_{t+k}^{\tau} | I_t]}{GDP_t}$$

where $\sum_{\tau=0}^{2} E[D_{t+k} | I_{i,t}]$ is the sum of the expected outstanding amount of German bonds at the end of the year with original maturity below 2 years, based on the information available at time t. We also take advantage of some specific features of the PSPP to make sure that our measure is a reliable estimate of the net outstanding amount of short-term debt. In fact, at the start of the program, the ECB could not purchase neither bonds with remaining maturity below 2 years nor bonds that traded below the deposit rate. Since short-term German bonds have been trading below this threshold consistently since the start of the PSPP, we know that our measure of short-term supply is a good estimate of the total amount of bonds available to investors. Even if the implementation aspects slightly changed in January 2017, allowing the ECB to buy bonds with yields below the deposit rate, we believe the purchases in this maturity bucket were limited. Nonetheless, in our robustness tests we also restrict our sample and define our variable slightly differently to check the consistency of our results. We split the variable into specific supply buckets (less than one year maturity supply, between one and two years supply) and regress the specific spread on that splitted variable.

Table A.1 in the Appendix lists the main variables used in our empirical analysis and specifies their sources, while in Table 1 we provide summary statistics for yields, various supply proxies and other variables used in our empirical analysis. Not surprisingly, the mean of the Italian maturity-weighted debt to GDP (7.3) is twice as big as the German maturity-weighted debt to GDP (3.2). The standard deviation of maturity-weighted debt for Italy is ten times larger than the standard deviation of maturity-weighted debt for Germany. Table A.2 in the Appendix shows the correlations in levels and first difference between the main variables in our study. The top panel shows that our measure of expected supply is more correlated to 10 and 5 year spreads than current supply, both in levels and in first difference. Looking at Italy, the correlations are very similar in levels, while current supply is more correlated to yield spreads than expected supply in first difference. Finally, Figure 2 plots a separately the short-term (blue dashed line) and long-term (red line) supply curves of German bonds. Short-term debt increases sharply towards the end of 2009 and then steadily decreases reaching very low levels in October 2017. The situation is even more dramatic if we look at bonds below 1 year maturity, where the total amount outstanding decreased from around €100 billion before 2010 to about €10 billion at the end of 2017.

# 3 Identification

## 3.1 Linear Regressions

We estimate the following monthly regressions of yields on current and expected future supply separately for both countries:

$$y_{i,t}^{(\tau)} - y_{i,t}^{(1)} = \alpha + \beta_1 MWD_{i,t} + \beta_2 MWQE_{i,t} + \beta_3 t + \epsilon_{i,t} \quad \forall \tau > 1 \tag{1}$$

$$y_{i,t}^{(\tau)} - y_{i,t}^{(1)} = \alpha + \beta_1 E[MWD_{i,t+k}|I_{i,t}] + \beta_2 MWQE_{i,t} + \beta_3 t + \epsilon_{i,t} \quad \forall \tau > 1 \tag{2}$$

where $y_{i,t}^{(\tau)} - y_{i,t}^{1}$ is the spread between the $\tau$-year and the 1-year bond and $t$ is a time trend. We also run a horse-race regression in which we jointly estimate the contribution of both current and future expected supply to the yield spread:

$$y_{i,t}^{(\tau)} - y_{i,t}^{(1)} = \alpha + \beta_1 MWD_{i,t} + \beta_2 E[MWD_{i,t+k}|I_{i,t}] + \beta_3 MWQE_{i,t} + \beta_4 t + \epsilon_{i,t} \quad \forall \tau > 1. \tag{3}$$

We adjust standard errors to account for autocorrelation. Obviously, yield spreads may depend on other variables besides supply and/or expected supply. Thus we decide to use a parametric approach and estimate an AR(1) process for regression residuals. We also estimate the regressions with robust-standard errors. Furthermore, in Table 4 we estimate the models in first difference with Newey and West (1987) standard errors allowing for 12 lags and show that our results are still significant, even though somewhat weaker.

We also run a very simple event-study regression, in which we assess how unexpected changes in expected supply affected German bonds around press-release dates. We focus our attention to dates in which the Treasury decreased the expected amount of planned issues in the future months, since we have more of those events in our sample. Figure 3 plots how yields moved around some of those dates. We estimate a regression as follows:

$$\Delta y_t^{(\tau)} = \alpha + \beta_1 News + \epsilon_{i,t} \tag{4}$$

where $News$ is a dummy variable that has value 1 on days with unexpected reductions in expected supply but only when there is a decrease in expected supply and $\Delta y_t^{(\tau)}$ is the daily change in interest rates with $\tau$ maturity. Our event variable is unweighted, in the sense that we do not look at the amounts of decreased supply in the separate event days in our sample. So, we can interpret the $\beta$ in the regression as the average effect of decreased bond supply across all events. We estimate the regression with standard errors robust to heteroskedasticity.

We also adopt an instrumental variables approach to check whether or not endogeneity could bias our results. Endogeneity could arise from the fact that the Government could choose the structure of its debt to minimize interest payments. The Treasury could have an incentive to shift towards issuing a higher percentage of long-term bonds if the spread between long and short-term interest rates decreased, due for example to a higher demand for bonds with longer maturity.We focus our instrumental variables approach on equation (1) for Italy and (2) for Germany. We choose Debt to GDP as instrument for Maturity Weighted Debt for Italy, while we use the future expected Debt to GDP for future expected German supply. Our approach is consistent with the one proposed by Krishnamurthy and Vissing-Jorgensen (2012).

## 3.2 A Term Structure Model with Bond Supply

We also estimate a Gaussian Dynamic Term structure Model in which we can estimate the impact of supply in a no-arbitrage setting. We let the short rate be a linear function of a vector of state variables $Z_t$:

$$r_t = \delta_0 + \delta_1 Z_t \tag{5}$$

where Z is a vector comprised of $M_t$, our bond supply variable and $P^{\psi}$ additional pricing factors with $\psi$=2. The additional pricing factors can be either latent or observed portfolio of yields. We use the first two principal components derived from bond yields as our additional pricing factors. Joslin et al. (2013) show that this model is observationally equivalent to a model with $P_t^N$ pricing factors, the $N = M + \psi$ portfolios of yields. We also assume that $M_t$ and the first $P_t^{\psi}$ yield portfolios are measured without error, while the remaining yield factors are different from their theoretical values by a mean-zero measurement error $\sigma_e$ . it is a well known fact that the term structure of interest rates is well defined by a low-dimensional factor structure, so we choose N=3 in order to obtain estimates that will fit the observed yields without incurring in the risk of over-fitting the model.

$Z_t$ follows a VAR(1) process under the risk neutral dynamics

$$Z_{t+1} = K_0^Q + K_1^Q Z_t + \epsilon_{Z,t+1}^Q \tag{6}$$

where $\epsilon_{Z,t+1}^Q \sim iidN(0, \Sigma_Z)$ under the risk-neutral measures and $K_0^Q$ and $K_1^Q$ are a Nx1 vector and a NxN matrix, respectively. In this setup, yield portfolios for all maturities take an exponentially linear form of $Z_t$ and are expressed as:

$$P_t = A_{n,Z} + B'_{n,Z} Z_t \tag{7}$$

where $A_{n,Z}$ and $B'_{n,Z}$ are dependent on the risk-neutral parameters $\Theta^Q = \{\delta_0, \delta_1, K_0^Q, K_1^Q, \Sigma_Z\}$ and are estimated recursively as:

$$A_{n+1} = A_t + B'_n K_0^Q - \frac{1}{2} B'_n \Sigma_Z B_n + \delta_0, \tag{8}$$

$$B'_{n+1} = \delta'_1 + B'_n K_1^Q. \tag{9}$$

The state vector also follows a VAR(1) under the physical distribution:

$$Z_{t+1} = K_0^P + K_1^P Z_t + \epsilon_{Z,t+1}^P \tag{10}$$

where $\epsilon_{Z,t+1}^P \sim iidN(0, \Sigma_Z)$ under the physical measures. We employ the same normalizations suggested in Joslin et al. (2011) and based on the work of Dai and Singleton (2000) in order to obtain identification, thus we estimate the Macro Term Structure Model (MTSM) in its canonical form. In this canonical form, the risk neutral distribution is characterized by $\Sigma_Z$, the long-run risk neutral mean $r_\infty^Q$ of the short-rate and $\lambda^Q$, the N-vector of real eigenvalues of the feedback matrix $K_1^Q$ that is rotation-invariant. Moreover, an implication of the observational equivalence of a model with $Z_t$ and $P^N$ as pricing factors is that the macro-factor is a linear combination of $P_t^N$:

$$M_t = \gamma_0 + \gamma_1 P_t^N. \tag{11}$$

That is, our bond supply variable is completely spanned by the first N principal components of bond yields. This means we can rotate a model with $P_t^N$ as pricing factors to one with $Z_t = [M_t, P_t^\psi]$ by using the following transformation:

$$Z_t = \begin{bmatrix} 0 \\ \gamma_0 \end{bmatrix} + \begin{bmatrix} I_\psi & 0_{\psi(N-\psi)} \\ \multicolumn{2}{c}{\gamma_1} \end{bmatrix} P_t^N. \tag{12}$$

We also constrain the $K_1^P$ matrix as following:

$$\begin{bmatrix} k_{11} & k_{12} & 0 \\ k_{21} & k_{22} & 0 \\ 0 & k_{32} & k_{33} \end{bmatrix}$$

These constraints mean that under the physical measure, bond supply does not load on the yield-based pricing factors. Moreover, supply is only affected by the second yield factor (the slope factor). These constraints are similar as the ones in Li and Wei (2013), which helps to ensure that any evidence in support of supply effects is driven by the data. However, as described in Joslin et al. (2011), restriction on the P side of the model do not affect the factor loadings that depend only on the estimated risk-neutral parameters. The only advantage that might be obtained by constraining the matrix under the physical distribution is improving forecasts of bond portfolios. Nonetheless, we also estimate the model with an unconstrained $K_1^P$ matrix and check if our coinstrained model is statistically better than the unconstrained one according to a log-likelihood ratio test. Finally, market prices of risk, which modulate investors' behaviour towards risks, are also affine in our specification and are defined as $\Lambda_t = \Sigma_Z^{-1/2}(\lambda_0 + \lambda_1 Z_t)$ where

$$\begin{aligned} \lambda_0 &= K_0^P - K_0^Q \\ \lambda_1 &= K_1^P - K_1^Q. \end{aligned} \tag{13}$$

To summarize, our entire parameter set is $\Theta = (r_\infty^Q, \lambda^Q, \gamma_0, \gamma_1, \Sigma_Z, K_0^P, K_1^P, \sigma_e)$. We estimate the model using Maximum Likelihood, following the estimation proposed in Joslin et al. (2011).

### 3.3 Identification of Scarcity Effects

We also focus our analysis on short and medium-term German Bonds. We define $s_t^{(\tau)}$ as the yield spread between the $\tau$ year bond and the ECB deposit rate and estimate a threshold model for yield spread changes as follows:

$$\mathit{\Delta}_4 s_t^{(\tau)} = \alpha + \beta_1 \mathit{\Delta}_4 E[STdebt_{t+k}]\mathbb{1}_{(s_{t-4}^{(\tau)}>0)} + \beta_2 \mathit{\Delta}_4 E[STdebt_{t+k}]\mathbb{1}_{(s_{t-4}^{(\tau)}<0)} + \sum_{j=3}^{n} \beta_j \Delta_4 X_j + \epsilon_t$$

where $\mathit{\Delta}_4 s_t^{(\tau)}$ is the spread change over a four-week period, $E[STdebt_{t+k}]$ is the expected supply of Government Debt with original maturity below 2 years and $X_j$ is a matrix of control variables. $\mathbb{1}_{(s_{t-4}^{(\tau)}>0)}$ and $\mathbb{1}_{(s_{t-4}^{(\tau)}<0)}$ are two indicator functions that assume value of one whenever the lagged spread is positive and negative, respectively. We estimate our model with Newey and West (1987) standard errors allowing for 8 lags. For robustness, we also consider an alternative specification and assume an AR(1) process for the regression residuals and estimate the extended model with robust standard errors. We control mainly for flight-to-safety effects, since German governments bonds might be prone to an increase demand at times of high market stress, given their status of safe-haven.

# 4 Results

### 4.1 Linear Regressions Results

We start the empirical analysis by investigating the importance of current bond supply versus expected bond supply for explaining yield spreads. Table 3 shows the result of regressions of current and future expected supply on yield spreads. The second and the ninth Columns of Panel A and Panel B report the coefficients of current and expected maturity-weighted supply for both countries. The outcome is completely different depending on the country we consider. For example, the coefficients of current maturity-weighted supply are not significant for any maturity for German yields. However, future expected maturity-weighted supply carries significant coefficients at all maturities. We get completely opposite results for Italy. In fact, current maturity-weighted debt shows significant coefficients for Italy, while future expected maturity-weighted supply has no impact on yield spreads.

Looking at the economic significance of our results, current maturity-weighted supply carries a coefficient of 0.005 (t=2.38) on the 10 year yield spread for Italy. Thus, an increase of one standard deviation in current supply would increase the spread between the 10 year and the 1 year bond by around 50 basis points. Results are doubled for expected future supply for Germany. More specifically, an increase of one standard deviation in future expected supply (coefficient=0.011, t=1.99) would increase the spread between the 10 and the 1 year German yield by around 110 basis points. We can compare these estimates with estimates of the impact of the PSPP program the ECB implemented in Europe from March 2015 (it announced on January 2015). If we look at the first year and a half of purchases, the ECB bought around €160 billion of Italian government Bonds. Assuming an average duration of around 5 years for purchased bonds and a GDP of €1.6 trillions, the decrease in current maturity-weighted supply would be 0.16*5/1.6=0.5. This magnitude would decrease the yield spread by around 25 basis points.

The same calculation for Germany has more caveats. In fact, we would have to estimate the expected amount and average maturity of purchases that was anticipated by market participants before the program even took place. This is a daunting task, in the sense that it is complicated to assess when agents incorporated information on future purchases. While the announcement of the program may have had a sizable impact, it is also possible that the PSPP was anticipated even before the announcement. According to Gambetti and Musso (2017), the announcement of the Public Sector Purchase Programs was anticipated, up to a certain extent, by market participants. However, there were uncertainties the total size of the program, that could only be estimated by investors. Assuming that agents could have had an imperfect estimate of the amount and maturity of the purchases in the first part of the PSPP (for example around €200 billions with an average duration of 5 years for German Government bonds) and with a GDP of €3.2 Trillions, hence a decrease in expected maturity-weighted supply would be 0.31 (0.2*5/3.2). This would imply a total decrease of the yield spread by around 200 basis points. While almost in line with the estimates of Greenwood and Vayanos (2014), our estimates of the impact of current supply on yield spreads for Italy is somewhat smaller compared to other estimates of the impact of the PSPP, while it is of bigger magnitude than expected for the expected German supply. This dissonance could be due to the intrinsic difference in the two variables, with one being a measure of the present outstanding amount of government bonds, while the second one being a forward-looking measure. It is also possible that we overestimate the impact of the PSPP on german Bonds, because in our calculation we assume that agents have a reliable estimate of specific features of the program months in advance, which is unlikely.

Moreover, columns 4 and 11 of Panel A and B of Table 3 report the coefficients related to maturity weighted purchases by the ECB. The variable measures the impact of actual purchases (the flow effect) on yield spreads. Coefficients are not significant for both countries at any maturity. At first sight, this may seem inconsistent. However, the existing literature (for example D' Amico and King (2013)) estimates that flow effects have a limited impact on yields compared to stock effects (the impact at the announcement). Flow effects are also transitory and converge to zero a few days after the actual purchases. Therefore, our monthly time-series regressions may not be well equipped to capture this flow effect that could be observed at higher frequencies. Panel C of Table 3 reports the results of the horse-race regressions between current and expected maturity-weighted supply. Consistent with our results in Panel A and B of the same Table, our measure of expected maturity-weighted supply dominates current supply for Germany, while current supply flushes out expected supply for Italy. The magnitude of the coefficients is similar to our base-case, so adding current supply or expected supply for Germany and Italy respectively does not add any information to our baseline specifications.

In Table 2 we also report the coefficients and standard errors of our event-study regression. We run regressions on daily changes of 2,5 and 10 year German yields. We use two different event windows, the first only on t and the second one from t-1 to t+1, with t being the event dates of press-releases about future supply. We use short event windows to reduce the likelihood of confounding events on the event dates. Coefficients at all maturities are significant in both event windows. The overall magnitude is limited. For example, the 10 year bond has an abnormal change of 2.2 basis points in press-release days. However, we stress out this is the average effect on any reduction in expected supply, thus future small supply reduction have exactly the same weight as major changes in planned auctions by the Treasury. Moreover, this regression does not assess the persistence of the yield changes after the event took place, but only that there are abnormal yield change movements in the event days.

Panel A and B of Table 5 show the results of our instrumental variables estimation. Columns 8-13 report the coefficients of the first stage regressions. The t-stat of our instruments are highly significant and the R-squared are around 0.90 for all regressions. Compared to our base case in Table 3 we add the lag of the yield spread as an additional exogenous independent variable. T-statistics are computed with Newey and West (1987) standard errors and allowing for lags up to 12 months. Columns 2-7 of both tables report the second stage regressions for both countries. In this tables it is possible to see a clear difference between the two countries. For Germany, the coefficient on the 10 year spread is 0.008 (0.01 for the OLS) and still significant, even if with a smaller magnitude. For Italy, the results is completely different. In fact, current maturity-weighted supply is not significant at any maturity (the coefficient for the 10 year spread is 0.0003) which corresponds to an impact of 3 basis points for each standard deviation increase in the variable.

The difference between the two countries is staggering. Our main takeaways from this exercise are the following: the amount of information on German expected supply does have an influence on German yields and the German treasury does not seem to "time the market" by changing the amount and maturity of its debt structure according to market rates. Regarding Italy, we do not find a strong and significant relationship between expected supply and interest rates. However, it is indeed possible that shocks to interest rates derive from changes in future budget deficits deriving by future fiscal measures from the Government that would increase future amounts of issued debt. Since we do not control for that, but only from information stemming from the Treasury press-releases, we cannot completely assess the impact of supply expectations for Italy. Finally, we can claim that, once accounting for endogeneity, the impact of the current amount of maturity-weighted debt on Italian yields is negligible.

## 4.2 Estimation and Results of the MTSM

Given the results in the previous section, we focus our attention on Supply expectations and German interest rates. We estimate our MTSM using yields with maturity of 3, 12, 24, 36, 48, 60, 96 and 120 months from January 2005 to December 2017 (156 observations). We also compute a parametric bootstrap in order to obtain bootstrapped standard errors in the spirit of Bauer and Rudebusch (2016). In fact, as also noted in Bauer et al. (2012), estimates from dynamic term structure models can be biased especially in small samples, thus leading to misleading inference on parameter estimates. Our simulation design is as follows: using the parameter estimates from our MTSM, we simulate n=1000 yield and macro factors from the VAR and then construct fitted yields from the factor loadings and the simulated data[4]. We also add an iid Gaussian measurement error to obtain simulated

[4]We take t=1 as starting point of our VAR. We also compute the bootstrap by choosing a random t from which simulate our factors and results are not affected.

yields[5]. Our simulated samples have the same length as the actual data (T=156). We then run the model for each simulated sample and obtain maximum likelihood estimates of our parameters from the simulated data.

In Tables 8 and 9 we report parameter estimates under the risk-neutral and the physical measures. $\lambda^Q$ represents the eigenvalues of $K_1^Q$ matrix, which governs the $Q$-rates of the factors' mean reversion, while the bottom line of the $K_1^P$ matrix reports the eigenvalues from the feeddback matrix of the physical parameters. The eigenvalues on the physical dynamics are close enough to unity to imply that expected future interest rates on longer maturities are not constant, which is in line with survey forecasts as shown in Kim and Orphanides (2005). In fact, low eigenvalues would imply a faster mean reversion process, which would attribute too much of the variation in long-term forward rates to risk premiums. Looking at risk premium parameters, In table 10 we show the market prices of risk that capture the excess return required from risk-neutral investors. In fact, market prices of risks affect the intercept and the loadings in equation 7. The bottom-right coefficient in the matrix (-0.071) related to supply expectations is significant. That means expected supply drives time-variation in risk premia in our model. The negative sign also implies that a shock to supply expectations has a positive and increasing impact on longer bond maturities compared to short-term bonds. We also plot in Figure 4 the loadings of our three factors in the model. The loadings for the macro-factor are hump-shaped and mostly affect the long-end of the curve, while they are slightly positive or negative and close to zero for short and medium maturities. Moreover, in figure 5 we show how our expected supply factor drives excess returns in our sample. Excess returns implied from the model reach the highest point during the financial crisis, in which higher risk aversion and a higher supply from the government increased the return requested from investors to hold this risk. Furthermore, Germany was largely unaffected by the Sovereign Crisis that hit Euro Area from 2011, so the excess return from our supply factor does not spike

[5] We take as measurement error the cross-sectional average of our pricing error in the MTSM.

up during that period.

We also check whether our restricted model performs better than an unrestricted model estimated with a maximally flexible vector autoregressive model under $P$. We perform a log-likelihood ratio test between the two log-likelihoods implied by the models. The t-stat of the test is 0.4, so we cannot reject the null that the unrestricted model is more efficient. We report in the appendix the $K_1^P$ matrix estimated with the unrestricted model.

The results derived from the MTSM confirm our findings that supply expectations impact interest rates and affect term premium variation in Germany.

## 4.3 Scarcity Effects

Table 6 shows the results of the threshold model we estimate to assess the impact of scarcity effects whenever German short-term bonds trade at lower yields than the ECB deposit rate. Columns 2-6 estimate the model with Newey and West (1987) standard errors allowing for 8 months of lag. Adding more lags does not seem to alter our results. Instead, columns 7-11 assume an AR(1) process for regression residuals. In this case, we also use robust standard errors. The two different estimations carry similar results, with the latter being more conservative in terms of t-stats and magnitude of the coefficients. For instance, the coefficient of 0.19 (t=7.6) in Column 3 implies that a 1 percent increase in the expected short-term debt to GDP (more or less half of the variable standard deviation) decreases the spread between the 1 year bond and the short rate by 19 basis points whenever the lagged spread is negative. The correspondent coefficient of 0.134 in Column 8 (t=2.88) means that a 1 percent increase in expected short-term debt to GDP decreases the same spread by almost 14 basis points. In both specifications we find the stronger effect around the 1 year maturity, with the size and the significance of the coefficients declining moving towards longer maturities. Furthermore, the impact of expected short-term debt on the spread between government bonds and the deposit rate is negligible whenever the spread is positive (first row of Table 6). The only maturity in which the expected outstanding amount of short-term debt seems to have an impact on the spread is at 4 year maturity. However, this could be due to the limited amount of days in which 4 year bonds traded below the deposit rate. In our robustness tests, we apply the model to different sample periods and we also change how we calculate our measure of expected supply. In all our specifications, the results are significant and robust. To the best of our knowledge, we are the first to find a link between the amount of German bonds that have been trading below the ECB deposit rate and the expected amount of short-term bond supply.

We also control our model for flight-to-safety effects, because an increased demand for German Bonds during times of high market stress and risk aversion may drive downward movements of interest rates on safe-haven markets. We add 4-week changes in stock market volatility and in the German CDS Spread as controls for flight-to-safety. Indeed, we find a negative relationship between our controls and German yields, confirming the presence of a flight-to-safety effect in our sample. The coefficients of Row 3 and 4 of Table 6 are negative and significant, especially when we control for higher risk aversion in the equity market. However, our variable of interest is still significant, even after controlling for this effect.

# 5 Robustness Tests

We perform a number of robustness tests on our baseline specifications. First, we estimate the same horse-race regression of Table 3 in first difference. We compute the t-statistics with Newey and West (1987) standard errors allowing for up to 12 lags. The results in Table 4 are very similar to our regressions in levels, even if somewhat weaker. Next, we add to our level regressions several controls. We focus our attention on the robustness of future expected supply for Germany. Table A.3 in the Appendix report the results.

First, in Column 3 we add controls for credit and liquidity risk. Credit and liquidity conditions may drive interest rates, especially in times of high market stress, for example during the Financial Crisis and, more specifically, during the Sovereign Debt Crisis that happened in Europe between 2010 and 2012. Next, in Column 4 we add a control for risk aversion in the equity market and a dummy for the Sovereign Crisis. Moreover, in columns 5 and 6 we add two macroeconomic controls. Macroeconomic variables such as GDP and inflation could affect interest rates through the risk premium, such as shown in Ludvigson and Ng (2009) and Joslin et al. (2014). We control for output growth and inflation risk in Columns 5 and 6. Our results remain significant after controlling for all these factors.

We also check for possible effects of the Securities Market Program (SMP) on the overall supply stock for Italy. We then modify our maturity-weighted debt by the amount and the average maturity of the purchases during the SMP. We define

$$MWD_{ITA,SMP} = \frac{\sum_{\tau=0}^{30} D_t^{\tau}\tau - D_{SMP} * \overline{M}_{SMP}}{GDP_t}$$

where $D_{SMP}$ is the total amount of government bond purchases and $\overline{M}_{SMP}$ is the average maturity of the purchases during the program. Table A.4 in the Appendix shows the results of our baseline regression with this modified variable. Results are largely unaffected, with the coefficients of current supply in Column 2 still significant.

We also control for quarterly and annual effects of future expected supply on interest rates. Since the main press releases happen at the end of each quarter, it is possible that the impact on interest rates of our forward-looking measure is concentrated in those months. For Germany, we also check for annual effects, because the most important announcement regarding future auctions takes place every December. We interact a quarterly dummy with our measure of future expected supply. In the case of Germany, we also interact our variable with an yearly dummy. The results are shown in Table A.5. In columns 5 and 6 of the Table we show that the interaction terms are not significant. We also perform an F-test between the coefficients of the interaction with our variable of expected supply in column 9. Quarterly and yearly dummies do not affect our baseline results that remain significant and are largely unchanged.

We also check whether the results regarding the impact of expected short-term debt on the spread between German Bonds and the deposit rate of the ECB remain significant with different specifications. In Columns 2-6 of Table A.6 we modify our measure of expected short term debt. We calculate separately the specific amount of expected supply below 1 year of original maturity and below 2 years original maturity. We regress the 3 months and the 1 year spread on the expected supply below 1 year, while we regress the 2 year spread on the expected supply with 2 year maturity. Since the German Government does not issue bonds with 3 and 4 years original maturity, we use the expected supply of 2 year bonds as the closest proxy of expected supply for similar bonds. Furthermore, Columns 7-11 show the results if we decrease the sample size from 2010 to 2017, omitting the financial crisis. In fact, the Government might have responded endogenously to the decrease in short-term interest rates by issuing a larger fraction of short-term debt. In this specification the coefficients are doubled compared to the ones in Table 6. In Columns 12-16 we omit 2017. It is possible, in fact, that the ECB purchased some bonds around the two years maturity and below the deposit rate from January 2017. However, our results are largely unaffected if we omit 2017. Finally, we estimate a horse-race threshold regression between current and expected future short-term supply. We also augment this specification with a control for liquidity risk. Table 7 shows the results. Our measure of expected short-term debt flushes out current short-term supply when the spread is negative. This also confirms our previous findings on the intrinsic value of specific forward-looking information compared to the actual quantities observable on the market.

# 6 Conclusion

This paper provides evidence on the impact of current and expected supply on government bond yields in the European market. We find that, whenever agents have specific information of future issues from the Government, the current level of supply that is observable in the market does not affect interest rates. We also find that, after accounting for endogeneity, current supply does not affect interest rates. We also provide an explanation for the sizable amount of German government bonds trading consistently below the deposit rate of the European Central Bank. Our findings are both statistically and economically significant. For example, a standard deviation increase in expected future supply steepens the yield curve by around 110 basis points. Moreover, one standard deviation increase in expected short-term supply decreases the spread between short-term bonds and the short rate by around 10-15 basis points whenever the spread is negative. We also validate our results with a Macro Term Structure model in which we fine supply expectation to affect risk premium.

We provide empirical support for portfolio-rebalance and preferred-habitat theories of the term structure of interest rates. Understanding how the channels through which current and expected supply affect interest rates might be useful both for policy-makers and for Treasury Departments. For example, Treasury departments that do not have a specific forward guidance on the future issuance planning could take advantage of this feature in the future. Moreover, the channel of transmission regarding expectations of future supply might be useful for Central Banks in case new large-scale asset purchase programs will be undertaken in the future.

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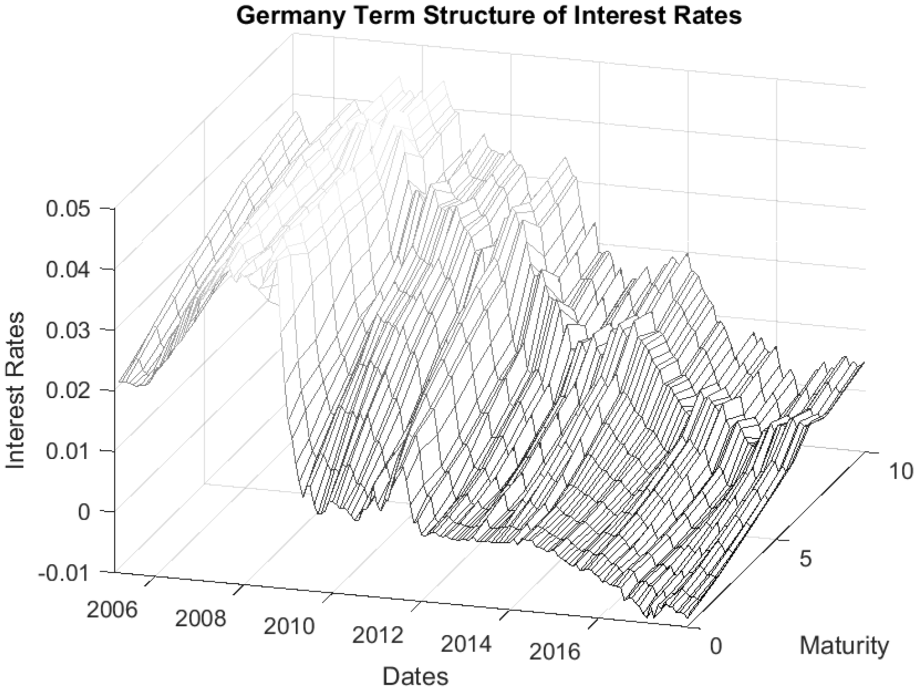
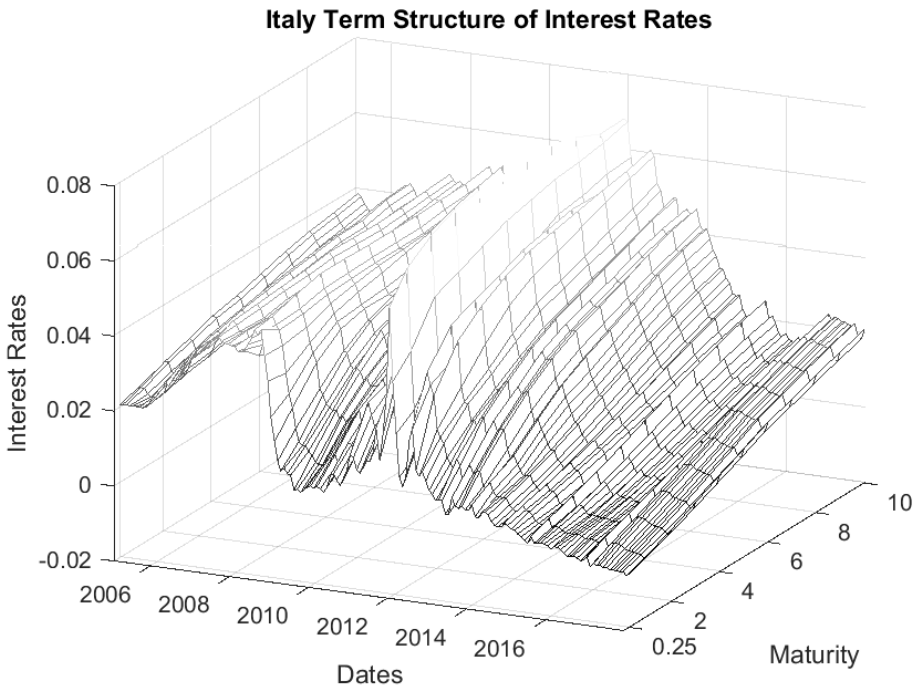



**(a)** Germany




**(b)** Italy

**Figure 1: German and Italian Zero-Coupon Yields**
Italian and German zero-coupon interest rates. The dashed vertical line marks the start of the Public Sector Purchase Program.

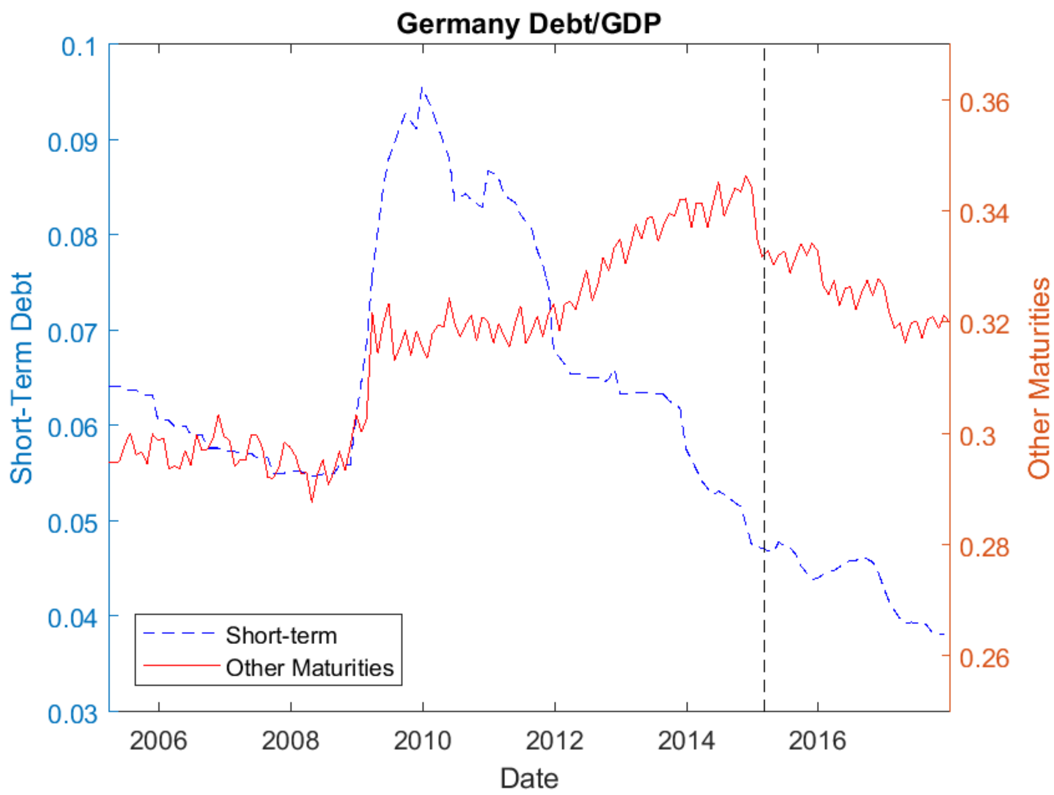



**Figure 2: German Short and Long-Term Supply**

The figure plots the amount of outstanding german debt divided in two sub-groups. The blue line represents the amount of debt with original maturity below 2 years scaled by GDP, while the red line is all the remaining maturity scaled by GDP. The dashed vertical line represents the start of the Public Sector Purchase Program. In this graph we do not subtract the amount of purchases from the outstanding amount of debt above 2 years maturity (the red line).

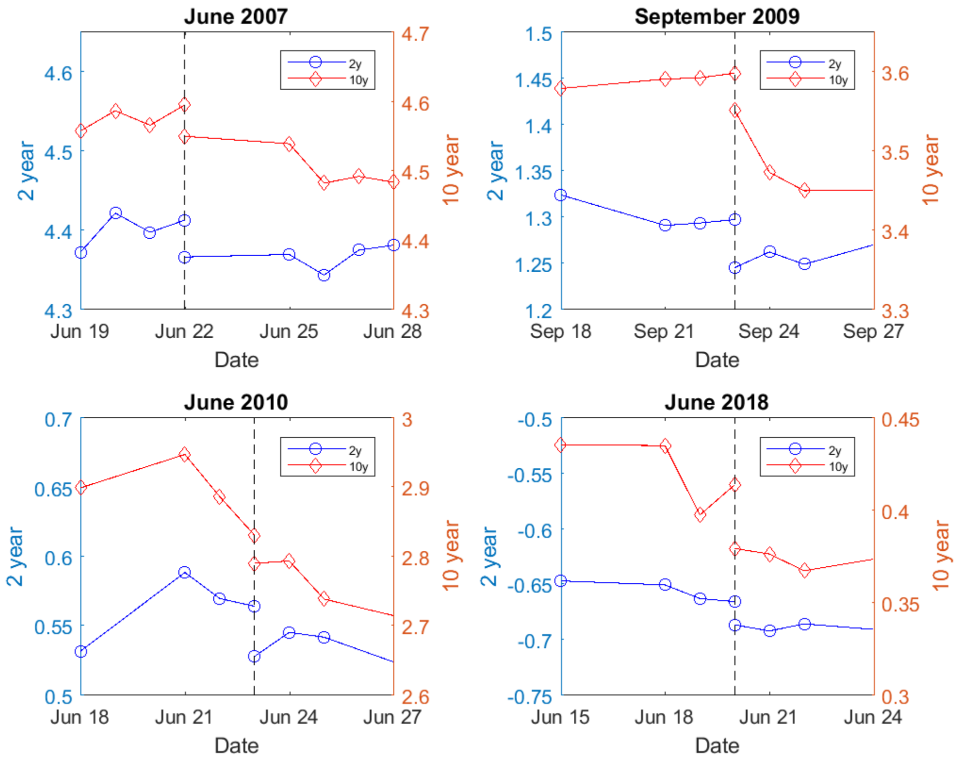



**Figure 3:**

**German Interest Rates around Treasury Press Releases that reduced overall Supply**

The figure represents interest rate movements for 2 and 10-year German bonds in the days around press releases about future bond auctions. The dashed vertical line represent the day of the press-release. The break in the yields represents $\Delta y_{t,t-1}$, the yield difference between t and t-1. The events in the figure represent instances in which the Treasury decreased the expected issued amount at different maturities.

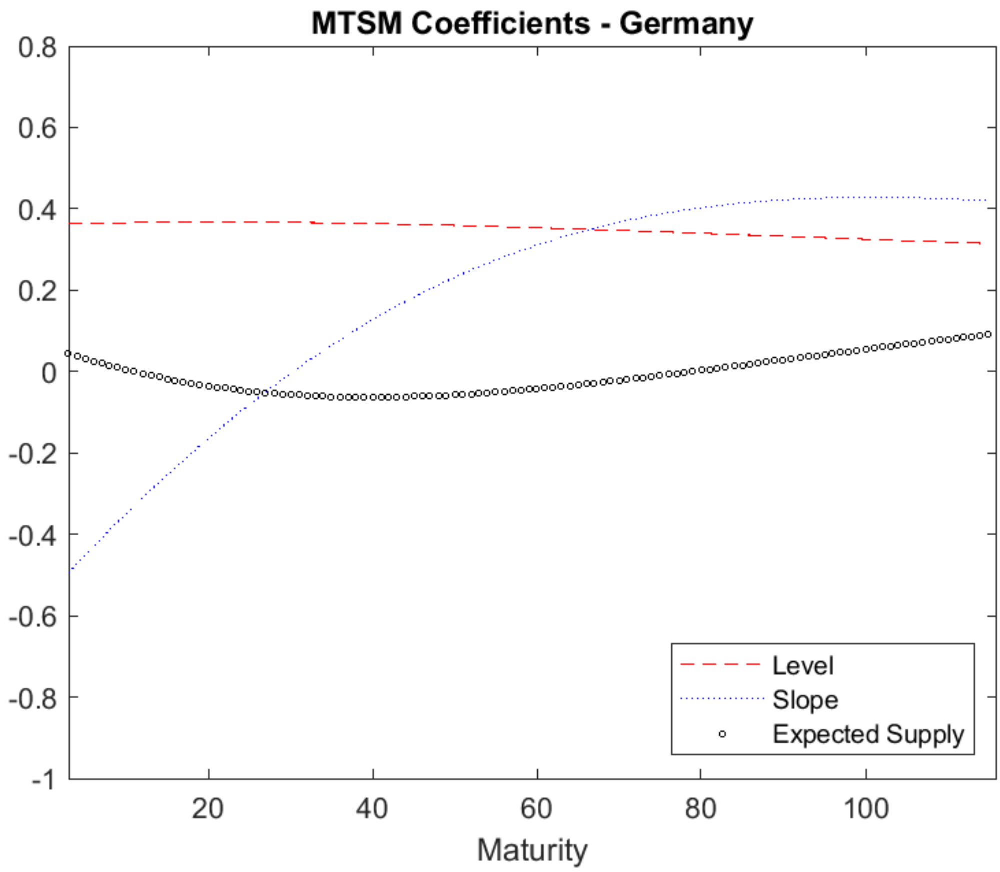



**Figure 4: Estimated coefficients from the Term structure model for Germany.** The figure plots the loadings from the Macro Term Structure Model that are estimated under the risk-neutral measures. The red dashed line is the level factor, the blue dotted line the slope factor and the black dots are the loadings for Expected Supply. Maturity is in months.

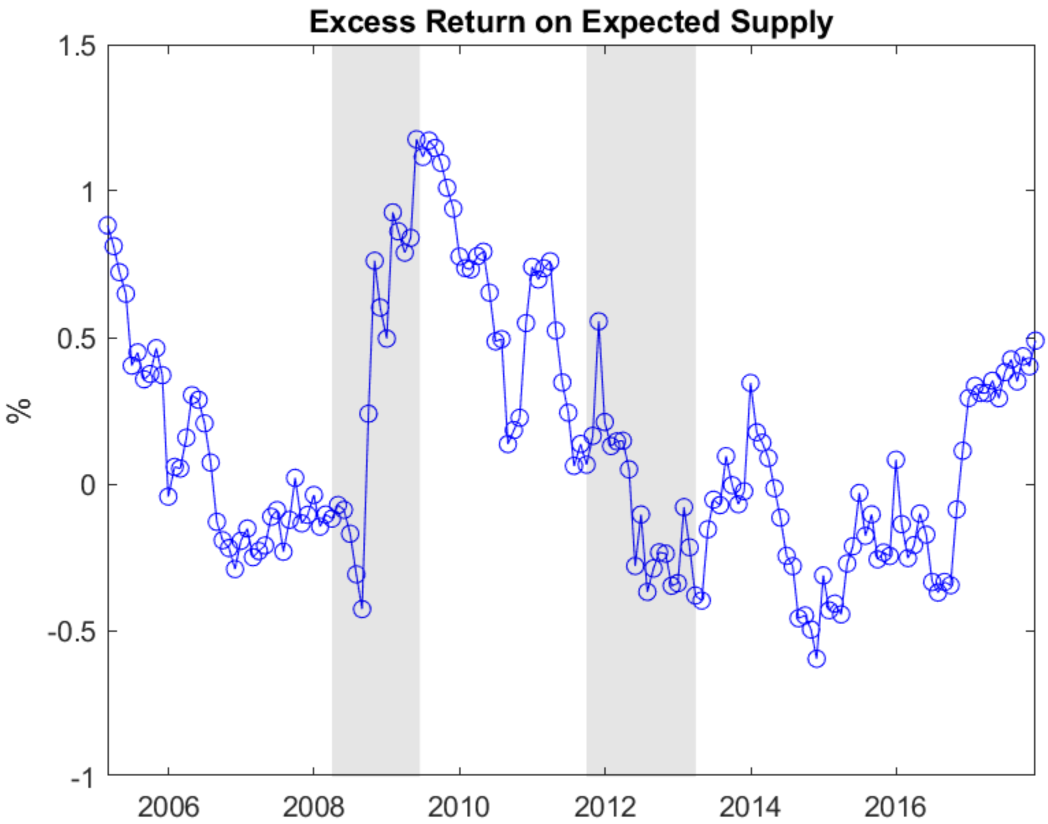



**Figure 5: Excess Returns for Expected Supply estimated from the MTSM**
The figure plots the excess returns estimated from the Macro Term Structure model. Grey shaded areas represent recession periods provided by CEPR.

**Table 1: Summary Statistics**

The Table summarises the main variables in our sample (2005-2017). ECB Dep. Rate is the interest applied on deposits at the European Central Bank. 2y, 5y, 10y, 30y are zero-coupon yields on 2, 5, 10 and 30 year bonds. $MWD$ is the Maturity-Weighted Debt scaled by GDP. $E[MWD|I_t]$ is the future expected value of Maturity-Weighted Debt scaled by $GDP$. $MWQE$ is the amount of Maturity-Weighted Purchases by the ECB during the PSPP Program scaled by GDP. $E[STdebt]$ is the expected outstanding amount of German short-term bonds scaled by GDP. Liquidity Risk is the Time-Weighted Bid-Ask Spread from MTS. For both countries, we average across all maturities the intra-day Bid-Ask Spread of each bond displayed in the order book, weighted by the length of time each spread is displayed. Credit Risk is the log of the 5-year us dollar denominated Sovereign CDS Spread. Inflation is monthly inflation. Inflation Risk is the standard deviation of monthly inflation over the past twelve months. Output Growth is the difference between log real GDP in the current quarter and log real GDP in quarter t-4. Stock market volatility is the log of the Vstoxx index. Crisis Dummy is a dummy that assumes the value of 1 between October 2010 and September 2012.

| **Sample: 2005-2017 (Monthly Data)** | **ITALY** | | | | **GERMANY** | | | |
|---|---|---|---|---|---|---|---|---|
| **Yields** | **Mean** | **Std. Dev.** | **Min** | **Max** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| ECB Dep. Rate | 0.007 | 0.01 | -0.004 | 0.0325 | 0.007 | 0.01 | -0.004 | 0.0325 |
| 2y | 0.021 | 0.016 | -0.002 | 0.069 | 0.012 | 0.016 | -0.009 | 0.044 |
| 5y | 0.029 | 0.015 | 0.003 | 0.073 | 0.016 | 0.016 | -0.006 | 0.045 |
| 10y | 0.038 | 0.013 | 0.012 | 0.068 | 0.023 | 0.014 | -0.002 | 0.045 |
| 30y | 0.045 | 0.010 | 0.022 | 0.067 | 0.029 | 0.012 | 0.004 | 0.047 |
| **Supply** | | | | | | | | |
| $MWD$ | 7.298 | 1.177 | 5.297 | 8.928 | 3.199 | 0.133 | 2.97 | 3.42 |
| $E[MWD\|I_t]$ | 7.273 | 1.156 | 5.284 | 8.789 | 3.236 | 0.14 | 3.022 | 3.50 |
| $MWQE$ | 0.196 | 0.444 | 0.000 | 1.651 | 0.129 | 0.293 | 0.000 | 1.021 |
| $D/GDP$ | 0.775 | 0.146 | 0.560 | 0.962 | 0.384 | 0.021 | 0.351 | 0.420 |
| $E[STdebt]$ | | | | | 0.061 | 0.016 | 0.037 | 0.096 |
| **Other Variables** | | | | | | | | |
| Liquidity Risk | 0.125 | 0.159 | 0.016 | 1.223 | 0.106 | 0.060 | 0.029 | 0.376 |
| Credit Risk | 4.38 | 1.30 | 1.74 | 6.33 | 2.82 | 1.03 | 0.75 | 4.72 |
| Inflation | 0.001 | 0.010 | -0.025 | 0.025 | 0.001 | 0.004 | -0.012 | 0.012 |
| Inflation Risk | 0.010 | 0.003 | 0.005 | 0.013 | 0.004 | 0.001 | 0.003 | 0.005 |
| Output Growth | 0.000 | 0.010 | -0.051 | 0.016 | 0.005 | 0.012 | -0.065 | 0.028 |
| Stock Market Vol. | 22.81 | 8.20 | 11.99 | 60.68 | 22.81 | 8.20 | 11.99 | 60.68 |
| Crisis Dummy | 0.15 | 0.36 | 0.00 | 1.00 | 0.15 | 0.36 | 0.00 | 1.00 |

| Reduced Supply Events - German bond press releases | | | | |
|---|---|---|---|---|
| Bond | $\beta(t)$ | Std. Error | $\beta(t-1,t+1)$ | Std. Error |
| 2y | **-1.6**** | (0.8) | **-0.82*** | (0.4) |
| 5y | **-2.4**** | (1.1) | **-1.1**** | (0.55) |
| 10y | **-2.2**** | (0.96) | **-1.2***** | (0.5) |

**Table 2: Event Study regressions for Germany**

Event study regression of bond yields on a dummy equal to 1 whenever the German Treasury communicated an expected reduction in bond supply in future auctions. Robust standard errors are reported in parenthesis. Coefficients in bold are significant.*** p<0.01, ** p<0.05, * p<0.1.

**Table 3: Current and Expected Debt Supply as a Determinant of Yield Spreads**

This table reports monthly regressions of yield spreads on Current and Expected Future Maturity-Weighted Supply for Germany and Italy:

$$y_{i,t}^{(\tau)} - y_{i,t}^{(1)} = \alpha + \beta_1 MWD_{i,t} + \beta_2 E[MWD_{i,t+k}|I_{i,t}] + \beta_3 MWQE_{i,t} + \beta_4 t + \epsilon_{i,t}.$$

Panel A shows the results for the regression of yield spreads on current supply, while Panel B for expected future supply. Panel C reports horse-race regressions in which current and expected supply are estimated together. T-stats are reported in brackets.We estimate all regression models with an AR(1) Process for Residuals and with Robust Standard Errors. Coefficients in bold are significant. *** p<0.01, ** p<0.05, * p<0.1.

**Panel A**: Current Supply

| | GERMANY | | | | | | | ITALY | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yield Spreads | $MWD_{GER}$ | t-stat | $MWQE_{GER}$ | t-stat | $\alpha$ | t-stat | R-squared | $MWD_{ITA}$ | t-stat | $MWQE_{ITA}$ | t-stat | $\alpha$ | t-stat | R-squared | Trend |
| 2y | 0.0008 | [0.56] | 0.001 | [0.43] | -0.0006 | [-0.14] | 0.01 | **0.002*****| [2.70] | -0.001 | [-0.84] | **-0.001**** | [-2.11] | 0.04 | YES |
| 3y | 0.001 | [0.78] | 0.002 | [0.66] | 0.0001 | [0.027] | 0.02 | **0.002**** | [2.22] | -0.0006 | [-0.20] | -0.005 | [-1.04] | 0.02 | YES |
| 4y | 0.002 | [0.85] | 0.003 | [0.66] | 0.0009 | [0.12] | 0.02 | **0.002**** | [2.02] | 0.0006 | [0.16] | -0.004 | [-0.64] | 0.02 | YES |
| 5y | 0.002 | [0.90] | 0.004 | [0.70] | 0.001 | [0.15] | 0.02 | **0.002**** | [1.98] | 0.001 | [0.24] | -0.003 | [-0.53] | 0.02 | YES |
| 6y | 0.002 | [0.83] | 0.005 | [0.76] | 0.003 | [0.32] | 0.02 | **0.003**** | [2.44] | 0.002 | [0.33] | -0.006 | [-0.91] | 0.03 | YES |
| 8y | 0.003 | [0.90] | 0.006 | [0.79] | 0.004 | [0.39] | 0.03 | **0.004**** | [2.57] | 0.0006‘ | [0.11] | -0.011 | [-1.26] | 0.05 | YES |
| 10y | 0.002 | [0.70] | 0.007 | [0.77] | 0.007 | [0.59] | 0.02 | **0.005**** | [2.38] | -0.0002 | [-0.03] | -0.014 | [-1.21] | 0.05 | YES |
| 20y | 0.004 | [1.06] | 0.007 | [0.64] | 0.007 | [0.48] | 0.03 | 0.004 | [1.58] | 0.0003 | [0.04] | -0.001 | [-0.09] | 0.04 | YES |
| 30y | 0.004 | [1.15] | 0.007 | [0.69] | 0.005 | [0.33] | 0.04 | **0.007**** | [2.08] | -0.0004 | [-0.072] | -0.02 | [-1.21] | 0.10 | YES |

**Panel B**: Expected Supply

| | $E[MWD_{GER}\|I_t]$ | | | | | | | $E[MWD_{ITA}\|I_t]$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2y | **0.005**** | [2.32] | 0.0024 | [1.25] | **-0.013**** | [-2.05] | 0.05 | 0.001 | [0.90] | -0.002 | [-1.10] | -0.003 | [-0.49] | 0.02 | YES |
| 3y | **0.006**** | [2.16] | 0.0036 | [1.05] | -0.014 | [-1.65] | 0.05 | 0.0007 | [0.60] | -0.001 | [-0.39] | 0.001 | [0.25] | 0.01 | YES |
| 4y | **0.008**** | [2.35] | 0.0047 | [1.00] | **-0.02*** | [-1.72] | 0.05 | 0.0013 | [0.98] | -0.0001 | [-0.01] | 0.0007 | [0.10] | 0.01 | YES |
| 5y | **0.01**** | [2.39] | 0.0055 | [0.97] | **-0.022*** | [-1.71] | 0.06 | 0.0004 | [0.25] | 0.0003 | [0.06] | 0.007 | [0.85] | 0.01 | YES |
| 6y | **0.01**** | [2.32] | 0.0064 | [0.99] | -0.022 | [-1.56] | 0.06 | 0.0003 | [0.15] | 0.0008 | [0.14] | 0.009 | [0.97] | 0.01 | YES |
| 8y | **0.011**** | [2.12] | 0.0073 | [0.94] | -0.021 | [-1.25] | 0.05 | 0.0005 | [0.23] | -0.0005 | [-0.07] | 0.009 | [0.82] | 0.01 | YES |
| 10y | **0.011**** | [1.99] | 0.0078 | [0.90] | -0.02 | [-1.12] | 0.05 | 0.0003 | [0.12] | -0.002 | [-0.22] | 0.012 | [0.86] | 0.02 | YES |
| 20y | **0.013**** | [2.09] | 0.0078 | [0.73] | -0.02 | [-1.06] | 0.05 | 0.002 | [0.66] | -0.001 | [-0.13] | 0.011 | [0.81] | 0.02 | YES |
| 30y | **0.013**** | [2.07] | 0.0077 | [0.78] | -0.02 | [-1.14] | 0.06 | -0.0004 | [-0.17] | -0.003 | [-0.47] | 0.019 | [1.29] | 0.04 | YES |

**Table 3:** Continued

**Panel C**: Horse-Race Regressions

| GERMANY | $MWD_{GER}$ | t-stat | $E[MWD_{GER}\|I_t]$ | t-stat | $MWQE_{GER}$ | t-stat | $\alpha$ | t-stat | R-squared | Trend |
|---|---|---|---|---|---|---|---|---|---|---|
| 2y | 0.0006 | [0.42] | **0.005**** | [2.25] | 0.003 | [1.33] | **-0.015**** | [-2.05] | 0.04 | YES |
| 3y | 0.001 | [0.64] | **0.006**** | [2.10] | 0.04 | [1.15] | **-0.017*** | [-1.77] | 0.05 | YES |
| 4y | 0.001 | [0.70] | **0.0081**** | [2.29] | 0.005 | [1.09] | **-0.024*** | [-1.87] | 0.06 | YES |
| 5y | 0.002 | [0.77] | **0.009**** | [2.33] | 0.006 | [1.06] | **-0.028*** | [-1.89] | 0.06 | YES |
| 6y | 0.002 | [0.69] | **0.01**** | [2.27] | 0.007 | [1.07] | **-0.028*** | [-1.72] | 0.06 | YES |
| 8y | 0.002 | [0.76] | **0.01**** | [2.06] | 0.008 | [1.00] | -0.027 | [-1.48] | 0.05 | YES |
| 10y | 0.002 | [0.58] | **0.011*** | [1.95] | 0.008 | [0.95] | -0.026 | [-1.27] | 0.05 | YES |
| 20y | 0.004 | [0.93] | **0.013**** | [2.02] | 0.008 | [0.81] | -0.033 | [-1.38] | 0.06 | YES |
| 30y | 0.004 | [1.03] | **0.013**** | [2.01] | 0.008 | [0.88] | -0.035 | [-1.50] | 0.07 | YES |

| ITALY | $MWD_{ITA}$ | t-stat | $E[MWD_{ITA}\|I_t]$ | t-stat | $MWQE_{ITA}$ | t-stat | $\alpha$ | t-stat | R-squared | Trend |
|---|---|---|---|---|---|---|---|---|---|---|
| 2y | **0.002**** | [2.39] | 0.0007 | [0.58] | -0.001 | [-0.75] | **-0.013**** | [-2.06] | 0.05 | YES |
| 3y | **0.002**** | [2.06] | 0.0003 | [0.23] | -0.001 | [-0.33] | -0.007 | [-1.00] | 0.02 | YES |
| 5y | **0.002*** | [1.86] | -0.0001 | [-0.08] | 4E-04 | [0.08] | -0.003 | [-0.42] | 0.02 | YES |
| 6y | **0.003**** | [2.29] | -0.0004 | [-0.23] | 0.001 | [0.17] | -0.005 | [-0.55] | 0.03 | YES |
| 8y | **0.005**** | [2.37] | -0.0005 | [-0.19] | -2E-04 | [-0.04] | -0.01 | [-0.90] | 0.05 | YES |
| 10y | **0.005**** | [2.18] | -0.0008 | [-0.28] | -0.001 | [-0.16] | -0.011 | [-0.83] | 0.05 | YES |
| 20y | 0.004 | [1.43] | 0.0008 | [0.31] | -0.001 | [-0.08] | -0.006 | [-0.37] | 0.04 | YES |
| 30y | **0.008*** | [1.92] | -0.0020 | [-0.62] | -0.002 | [-0.26] | -0.015 | [-0.90] | 0.10 | YES |

**Table 4:**
**Current and Expected Supply as a Determinant of Yield Spreads - First Diff. Regressions**

Results of the same regressions of Table 3 in first difference. Column 2 reports the coefficients of current maturity-weighted supply (top panel) and future expected maturity-weighted supply (bottom panel) for both countries. T-stats, reported in brackets, are based on Newey-West standard errors with 12 lags. Increasing the number of lags does not alter our results. Coefficients in bold are significant. *** p<0.01, ** p<0.05, * p<0.1.

| | GERMANY | | | ITALY | | |
|---|---|---|---|---|---|---|
| Yield Spreads | $\Delta MWD_{GER}$ | t-stat | R-squared | $\Delta MWD_{ITA}$ | t-stat | R-squared |
| 2y | 0.000 | [0.20] | 0 | 0.001 | [1.20] | 0 |
| 3y | 0.001 | [0.50] | 0.01 | **0.002*** | [1.68] | 0.01 |
| 4y | 0.002 | [0.65] | 0.01 | **0.002**** | [2.04] | 0.01 |
| 5y | 0.002 | [0.72] | 0.01 | **0.002**** | [2.14] | 0.01 |
| 6y | 0.002 | [0.68] | 0.01 | **0.003**** | [2.49] | 0.02 |
| 8y | 0.003 | [0.77] | 0.01 | **0.004**** | [2.21] | 0.02 |
| 10y | 0.002 | [0.57] | 0.01 | **0.004**** | [2.03] | 0.02 |
| 20y | 0.004 | [1.30] | 0.01 | 0.003 | [1.54] | 0.01 |
| 30y | 0.004 | [1.42] | 0.01 | 0.006 | [1.46] | 0.02 |
| | $\Delta E[MWD_{GER}\|I_t]$ | t-stat | R-squared | $\Delta E[MWD_{ITA}\|I_t]$ | t-stat | R-squared |
| 2y | **0.003*** | [1.75] | 0.01 | 0 | [-0.43] | 0 |
| 3y | **0.005*** | [1.96] | 0.02 | 0.000 | [0.22] | 0 |
| 4y | **0.007*** | [1.78] | 0.03 | 0.001 | [0.73] | 0 |
| 5y | **0.008*** | [1.81] | 0.03 | 0.000 | [0.04] | 0 |
| 6y | **0.009*** | [1.79] | 0.03 | -0.000 | [-0.05] | 0 |
| 8y | **0.010*** | [1.75] | 0.03 | -0.000 | [-0.05] | 0 |
| 10y | **0.010*** | [1.71] | 0.03 | -0.001 | [-0.19] | 0 |
| 20y | 0.012 | [1.609] | 0.03 | 0.001 | [0.353] | 0 |
| 30y | 0.012 | [1.585] | 0.03 | -0.002 | [-0.809] | 0 |

## Table 5: Instrumental Variables Regressions

Instrumental variables regressions of yield spreads on future expected supply for both countries. Compared to our baseline regressions we augment it with $y^{(\tau)}_{t-1} - y^{(1)}_{t-1}$, the lag of the yield spread, as independent variable. Columns 8-14 of Panel A report the first stage regressions for Germany. We instrument Future Expected Maturity Weighted Supply with Expected Debt/GDP. Columns 2-7 of Panel A report the coefficients for the first stage regressions. Columns 8-15 of Panel B report the second stage regressions for Italy. We instrument Current Maturity-Weighted Supply with $D/GDP$. Columns 2-7 of Panel B report the coefficients for the second stage regressions. T-stats are based on Newey-West standard errors with 12 lags. Coefficients in bold are significant. p<0.01, ** p<0.05, * p<0.1.

**Panel A:** Germany

| | **First Stage** | | | | | | **Second Stage** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E[D/GDP]$ | $MWQE_{GER}$ | $y^{(\tau)}_{t-1} - y^{(1)}_{t-1}$ | Trend | $\alpha$ | R Squared | $E[\widehat{MWD}_{GER}]$ | $MWQE_{GER}$ | $\alpha$ | R Squared | $y^{(\tau)}_{t-1} - y^{(1)}_{t-1}$ | Trend |
| 2y | **5.83*****| -0.06 | **-8.86**** | YES | **1***** | 0.93 | **0.003**** | **0.001**** | **-0.001**** | 0.81 | YES | YES |
| t-stat | [10.69] | [-1.54] | [-2.27] | | [5.18] | | [2.25] | [2.29] | [-2.23] | | | |
| 5y | **6.02***** | -0.06 | **-3.67*** | YES | **.94***** | 0.93 | **0.006***** | **0.003***** | **-0.018***** | 0.92 | YES | YES |
| t-stat | [8.42] | [-1.35] | [-1.89] | | [3.77] | | [3.60] | [3.21] | [-3.54] | | | |
| 8y | **5.82***** | **-0.07*** | -2.08 | YES | **1.01***** | 0.93 | **0.006***** | **0.002**** | **-0.018***** | 0.94 | YES | YES |
| t-stat | [8.35] | [-1.78] | [-1.41] | | [4.13] | | [2.77] | [2.55] | [-2.71] | | | |
| 10y | **5.59***** | -0.08 | -1.3 | YES | **1.09***** | 0.92 | **0.008***** | **0.003***** | **-0.025***** | 0.93 | YES | YES |
| t-stat | [8.07] | [0.036] | [-0.89] | | [4.47] | | [3.21] | [2.85] | [-3.21] | | | |
| 30y | **5.43***** | **-0.09***** | -0.81 | YES | **1.15***** | 0.92 | **0.01***** | **0.003***** | **-0.03***** | 0.94 | YES | YES |
| t-stat | [8.44] | [-2.51] | [-0.61] | | [5.08] | | [3.02] | [2.71] | [-3.03] | | | |

**Table 5:** Continued

**Panel B:** Italy

| | First Stage | | | | | | Second Stage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $D/GDP$ | $MWQE_{ITA}$ | $y_{t-1}^{(\tau)} - y_{t-1}^{(1)}$ | Time Trend | $\alpha$ | R Squared | $MWD_{ITA}$ | $MWQE_{ITA}$ | $\alpha$ | R Squared | Time Trend | $y_{t-1}^{(\tau)} - y_{t-1}^{(1)}$ |
| 2y | **7.61*****| 0.08 | **-8.86***** | YES | **1.2***** | 0.91 | 0.00009 | -0.0002 | **-0.001**** | 0.78 | YES | YES |
| t-stat | [24.69] | [-1.45] | [-2.27] | | [5.18] | | [0.57] | [0.71] | [-0.15] | | | |
| 5y | **7.54***** | 0.07 | **-3.67***** | YES | **1.31***** | 0.9 | 0.00002 | 0.0001 | **-0.018***** | 0.92 | YES | YES |
| t-stat | [22.6] | [-1.6] | [-1.89] | | [4.96] | | [0.1] | [0.40] | [-3.54] | | | |
| 8y | **7.47***** | 0.06 | -2.08 | YES | **1.34***** | 0.93 | 0.0002 | -0.00006 | -0.0006 | 0.91 | YES | YES |
| t-stat | [19.35] | [0.93] | [-1.41] | | [4.51] | | [0.69] | [-0.12] | [-0.33] | | | |
| 10y | **7.5***** | 0.05 | -1.3 | YES | **1.32***** | 0.92 | 0.0003 | -0.0001 | -0.001 | 0.93 | YES | YES |
| t-stat | [19.07] | [0.75] | [-0.89] | | [4.5] | | [0.82] | [0.25] | [-0.45] | | | |
| 30y | **7.41***** | 0.037 | -0.81 | YES | **1.35***** | 0.92 | 0.0009 | -0.003 | **-0.03***** | 0.9 | YES | YES |
| t-stat | [15.48] | [0.62] | [0.83] | | [4.17] | | [1.37] | [-0.49] | [-1.10] | | | |

**Table 6: Scarcity Effects in the German Market**

Weekly 4-week changes threshold regressions of the form:

$$\Delta_4 y_t^{(\tau)} = \alpha + \beta_1 \Delta_4 E[STdebt_{t+k}] \mathbb{1}_{(y_{t-4}^{(\tau)}>0)} + \beta_2 \Delta_4 E[STdebt_{t+k}] \mathbb{1}_{(y_{t-4}^{(\tau)}<0)} + \sum_{j=3}^{n} \beta_j \Delta_4 X_j + \epsilon_t$$

where the dependent variable is the spread between the $\tau$ year bond and the deposit rate of the European Central Bank. The Independent variable $E[STdebt_{t+k}]$ is the outstanding amount of government debt with original maturity below 2 years scaled by $GDP$. $X_j$ denotes a matrix of controls. Columns 2-6 report the coefficients assuming Newey-West standard errors with 8 lags. Columns 7-10 assume an AR(1) process for residuals and robust standard errors. Coefficients in Bold are significant. *** p<0.01, ** p<0.05, * p<0.1.

**Four Week Changes**

| VARIABLES | 3m | 1y | 2y | 3y | 4y | 3m | 1y | 2y | 3y | 4y |
|---|---|---|---|---|---|---|---|---|---|---|
| $\Delta_4$E[STD] if Spr>0 | **-0.10*** | 0.013 | 0.083 | 0.1 | **0.17***** | -0.025 | 0.03 | 0.07 | 0.095 | **0.14***** |
| | [-1.93] | [0.18] | [0.84] | [1.02] | [2.82] | [-0.57] | [0.64] | [1.09] | [1.61] | [3.66] |
| $\Delta_4$E[STD] if Spr<0 | **0.12***** | **0.19***** | **0.17***** | **0.16***** | **0.092**** | **0.082**** | **0.134***** | **0.09*** | 0.07 | 0.021 |
| | [4.75] | [7.06] | [7.40] | [6.16] | [2.45] | [2.00] | [2.88] | [1.82] | [1.51] | [0.77] |
| $\Delta_4$Stock Market Vol. | **-0.002*** | **-0.002***** | **-0.002***** | **-0.002***** | **-0.002***** | **-0.0007**** | **-0.001***** | **-0.0014***** | **-0.0015***** | **-0.0018***** |
| | [-1.85] | [-2.71] | [-3.68] | [-3.88] | [-4.11] | [-2.23] | [-3.37] | [-4.40] | [-4.99] | [-5.77] |
| $\Delta_4$CDS | -0.002 | **-0.002*** | **-0.001*** | **-0.001*** | -0.001 | -0.0002 | -0.0003 | -0.0004 | **-0.0005*** | **-0.0007**** |
| | [-1.64] | [-1.69] | [-1.92] | [-1.84] | [-1.51] | [-0.43] | [-0.70] | [-1.22] | [-1.68] | [-2.28] |
| $\alpha$ | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 |
| | [-0.90] | [-0.80] | [-0.65] | [-0.66] | [-0.54] | [-0.49] | [-0.54] | [-0.47] | [-0.43] | [-0.38] |
| SE | NW(8) | NW(8) | NW(8) | NW(8) | NW(8) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) |
| Obs. | 667 | 667 | 667 | 667 | 667 | 667 | 667 | 667 | 667 | 667 |
| R-Squared | 0.17 | 0.2 | 0.15 | 0.14 | 0.13 | 0.02 | 0.06 | 0.05 | 0.06 | 0.09 |

**Table 7: Expected Short-Term Supply vs Current Short-Term Supply**

Columns 2-6 reports the coefficients of the same model described in Table 6, but we augment the regression with the outstanding amount of current short-term debt and with Liquidity Risk. We let current short-term supply have different region coefficients according to the threshold we choose (the deposit rate of the ECB). T-stats are based on Newey-West standard errors allowing for 8 lags. Coefficients in bold are significant. *** p<0.01, ** p<0.05, * p<0.1.

| | **Four Week Changes** | | | | |
|---|---|---|---|---|---|
| **VARIABLES** | **3m** | **1y** | **2y** | **3y** | **4y** |
| $\Delta_4$E[STD] if Spr>0 | **-0.090*** | 0.028 | 0.093 | 0.102 | **0.172***** |
| | [-1.83] | [0.39] | [0.93] | [0.99] | [2.83] |
| $\Delta_4$E[STD] if Spr<0 | **0.130***** | **0.194***** | **0.174***** | **0.161***** | **0.086**** |
| | [3.98] | [6.05] | [6.68] | [5.10] | [2.04] |
| $\Delta_4$[STD] if Spr>0 | -0.048 | -0.05 | -0.032 | 0.008 | 0.017 |
| | [-0.77] | [-0.98] | [-0.67] | [0.19] | [0.32] |
| $\Delta_4$[STD] if Spr<0 | 0.089 | 0.058 | 0.089 | 0.011 | **-0.126**** |
| | [1.32] | [0.67] | [0.80] | [0.10] | [-1.97] |
| $\Delta_4$Stock Market Vol. | **-0.002*** | **-0.002***** | **-0.002***** | **-0.002***** | **-0.002***** |
| | [-1.95] | [-2.95] | [-3.64] | [-3.62] | [-3.84] |
| $\Delta_4$CDS | **-0.002*** | **-0.002*** | **-0.001*** | -0.001 | -0.001 |
| | [-1.69] | [-1.72] | [-1.83] | [-1.64] | [-1.26] |
| $\Delta_4$Liquidity Risk | **-0.011*** | **-0.008*** | -0.005 | -0.005 | -0.004 |
| | [-1.81] | [-1.69] | [-1.55] | [-1.25] | [-0.91] |
| $\alpha$ | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 |
| | [-0.86] | [-0.73] | [-0.54] | [-0.65] | [-0.58] |
| SE | NW(8) | NW(8) | NW(8) | NW(8) | NW(8) |
| Obs. | 667 | 667 | 667 | 667 | 667 |
| R-Squared | 0.23 | 0.22 | 0.16 | 0.14 | 0.13 |

**Table 8: Estimated Risk Neutral Parameters for Germany**

This table presents maximum likelihood estimates of the risk neutral parameters from our MTSM: the long-run risk neutral mean under $r^Q_\infty$, the eigenvalues of the feedback matrix under $Q$ ($\lambda^Q$) and the paramenters governing the macro-spanning equation $\gamma_0$ and $\gamma_1$. We report small-sample standard errors in parentheses and bootstrapped standard errors in brackets.

| **Risk Neutral Parameters** | | | | | | | |
|---|---|---|---|---|---|---|---|
| $r^Q_\infty$ | $\lambda^Q_1$ | $\lambda^Q_2$ | $\lambda^Q_3$ | $\gamma_0$ | | $\gamma_1$ | |
| 0.007 | 0.997 | 0.986 | 0.986 | -3.830 | -0.060 | 0.864 | 6.293 |
| (0.003) | (0.001) | (0.004) | (0.010) | (0.144) | (0.011) | (0.057) | (0.216) |
| [0.007] | [0.003] | [0.0053] | [0.041] | [0.759] | [0.017] | [0.179] | [0.541] |

**Table 9: Intercept and Feedback Matrix under $P$**

This table presents maximum likelihood estimates of $K^P_0$ and $K^P_1$ for our MTSM. Small-sample standard errors are reported in parentheses and bootstrapped standard errors in brackets.

| Z | $K^P_0$ | | $K^P_1$ | |
|---|---|---|---|---|
| PC1 | 0.026 | 0.995 | -0.055 | 0 |
| | (0.0812) | (0.01) | (0.05) | |
| | [0.1013] | [0.022] | [0.155] | |
| PC2 | 0.039 | 0.0011 | 0.964 | 0 |
| | (0.0405) | (0.004) | (0.023) | |
| | [0.1593] | [0.004] | [0.034] | |
| Expected Supply | -0.120 | 0 | -0.0987 | 0.914 |
| | (0.0456) | | (0.0324) | (0.0255) |
| | [0.1249] | | [0.0639] | [0.0516] |
| $\lambda^P$ | | 0.995 | 0.967 | 0.916 |

**Table 10: Risk Premium Parameters**

This table presents maximum likelihood estimates from our MTSM of the parameters $\lambda_0$ and $\lambda_1$ governing the investors' attitude toward risk. Market prices of risk are defined as $\Lambda_t = \Sigma_Z^{-1/2}(\lambda_0 + \lambda_1 Z_t)$. Bootstrapped standard errors are reported in square brackets.

| Z | $\lambda_0$ | | $\lambda_1$ | |
|---|---|---|---|---|
| PC1 | 0.079 | -0.0015 | -0.055 | 0 |
| | [0.052] | [0.0071] | [0.015] | |
| PC2 | -0.017 | 0.001 | -0.022 | 0 |
| | [0.042] | [0.004] | [0.0173] | |
| Expected Supply | -0.184 | 0 | 0.0987 | -0.071 |
| | [-0.239] | | [0.064] | [0.020] |

# A Appendix

**Table A.1: Variables Description**

| **Sample: 2005-2017** | **Source** | **Ticker ITA** | **Ticker GER** |
|---|---|---|---|
| **Yields** | | | |
| ECB Deposit Rate | Bloomberg | EUORDEPO Index | EUORDEPO Index |
| 2y | Bloomberg | I04002Y Index | I04002Y Index |
| 5y | Bloomberg | I04005Y Index | I04005Y Index |
| 10y | Bloomberg | I040010Y Index | I04010Y Index |
| 30y | Bloomberg | I040030Y Index | I04030Y Index |
| **Supply** | **Source** | | |
| $MWD$ | National Treasuries, Authors' Estimate | | |
| $E[MWD\|I_t]$ | National Treasuries Press Releases, Authors' Estimate | | |
| $MWQE$ | European Central Bank, Authors' Estimate | | |
| $D/GDP$ | National Treasuries, Authors' Estimate | | |
| $E[STdebt]$ | National Treasuries, Authors' Estimate | | |
| **Other Variables** | **Source** | **Ticker ITA** | **Ticker GER** |
| Liquidity | MTS | Authors Estimate | Authors Estimate |
| log (CDS) | Bloomberg | ITALY CDS USD SR D14 Corp | GERMAN CDS USD SR D14 Corp |
| Inflation | Bloomberg | ITCPEM Index | GRCP2HMM Index |
| Inflation Risk | Bloomberg, Authors Estimate | ITCPEM Index | GRCP2HMM Index |
| Output Growth | FRED Database, Authors Estimate | CLVMNACSCAB1GQ1T | CLVMNACSCAB1GQDE |
| Stock Market Vol. | Bloomberg | V2X Index | V2X Index |
| Crisis Dummy | Authors Estimate | | |

**Table A.2: Correlation Matrix**

The table shows the correlation matrix between the main variables in our analysis. The top part of the table represents the correlations for Germany, while the bottom part shows the correlation of Italian variables. We report the correlations in levels below the diagonal, while above the main diagonal we show the first-difference correlations. We highlight in bold the correlations between current and expected supply and 10 year and 5 year yield spreads in levels and first difference.

**GERMANY**

| | E[MWD] | MWD | 10y | 5y | CDS | Crisis D. | Output Gr. | Liquidity |
|---|---|---|---|---|---|---|---|---|
| E[MWD] | 1.00 | 0.08 | **0.17** | **0.16** | 0.08 | -0.03 | 0.10 | -0.05 |
| MWD | 0.87 | 1.00 | **0.06** | **0.07** | 0.08 | -0.06 | 0.08 | 0.16 |
| 10y | **0.76** | **0.64** | 1.00 | 0.89 | 0.17 | -0.01 | 0.11 | 0.24 |
| 5y | **0.66** | **0.47** | 0.94 | 1.00 | 0.15 | 0.01 | 0.10 | 0.13 |
| CDS | 0.70 | 0.71 | 0.69 | 0.52 | 1.00 | 0.16 | -0.09 | 0.27 |
| Crisis D. | 0.44 | 0.38 | 0.32 | 0.27 | 0.57 | 1.00 | -0.04 | 0.01 |
| Output Gr. | 0.02 | 0.03 | -0.04 | -0.01 | -0.28 | 0.02 | 1.00 | -0.16 |
| Liquidity | 0.10 | 0.15 | 0.36 | 0.27 | 0.63 | 0.19 | -0.57 | 1.00 |

**ITALY**

| | E[MWD] | MWD | 10y | 5y | CDS | Crisis D. | Output Gr. | Liquidity |
|---|---|---|---|---|---|---|---|---|
| E[MWD] | 1.00 | 0.22 | **-0.02** | **0.00** | 0.00 | -0.02 | 0.09 | 0.02 |
| MWD | 0.99 | 1.00 | **0.14** | **0.11** | -0.19 | -0.02 | -0.01 | -0.17 |
| 10y | **0.60** | **0.60** | 1.00 | 0.83 | 0.10 | 0.00 | 0.02 | -0.27 |
| 5y | **0.45** | **0.44** | 0.95 | 1.00 | 0.17 | 0.02 | -0.02 | -0.01 |
| CDS | 0.83 | 0.81 | 0.77 | 0.73 | 1.00 | 0.04 | -0.06 | 0.31 |
| Crisis D. | 0.18 | 0.16 | 0.24 | 0.39 | 0.45 | 1.00 | -0.09 | 0.03 |
| Output Gr. | 0.05 | 0.07 | -0.16 | -0.27 | -0.29 | -0.21 | 1.00 | -0.10 |
| Liquidity | 0.21 | 0.19 | 0.22 | 0.35 | 0.53 | 0.61 | -0.40 | 1.00 |

**Table A.3: Robustness Tests for Germany**

Regressions of the form:

$$y_t^{(\tau)} - y_t^{(1)} = \alpha + \beta_1 E[MWD_{t+k}|I_t] + \beta_2 MWQE_t + \beta_3 t + \sum_{i=3}^{n} \beta_i C_t + \epsilon_{i,t}$$

where $C_t$ is a matrix of controls. Column 2 reports the coefficients of expected supply in our base case. Column 3 adds controls for credit and liquidity risk. Column 4 adds controls for stock market volatility and a dummy for the sovereign crisis. Column 5 and 6 add a control for Output Growth and Inflation risk, respectively. The dependent variables are 2, 5, 10 and 30 year yield spreads. All control variables are defined in Table 2. We model the error process as an AR(1) and we use robust standard errors. T-stats are in brackets and coefficients in bold are significant. *** p<0.01, ** p<0.05, * p<0.1.

**GERMANY**

| $E[MWD_{GER}\|I_t]$ | Base Case | Credit Risk Liquidity Risk | Stock Market Vol. CrisisDummy | Output Growth | Inflation Risk |
|---|---|---|---|---|---|
| **2y** | **0.005****| **0.005**** | **0.005**** | **0.005**** | **0.007***** |
| t-stat | [2.32] | [2.24] | [2.15] | [2.16] | [2.72] |
| R-squared | 0.05 | 0.05 | 0.05 | 0.04 | 0.06 |
| **5y** | **0.01**** | **0.01**** | **0.01**** | **0.01**** | **0.01***** |
| t-stat | [2.39] | [2.39] | [2.33] | [2.17] | [2.77] |
| R-squared | 0.06 | 0.01 | 0.01 | 0.01 | 0.12 |
| **10y** | **0.011**** | **0.011**** | **0.012**** | **0.011**** | **0.018***** |
| t-stat | [1.99] | [2.09] | [2.19] | [1.99] | [2.82] |
| R-squared | 0.05 | 0.12 | 0.13 | 0.14 | 0.16 |
| **30y** | **0.013**** | **0.014**** | **0.015**** | **0.015**** | **0.024***** |
| t-stat | [2.07] | [2.24] | [2.41] | [2.32] | [3.37] |
| R-squared | 0.06 | 0.12 | 0.13 | 0.13 | 0.15 |

**Table A.4: The Effect of the ECB's Securities Market Program**

The Table shows the results of regressions of yield spreads on current Italian supply modified by the purchases conducted by the ECB during the Securities Market Program. Column 2 shows the coefficients of the modified supply variable. T-stats are in brackets. We assume an AR(1) process for residuals. T-stats in brackets are based on robust standard errors. Coefficients in bold are significant. p<0.01, ** p<0.05, * p<0.1.

| Yield Spread | $MWD_{ITA}$ | t-stat | $MWQE_{ITA}$ | t-stat | $\alpha$ | t-stat | R-squared | Trend |
|---|---|---|---|---|---|---|---|---|
| 2y | **0.002**** | [2.37] | -0.002 | [-1.11] | **-0.007*** | [-1.73] | 0.03 | YES |
| 5y | **0.002*** | [1.85] | 0.001 | [0.19] | -0.002 | [-0.34] | 0.02 | YES |
| 10y | **0.005**** | [2.18] | -0.001 | [-0.15] | -0.011 | [-0.97] | 0.04 | YES |
| 30y | **0.007*** | [1.84] | -0.002 | [-0.31] | -0.02 | [-0.98] | 0.09 | YES |

## Table A.5: Quarterly and Annual Interactions

This Table reports the coefficients of regressions of yield spreads on current and expected future supply for both countries. The independent variables include interactions between expected future supply and quarterly and yearly dummies. Quarterly dummies assume value of 1 in March, June, September and December. For Germany, we also control for a Yearly dummy that assumes the value of 1 only in December. Regression residuals are estimated according to an AR(1) process. We also use robust standard-errors. Column 2 reports the coefficients for current supply, Column 3 for expected future supply. Columns 4 and 5 report the coefficients of the interaction terms. Column 9 reports the p-value of the F-test between Expected supply and the interaction terms. T-stats are in brackets and coefficients in bold are significant.

**GERMANY**

| Yield Spreads | $MWD_{GER}$ | $E[MWD_{GER}\|I_t]$ | Quarterly Dummy | Yearly Dummy | $\alpha$ | R-squared | Trend | $\beta_2 + \beta_3$ |
|---|---|---|---|---|---|---|---|---|
| **2y** | -0.0007 | **0.004*** | **0.0001**** | | -0.008 | 0.07 | YES | 0.055 |
| t-stat | [-0.38] | [1.89] | [2.34] | | [-1.11] | | | |
| **5y** | 0.0007 | **0.008*** | 0.0001 | | -0.021 | 0.07 | YES | 0.088 |
| t-stat | [0.21] | [1.70] | [1.18] | | [-1.38] | | | |
| **10y** | 0.002 | **0.011*** | 0 | | -0.027 | 0.05 | YES | 0.096 |
| t-stat | [0.53] | [1.67] | [-0.17] | | [-1.41] | | | |
| **30y** | 0.004 | **0.013*** | 0 | | -0.03 | 0.07 | YES | 0.076 |
| t-stat | [0.92] | [1.78] | [0.01] | | [-1.56] | | | |
| **2y** | 0.0004 | **0.005**** | | 0 | **-0.014**** | 0.05 | YES | 0.02 |
| t-stat | [0.23] | [2.33] | | [0.43] | [-2.03] | | | |
| **5y** | 0.002 | **0.009*** | | 0 | **-0.028*** | 0.06 | YES | 0.063 |
| t-stat | [0.62] | [1.86] | | [-0.08] | [-1.84] | | | |
| **10y** | 0.002 | **0.011*** | | 0 | -0.027 | 0.05 | YES | 0.094 |
| t-stat | [0.59] | [1.69] | | [-0.27] | [-1.53] | | | |
| **30y** | 0.005 | 0.013* | | -0.0001 | **-0.037*** | 0.07 | YES | 0.08 |
| t-stat | [1.163] | [1.78] | | [-0.60] | [-1.71] | | | |

**ITALY**

| Yield Spreads | $MWD_{ITA}$ | $E[MWD_{ITA}\|I_t]$ | Quarterly Dummy | $\alpha$ | R-squared | Trend | $\beta_2 + \beta_3$ |
|---|---|---|---|---|---|---|---|
| **2y** | **0.003**** | 0.0002 | 0.0000 | **-0.013**** | 0.06 | YES | 0.89 |
| t-stat | [2.08] | [0.12] | [0.64] | [-2.09] | | | |
| **5y** | **0.004**** | -0.001 | 0 | -0.004 | 0.04 | YES | 0.57 |
| t-stat | [2.03] | [-0.58] | [1.18] | [-0.53] | | | |
| **10y** | **0.008**** | -0.003 | 0.0001 | -0.012 | 0.07 | YES | 0.52 |
| t-stat | [2.04] | [-0.64] | [1.07] | [-0.94] | | | |
| **30y** | **0.009*** | -0.003 | 0.0001 | -0.016 | 0.1 | YES | 0.5 |
| t-stat | [1.71] | [-0.68] | [0.60] | [-0.94] | | | |

## Table A.6: Scarcity Effects with Different Specifications

Columns 2-6 reports the coefficients of the same model described in Table 6, but we define a specific $E[STdebt_{t+k}]$ for each maturity up to 2 years. More specifically, in Column 2 and 3 we use the amount of bonds with original maturity (Bubills) below 1 year, while in Column 4 we define $E[STdebt_{t+k}]$ as the amount of bonds with 2 years original maturity (Schatz). Since the German Treasury does not issue 3 and 4 year bonds we use the amount of bonds with 2 year maturity even in Columns 5 and 6. Columns 7-11 restrict the sample from 2010 to the end of 2017, while Columns 12-16 exclude 2017. We model the error process as an AR(1). T-stats in brackets are based on robust standard errors. Coefficients in bold are significant. *** p<0.01, ** p<0.05, * p<0.1.

**Four Week Changes**

| | **Specific Maturities** | | | | | **2010-2017** | | | | | **2005-2016** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 3m | 1y | 2y | 3y | 4y | 3m | 1y | 2y | 3y | 4y | 3m | 1y | 2y | 3y | 4y |
| $\Delta_4$E[STD] if $s_{t-4}>0$ | 0.052 | 0.077 | -0.032 | 0.06 | **0.20*** | -0.03 | -0.017 | 0.004 | 0.047 | 0.074 | -0.03 | 0.03 | 0.067 | 0.09 | **0.14***** |
| | [0.89] | [1.18] | [-0.35] | [0.74] | [1.90] | [-0.71] | [-0.45] | [0.09] | [0.85] | [1.18] | [-0.57] | [0.63] | [1.08] | [1.60] | [3.65] |
| $\Delta_4$E[STD] if $s_{t-4}<0$ | **0.089*** | **0.15***** | **0.56***** | **0.64*** | -0.21 | **0.16**** | **0.22***** | **0.25***** | **0.19***** | **0.13*** | **0.08**** | **0.13***** | **0.09*** | 0.07 | 0.02 |
| | [1.94] | [2.82] | [3.08] | [1.69] | [-1.13] | [2.29] | [3.78] | [4.08] | [2.61] | [1.79] | [1.99] | [2.88] | [1.82] | [1.51] | [0.75] |
| $\Delta_4$Stock Market Vol. | **-0.0006**** | **-0.001***** | **-0.001***** | **-0.001***** | **-0.002***** | -0.0002 | **-0.0005**** | **-0.001***** | **-0.001***** | **-0.0015***** | **-0.001**** | **-0.001***** | **-0.0014***** | **-0.001***** | **-0.002***** |
| | [-2.19] | [-3.34] | [-4.58] | [-4.85] | [-5.68] | [-1.12] | [-2.05] | [-3.21] | [-3.77] | [-4.44] | [-2.09] | [-3.29] | [-4.23] | [-4.81] | [-5.58] |
| $\Delta_4$CDS | -0.0002 | -0.0003 | -0.0004 | **-0.0005*** | **-0.0006*** | **-0.001***** | **-0.001***** | **-0.001***** | **-0.002***** | **-0.002***** | -0.0002 | -0.0003 | -0.0004 | -0.0005 | **-0.001**** |
| | [-0.43] | [-0.69] | [-1.29] | [-1.68] | [-1.92] | [-3.12] | [-3.02] | [-3.28] | [-3.05] | [-3.37] | [-0.33] | [-0.63] | [-1.14] | [-1.59] | [-2.20] |
| $\alpha$ | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0000 | -0.0001 | -0.0001 | -0.0001 | -0.0002 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 |
| | [-0.45] | [-0.54] | [-0.44] | [-0.52] | [-0.43] | [-0.16] | [-0.46] | [-0.56] | [-0.75] | [-0.80] | [-0.54] | [-0.57] | [-0.50] | [-0.46] | [-0.43] |
| SE | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) | AR(1) |
| Obs. | 667 | 667 | 667 | 667 | 667 | 412 | 412 | 412 | 412 | 412 | 620 | 620 | 620 | 620 | 620 |
| R-squared | 0.02 | 0.05 | 0.06 | 0.06 | 0.07 | 0.06 | 0.1 | 0.12 | 0.11 | 0.12 | 0.02 | 0.06 | 0.05 | 0.06 | 0.09 |