Evidence on the Liquidity Effect in Euro Area Government Bond Markets - A Bayesian VAR Analysis

Stephan Maier
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Evidence on the Liquidity Effect in Euro Area Government Bond Markets - A Bayesian VAR Analysis

Stephan Maier*

Abstract

The interest rate is the rate of return on bonds rather than the rate of return on money. This might be one of the reasons for which up to the present the empirical evidence on the liquidity effect of monetary policy shocks has been quite mixed. Therefore, we are looking at the liquidity effect caused by shocks in the government bond supply and the implications these shocks have for fluctuations in short-term interest rates in five euro area countries. We find that in the 1980s and in the 1990s for some of the euro area countries which rely relatively heavily on short-term borrowing the ex-post real returns investors require on three-month treasury bills are bid up by shocks to the bond supply. This relationship however breaks down during the stable period of EMU and returns to the forefront only amid the recent EMU sovereign debt crisis.

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1. Introduction

We analyse the liquidity effect caused by shocks to government debt levels and the implications these shocks have for fluctuations in short-term interest rates. This is a deviation from and an extension to the work on the traditional liquidity effect stemming from monetary shocks. This analysis has been motivated, on the one hand, by the mixed results of empirical papers on the liquidity effect, and, on the other hand, by the need of analysing how shocks to government debt levels and to the amount of government debt securities outstanding influence real returns on short-term securities regardless of money supply shocks. Clearly, the analysis of how shocks to government debt feed through to short-term interest rates and government refinancing costs recently has become of paramount importance and interest due to the current sovereign debt crisis in the EMU periphery. The risk during the current adverse market scenario, characterised by the sovereign debt crisis, is that shocks to the amount of government debt outstanding lead to CDS and to spread widening and, thus, to even higher refinancing costs amidst a scenario of already tight public finances. The bottom line is that this calls for major clarity and transparency in public debt management agencies’ auction schedules at the moment.

The liquidity effect plays a central role in conventional monetary theory and policy. Furthermore, it is an important feature of empirical and theoretical work on the monetary transmission mechanism. In the presence of the liquidity effect, the initial impact of an unanticipated shock to the money supply is to lower nominal and, due to wage and price rigidities, real interest rates for a short period of time. Over a longer horizon agents will adjust their inflation expectations and interest rates will rise again. The theoretical proposition of standard economic textbooks that expansion in monetary aggregates lowers short-term interest rates seems to be widely accepted, yet to date the empirical evidence for it is mixed.

In the IS-LM framework the immediate effect of a monetary expansion is to reduce real rates. If prices are not completely flexible the expansion shifts the LM curve to the right along the downward sloping IS curve resulting in higher output and a lower real rate. When this decline in the real rate more than offsets the effect of the increase in inflation, which probably reacts only with a lag, the nominal rate decreases, too - this is the liquidity effect. In contrast, in a world of flexible-price dynamic general equilibrium models with total price and wage flexibility there would be no role for the liquidity effect because prices would adjust instantaneously during monetary expansions.

In the real world of sticky wages and prices, however, the liquidity effect does affect the way in which monetary policy transmission works. Within the framework of open market policy, fine-tuning operations of central banks provide liquidity to stimulate economic activity. Shocks to the level of government debt outstanding can have implications for market liquidity and, thus, for monetary transmission, too. In theory, market liquidity could be increased by both, central banks targeting the money supply or by central banks buying or selling government debt in the secondary market.
However, variations in the amount of government debt outstanding and traded in the secondary market do not have the same implications for liquidity as variations in the money supply do have. This is because the amount of government bonds outstanding can vary apart from the central banks’ open market operations due to the supply shocks caused by bond auctions and this in turn might have as well implications for short-term yields and interest rates. In the auctions in the US and most euro area countries foreign monetary authorities can roll-over their bond holdings but their roll-over plans are not always public information. This causes uncertainty about the actual amount of bonds issued and this uncertainty could manifest itself in investors demanding higher yields when the bond supply is shocked. Furthermore, even if the quantity of securities allotted is identical to the quantity of securities scheduled for auctioning, the fact that most debt management offices and the respective ministries of finance publicly announce precise auction schedules only one week prior to auctions causes uncertainty about the exact amount to be auctioned in any one specific month at the beginning of each month. Discrepancies between the agents forecasts about amounts to be auctioned and actually allotted amounts can cause shocks to the total amount of securities outstanding which could temporarily drive up the borrowing cost for a specific issuer.

The fact that the exact amounts to be auctioned are not known with certainty prior to auctions makes the primary dealers subject to bond-supply risk. The primary dealers that participate in bond auctions commit funds to the bond market before knowing the exact supply and, thus, the exact prices and yields of the bonds. This risk is then passed on to institutional and retail investors on the secondary market. A higher than expected supply in an auction ceteris paribus causes prices to fall and yields to rise. This manifests itself in investors in the secondary market requiring higher yields when the bond supply has been subject to shocks. Note, however, that bond supply in our paper is not defined as the flows but as the total amount of government debt securities outstanding and available for trading in the market.

Given the mixed empirical support for the traditional liquidity effect of monetary policy, in this paper, we study the liquidity effect in euro area government bond markets before and after the introduction of the single currency. The aim is to analyse the implications of supply shocks of government bonds for market liquidity and for short-term interest rates. As already has been pointed out, the liquidity effect of the bond supply is the reaction of the nominal or the real short-term interest rate to a shock in the outstanding amounts of government securities in any specific country.

In our analysis we explain movements in real rates rather than movements in nominal rates because rational bond investors think in real terms about their investments and try to incorporate inflationary expectations when evaluating their investment opportunities. Public debt management agencies need to calculate in terms of real costs, too, when placing the sovereign debt with the public.

We apply a semi-structural VAR and Bayesian VARs (BVAR) in order to study how interest rates respond to monetary policy shocks and to shocks in government bond amounts outstanding in selected countries of the Economic and Monetary Union (EMU) at monthly frequency. The semi-structural VAR leaves the relationships among macro-economic variables in the system unrestricted.
but imposes some straightforward contemporaneous identification restrictions on the variables. We build on the work of Jovanovic and Rousseau [15] who find that short-term interest rates react stronger to changes in the supply of marketable treasury securities than they do to changes in the money supply in the United States.

Apart from quantifying the traditional liquidity effect whose causal relationship goes from monetary aggregates to short-term interest rates, we identify and quantify the liquidity effect in the bond market that has been analysed by Grossman and Weiss [13], Jovanovic and Rousseau [15] and Rotemberg [25]. The interest rate being the return on bonds rather than the return on money, the aim is to show that the analysis of the liquidity effect in the bond market is an important building stone in understanding short-run fluctuations in short-term interest rates. We find that in Italy, and to some degree in Belgium and in Spain, shocks to the bond supply lead to increases in ex-post real returns of three-month treasury bills in the 1980s and the 1990s. This, however, does not seem to be the case in Germany and in France.

More interestingly, analysing the liquidity effect in the bond market during the first decade of EMU we find that in Italy, Belgium and Spain shocks to government debt levels cease to exert an upward pressure on the real return of 3m T-Bills.

Descriptive statistics on the time-series behaviour and interdependencies of the bond supply, the monetary aggregate M1 and interest rates in some euro area countries and in the broader international context in the 1980s and the 1990s are provided in section 4. Section 3 reviews Jovanovic and Rousseau’s [15] methodology of measuring surprises to the growth of the bond supply and estimates the effects on the ex-post real return of treasury bills. Section 2 reviews the main pieces of empirical evidence on the liquidity effect and on monetary policy and summarises their most important results. In order to analyse the dynamics of shocks in government debt securities outstanding, monetary aggregates and the real return on treasury bills in some euro area countries a VAR framework will be introduced in section 6. In section 7 a Bayesian VAR will be employed. The Bayesian VAR overcomes the over-parameterisation problem of the classical VAR by assigning probability distributions to the coefficients. We carry out the BVAR analysis for the period before the introduction of the monetary union in Europe (1980-1998) and afterwards for the first decade of monetary union (1999-2009). Finally, the conclusions will be drawn in section 8.
2. Review of Literature on the Liquidity Effect

Empirical studies traditionally employed a wide range of specifications, data frequencies and measures for market liquidity. Early studies like Cagan [6] were favourable to the existence of the liquidity effect. In the 1990s and in the new millennium the liquidity effect received support from VAR-based studies such as the ones of Bernanke and Mihov [3], Pagan and Robertson [22], Strongin [29], Leeper, Sims and Zha [17], Christiano et al. [8], Mojon and Peersman [21] and Peersman and Smets [24]. All of these works identified a more or less strong and persistent liquidity effect. Hamilton [14] measured a significant liquidity effect due to variations in the cash balance of the US treasury with the Federal Reserve System on the federal funds rate during and at the end of the two-week reserve maintenance periods.

Leeper and Gordon [16], Christiano [7] and Pagan and Robertson [23], however, raised doubts on the existence of the liquidity effect and reported a vanishing liquidity effect. According to Bernanke and Mihov [3] this might be due to the bias associated with using non-borrowed reserves as a policy indicator. The results of Leeper and Gordon [16] and Christiano [7] stand in the tradition of the rational expectations literature in the 1980s represented, for example, by Mishkin [20] who found that unanticipated changes in the money stock, typically, had no effects on interest rates.

Within the domain of economic theory, Grossman and Weiss [13], Rotemberg [25] and Lucas [19] worked out the liquidity effect of Federal Reserve open-market operations. In these models, in which liquidity-constrained agents require cash or liquidity in order to trade in securities, open-market operations give rise to liquidity effects which generate interest rate behaviour very different from the one predicted by models based on Fisherian fundamentals. In contrast to these models, the sceptical view about the liquidity effect has led to the development of monetized real business cycle models in which persistent money growth leads to an increase in the nominal interest rate¹.

Leeper et al. [17] analyse models incorporating monetary targeting and interest rate targeting and find that, in line with other monetary policy literature, only a modest portion of output and price level variation in the USA since 1960 can be attributed to shifts in monetary policy. In a four-variable recursive VAR in the CPI, real GDP, the Federal Funds rate and M1 they encounter the liquidity puzzle. When M1 is shocked the Federal Funds rate decreases initially but then bounces back and gains positive territory quickly. Instead, standard textbook macroeconomics would suggest lower interest rates rather than higher interest rates when a monetary aggregate is shocked. On the other hand, when the Federal Funds rate is shocked M1 shows the right reaction. Money goes down quickly and persistently. Besides, interest rate tightening leads to an output contraction after six months but creates a price puzzle in the sense that prices increase persistently as a reaction to interest rate tightening whereas one would instead expect them to go down.

The price puzzle could be overcome by including stock prices, long interest rates, exchange rates or commodity prices, which reflect the state of the economy and contain information on the future

evolvement of prices in the model. Leeper et al. [17], however, introduce another identification scheme and go away from the recursive identification in order to deal with the price puzzle. If one assumes that it is time-consuming and costly to collect data on prices and on output the money authorities cannot react to prices and output immediately. Therefore, M1, which is now treated as policy variable will neither be contemporaneously affected by the CPI nor by the output Y. Neither do the CPI or the output react to shocks in the interest rate or in money within the period. This is due to the planning processes of the private sector in changing prices and output that take time and are costly. The Federal Funds rate, which is not a policy variable, but treated as informational variable by Leeper et al. [17] responds quickly to all kind of financial market innovations and responds contemporaneously to all other variables. The fact that the interest rate can react immediately to the CPI and to output, but the central bank is not conceded this capacity to react immediately leaves room for discussions about the central bank procedures and about its capabilities of reaction.

The model with the second identification scheme of Leeper et al. [17], incorporating lags to allow for the decision-making process of private agents and the central bank, delivers straightforward impulse responses to shocks in M1. A policy tightening in the form of lower M1 leads to lower prices, an initial but only slight decrease of output which then returns to its previous level and an increase in the interest rate, which then returns to its initial level after about one year. A striking feature is that M1 decreases very strongly and persistently while output and the price level hardly react. What is problematic in this model is, however, the positive reaction of M1 and the very strong positive reaction of the CPI to interest rate shocks.

The model imposing constraints on private agents’ reactions to the interest rate and M1 combined with the central bank’s reactions to output and prices generates a liquidity effect of M1 on the interest rate for about one year before the nominal interest rate returns to its initial level. Instead, the above model with a recursive identification scheme displays the wrong reaction of the interest rate to M1 shocks.

Clearly, both models have drawbacks as displayed by their impulse responses and, what is more relevant for our study, they are not very helpful in resolving the liquidity puzzle. The recursive model delivers the right reaction of M1 to the Federal Funds rate shocks but the wrong reaction of the Federal Funds rate to M1 shocks. M1 and the Federal Funds rate in the non-recursive model react vice versa. This means that the two models neither can explain whether positive M1 shocks decrease interest rates, nor whether positive interest rate shocks decrease M1.

One problem in identifying the liquidity effect might be that M1 is not a very good proxy for measuring the policy stance of the Federal Reserve because it is demand determined up to a certain degree. Private sector decisions on prices and on output have direct effects on M1 and, therefore, M1 can not be controlled in the short run by the Federal Reserve. This would suggest the use of aggregates such as borrowed reserves, non-borrowed reserves or total reserves, which are more directly controlled by the central bank, as a measure for liquidity.
Christiano et al. [8] follow up this approach. They distinguish between three different benchmark identification schemes, each of which is recursive. The three benchmark identification schemes are one model in which the federal funds rate is the policy variable, one in which non-borrowed reserves (NBR) are the policy variable and a third one, with which we will not deal here, in which both NBR and total reserves are policy variables.

Variables are determined in a block recursive way within the quarter. First goods market variables are determined, then policy variables and lastly money market variables. Recursiveness requires that a set of variables is predetermined relative to the policy variable. When deciding on monetary policy the central bank looks only at predetermined variables and monetary policy shocks can be identified using the fitted residuals of ordinary least squares regressions of the policy variable on the predetermined variables. This is in contrast to many papers in the literature that drop the assumption that the central bank looks only at predetermined variables and which require further identifying assumptions.

The model variables included are: a monetary aggregate, output, the price level, a commodity price index, the federal funds rate, NBR and total reserves. The block-recursive nature of the benchmark models implies that the output, the prices and the commodity price index are not shocked by the policy variables within the quarter. Their sample data refers to the US economy from 1965 to 1995. In all three models Christiano et al. [8] assume that the central bank contemporaneously reacts to output, the price level and a commodity price index when it takes its decisions on the policy variable. This assumption, according to them, is at least as realistic as the assumption, taken by many other researchers, that monetary authorities can’t react to the price level and to output within the period. Their data frequency being quarterly, this might be an innocuous assumption. Even if the central bank has no precise within quarter information on output and prices at its disposal it can check weekly and monthly statistics on many important and meaningful variables such as unemployment figures, retail sales and wages. The assumption that the central bank takes into account prices and output within the period might be a bigger issue when monthly data are used. The higher the frequency of the data, the more difficult it is for the monetary authorities to get the development of prices and output right.

In Christiano et al.’s [8] Federal Funds rate model a shock to the Fed Funds rate leads to an increase in the Fed Funds rate, a fall in output, a fall in the price level after a lag of six quarters, a fall in the commodity price index with a later rebound of the commodity prices after six quarters, a negative response of NBR which, however, returns to zero after only three quarters, a slight fall in TR and, finally, a persistent fall in the monetary aggregate M1. There is a strong liquidity effect at work in this model. A contractionary shock to the Fed Funds rate generates negative responses of M1 and of NBR.

It should be very informative to analyse the NBR model as NBR innovations are supposed to reflect mainly exogenous shocks to monetary policy, whereas innovations to broader monetary aggregates are heavily influenced by private sector shocks to money demand.
In Christiano et al.’s [8] NBR model a contraction in NBR leads to a fall in output which is less pronounced than the fall in output caused by a rise in the interest rate in the federal funds model. The negative shock to NBR leads to a fall in the price level, a fall in the commodity price index similar to the one in the federal funds rate model, a rise in the federal funds rate, a strong fall in total reserves, and a larger fall in M1 than in the first model. So, the liquidity effect seems to be even stronger in the NBR model.

Both models, the Federal Funds rate and the NBR model display clear evidence of the traditional liquidity effect by which positive shocks to the Federal Funds rate and negative shocks to NBR generate negative responses of M1.

For the euro area Peersman and Smets [24] analyse the liquidity effect. Peersman and Smets [24] analyse the monetary transmission mechanism for the euro area as a whole on the basis of synthetic euro area data from 1980 till 1998 at a quarterly frequency. They apply an identified VAR framework to study the macroeconomic effects of monetary policy shocks in the euro area. They find that their macroeconomic effects are similar to the ones found in US data and that they are surprisingly stable over time.

Using various standard identification schemes their main findings are that temporary rises in nominal and real interest rates lead to temporary falls in output and to a sluggish response of prices which tend to fall only several periods after the monetary policy shock takes place. They identify an immediate but subdued liquidity effect of a temporary rise in the short-term interest rate on M1. M3, containing as well interest-bearing assets decreases, however, more gradually. Share prices fall, house prices are sluggish and long-term interest rates rise slightly in response to a short rate hike. Furthermore, they find evidence of an appreciating exchange rate.

Peersman and Smets [24] analyse a VAR containing a vector of exogenous and a vector of endogenous variables. The vector of exogenous variables consists of the world commodity price index, US real GDP and the US short-term nominal interest rate. These variables, on which the euro area variables have no feedback, should control for developments in the world economy and deal with the price puzzle. The vector of endogenous variables includes euro area real GDP, euro area consumer prices, the monetary aggregate M3, the nominal short-term euro area interest rate and the real effective euro exchange rate.

Peersman and Smets [24] use a Choleski-decomposition of the exogenous and the endogenous variables vector. So, monetary policy shocks have no contemporaneous effects on output, prices and money but on the exchange rate. The exchange rate is last in the Choleski ordering as in a large economy like the euro area the exchange rate is assumed to have no contemporaneous effect on monetary policy.

The results of Peersman and Smets [24] VARs are in line with other work in the area. A monetary contraction lowers output after two quarters and leads to an appreciation of the exchange rate. Prices react sluggish initially but decrease after a couple of periods.
For a model for the US economy their impulse responses are very similar to the euro area ones with the only exception that policy shocks in the US on average have a bigger magnitude than in the euro area and a bigger effect on output and prices.

Regarding the liquidity effect, Peersman and Smets [24] find an initial negative reaction of M1 to monetary policy shocks. However, after four quarters M1 becomes positive before returning to the baseline after nine quarters. The reaction of M3 is initially less pronounced but over time shows more persistence. Initially, monetary tightening causes substitution of funds that bear no interest with time deposits or money market funds, which are included in the broad monetary aggregate M3. Therefore, M3 as a whole hardly shows a reaction in the first six quarters. Then, after seven quarters M3 declines persistently.

The reaction of M1 casts some doubt on the liquidity effect in the synthetic euro area model. This is in contrast to Christiano et al.’s [8] findings of a negative reaction of M1 to Federal Funds rate shocks for the US. However, this clear contrast in the results could very well be due to aggregation problems in the synthetic euro area data. Countries are assumed to have central banks with identical monetary policy reaction functions. Clearly, this is not a very satisfying working assumption and could generate incorrect results on the existence of the liquidity effect.

Therefore, Mojon and Peersman [21] follow a different line of reasoning than Peersman and Smets [24]. Instead of looking at an area wide model they account for the fact that members of the euro area are heterogeneous when it comes to the monetary transmission mechanism. When the effects of monetary policy on economic activity and on the price level differ from country to country it is essential to estimate central bank reaction functions at the country level. Mojon and Peersman [21] analyse the transmission mechanism of monetary policy in ten countries that are members of the euro area. They classify countries into three groups according to the degree by which their monetary policy was constrained by the EMS. Germany as the EMS anchor constitutes a group of its own, the second group consists of the Netherlands, the monetary union of Belgium and Luxembourg, and Austria which had de facto a fixed exchange rate towards the German Mark and no autonomy in monetary policy. Finally, there is the third group of countries headed by France and Italy that maintained a certain degree of autonomy in monetary policy.

Mojon and Peersman’s [21] results are qualitatively similar to Peersman and Smets [24]. A contractionary monetary policy shock leads to a temporary fall in output, to a gradual decrease in the price level and to an initial decrease of M for most countries. Although EMS countries were subject to asymmetric monetary policy shocks, these country level results resemble the results of the aggregate euro area economy of Peersman and Smets [24].

Mojon and Peersman [21] introduce different identification schemes for each country group. For Germany they choose one of the benchmark models from Peersman and Smets [24]. The model consists of a vector of exogenous variables including the world commodity price index, US real GDP and the US short-term nominal interest rate. The choice of these variables should solve the price puzzle and control for world demand and world inflation. The exogenous variables have
contemporaneous effects on the vector of endogenous variables which is identical to the one as in Peersman and Smets [24].

For the group consisting of Austria, Belgium and the Netherlands, German output, German prices, the German short-term interest rate and the bilateral exchange rate with Germany are included into the vector of endogenous variables because economic developments in these countries are dominated by developments in neighbouring Germany and, therefore, autonomous monetary policy shocks are very unlikely. Hence, the monetary policy shock is identified as the shock to the German interest rate in these countries.

The respective endogenous macro variables of the three countries have no contemporaneous effects on the German variables. The macro variables included are GDP, the CPI, a short-term interest rate, the real effective exchange rate and M1.

Constituting an interest rate anchor for the EMS, the short-term German interest rate is included in the endogenous variables vector for the third country group. The omission of the German interest rate could cause a price puzzle because a domestic interest rate increase on the grounds of an interest rate increase in Germany could be wrongly associated with an exchange rate depreciation. This would put upward pressure on prices in contrast to the expected decrease of the CPI in contractionary periods.

Mojon and Peersman [21] measure domestic monetary policy shocks as the deviation of domestic short-term interest rates from the German rate and identification is achieved by a standard recursive identification scheme.

For all countries a contractionary domestic monetary policy shock leads to a fall in output and in prices. Interestingly, these effects are much less pronounced for the euro area as a whole than on the single country level. Less consistence is found in the effect of a policy shock on the exchange rate. The exchange rates of Belgium and the Netherlands do not react to monetary policy shocks. This reflects the credibility of these countries’ EMS parities. The exchange rates of all other countries with the exception of Italy and Spain do, however, appreciate in response to a tightening of policy. Finally, Italy and Spain experience an exchange rate puzzle in the sense that their currencies depreciate when policy is tightened. This might be due to a market sentiment postulating that the monetary tightening represents in reality a manoeuvre to protect a depreciating currency.

For countries that try to fix their bilateral DM exchange rates Mojon and Peersman [21] find just a limited role for monetary aggregates in the model. Therefore, their evidence on the existence of the liquidity effect is quite mixed.

M1 hardly reacts to monetary policy shocks in France, Greece, Ireland and the euro area as a whole. For Spain, Finland and Italy M1 initially declines but returns to its old level after approximately ten quarters. For Germany, Austria, Belgium and the Netherlands M1 initially declines but then rebounds and increases above its starting level after five quarters. As could have been expected, M3-M1 which is mainly driven by time deposits and money market funds increases in all countries with the exception of Greece.
On a whole, the recent empirical results are quite favourable to the existence of a liquidity effect of monetary expansions. However, they show that the evidence that has been collected on the liquidity effect depends crucially on the identification schemes and on the sample periods which have been employed. The fact that there is some doubt on the existence of the liquidity effect led Jovanovic and Rousseau [15] to analyse the liquidity effect caused by shocks to the bond supply. The liquidity effect of the bond supply is the reaction of the nominal and real short-term rates to shocks to the bond supply.
3. Earlier Evidence on the Liquidity Effect in the Bond Market

Jovanovic and Rousseau [15] quantify the liquidity effect on interest rates stemming from supply-risk in the US bond market. At the monthly frequency, surprise bond purchases by the Federal Reserve System raise bond prices and reduce yields. Furthermore, the residual bond supply-risk due to random rollover plans of foreign financial and monetary institutions prevents the market makers from precisely predicting the actual bond supply. The supply-risk adds between 10 and 40 basis points to the standard deviation of the real interest rate on three-month treasury bills. Towards the end of the Clinton administration it was thought that in the US the bond supply-risk might increase in the future as the gradual paying down federal debt would have implied that it would have become harder to expand treasury bill issues to accommodate unexpectedly large rollover demands from foreign financial and monetary institutions. This problem does not pertain to EMU with its higher and more persistent levels of government debt.

In contrast to monetarist theory, money does not seem to have had clear effects on real interest rates in the US since the 1970s. Jovanovic and Rousseau [15] suggest that, the interest rate being the return on bonds and being pinned down by the supply of bonds rather than by the supply of money, the bond supply is in any case the better measure in order to analyse the liquidity effect than is money.

The importance of analysing the variance in the bond supply shows up in the fact that since 1980 growth in NBR has reduced short-term interest rates, but not as strongly as a contraction of treasury securities would have done. Surprisingly, over the whole period from 1960 to 1999 growth in NBR is positively correlated with short-term rates. As would have been expected, growth in marketable treasury securities is positively correlated with short-term rates for both the 1961 to 1999 and the 1980 to 1999 sub-period.

The evidence from Jovanovic and Rousseau [15] seems to suggest that at least for the US the liquidity effect in the bond market is a more straightforward vehicle to explain changes in short-term rates than the traditional liquidity effect via a monetary aggregate. Their conclusions do not change when they look instead at surprises in the bond supply and in NBR. The amount of marketable treasury securities outstanding and money in the form of non-borrowed reserves could be expected to be negatively correlated. When the central bank buys treasury securities by the means of open-market operations NBRs increase. Jovanovic and Rousseau [15], however, find only for the period between 1980 and 1999 a negative correlation between the growth in real per capita supply of outstanding treasury securities and NBR. For the period from 1961 to 1999 as a whole they find a positive correlation.

The main result of [15] consists in quantifying surprises to the bond supply and to inflation and measuring their impact on movements of the real ex-post return of three-month treasury bills. They measure surprises as the one-step ahead forecast errors of a system of forecasting equations.
which comprise the monthly real return to a US three-month treasury bill, the monthly US inflation rate based on the CPI for all urban consumers, the monthly growth rate of the real level of marketable US government securities outstanding and, finally, the monthly real return on the S&P500 index. The forecasting equations are based on a rolling VAR with a 36-month estimation window to allow for the inclusion of contemporary economic developments. Eventually, the surprises to the real return, to the bond supply and to inflation are pooled over the rolling sample of the VAR and, finally, the surprises to the real return are regressed on the surprises of the other two variables.

Treasury bills being zero-coupon bonds, the nominal return $R_{t,t+1}$ needed to calculate the real ex-post return $r_{t,t+1}$ for the forecasting equations is based on a zero-coupon bond with price $P_t$ at date $t$:

$$R_{t,t+1} = \frac{1 - P_t}{P_t}$$

(1)

The real ex-post return on this bond is

$$r_{t,t+1} = \left( \frac{1}{P_t} \left( \frac{1}{1 + \pi_{t,t+1}} \right) - 1 \right)$$

(2)

where $\pi_{t,t+1}$ is the monthly inflation rate between dates $t$ and $t+1$. Taking logs yields

$$\ln(1 + r_{t,t+1}) = -\ln P_t - \ln (1 + \pi_{t,t+1})$$

(3)

For any small number $s$, $\ln(1 + s) \approx s$. Thus,

$$r_{t,t+1} \approx R_{t,t+1} - \pi_{t,t+1}$$

(4)

The nominal return $R_{t,t+1}$ on a zero-coupon bond equals the nominal market interest rate $i_{t,t+1}$. Then, if the real return $r_{t,t+1}$ can be broken up in an expected component and in a surprise component we can approximate,

$$r_{t,t+1} = i_{t,t+1}^e - \pi_{t,t+1}^\mu$$

(5)

This means that the surprise to the ex-post $r_{t,t+1}^\mu$ real return is made up of the surprise component to the nominal return $i_{t,t+1}^e$ and the surprise component to inflation $\pi_{t,t+1}^\mu$.

Concerning the information set of the agents, at the beginning of period $t$ agents do know the realised inflation $\pi_{t-1,t}$ between dates $t$ and $t-1$, the realised real T-bill return $r_{t-1,t}$ between dates $t$ and $t-1$ and the real return from the S&P 500 between dates $t$ and $t-1$. However, agents have no exact information on the growth rate $g_{t-1,t}$ of the bond supply between dates $t$ and $t-1$. This
information arrives too late to be included in their information set. Therefore, agents have no precise forecasts about the price $P_t$ of a bond. When agents commit funds to the bond market before the date $t$ auctions take place they do not know yet the growth of the bond supply during period $t-1$. 

[15] assume a liquidity effect of the bond supply on the price of bonds of the form

$$i_{t,t+1}^u = a g_{t-1,t}^u$$

(6)

where $g_{t-1,t}^u$ is the surprise component to the bond supply growth between dates $t$ and $t-1$. 6 into 5 yields

$$r_{t,t+1}^u = a g_{t-1,t}^u - \pi_{t,t+1}^u$$

(7)

The occurrence of bond supply risk implies that agents do not know the date $t$ supply of bonds at the time at which they form their expectations of the new auction price $P_t$ and, thus, do not know the future nominal interest rate $\pi_{t,t+1}$. The reason that agents at time $t$ can not precisely know the bond supply and, thus, the auction price is due to the residual supply-risk inherent to US treasury auctions. Apart from the published auction amount of bonds in an auction the actual supply depends on the rollover plans of foreign financial and monetary institutions which submit non-competitive bids. Their rollover plans not being known to the public, results in the creation of residual supply-risk. The problem then boils down to estimating the regression

$$r_{t,t+1}^u = \alpha + \beta g_{t-1,t}^u - \gamma \pi_{t,t+1}^u + \epsilon_t,$$

(8)

where $r_{t,t+1}^u$, $g_{t-1,t}^u$, and $\pi_{t,t+1}^u$ are the surprises to the monthly ex-post real return of a treasury bill with a remaining maturity of three months, to the growth in the real amount of marketable treasury securities outstanding and to the monthly inflation rate. These surprises are measured by one-step ahead forecast errors from three forecasting equations which include the real return, the growth of treasury securities, inflation, the real return to the S&P 500 index and, finally, a time trend. Eventually, the surprises to the real return, to the growth rate of treasuries and to inflation are pooled over the rolling sample of a VAR with monthly observations from January 1920 through December 1999 and then the surprise to the real return is regressed on the other two surprises as shown in equation 9. T-statistics are in parenthesis.
The surprise to the supply of government securities $g_{t-1,t}$ has a significant positive impact on the ex-post real return $r_{t,t+1}$ of three-month T-bills. Replicating the rolling VAR and the forecasting equations of Jovanovic and Rousseau [15] for our dataset from January 1966 through March 2000 we get slightly different results for the regression of the surprises as can be seen in equation 10:

$$r_{t,t+1} = 0.0001 + 0.0027 \; g_{t-1,t} - 0.2432 \; \pi_{t,t+1}$$  

(0.33)  (0.29)  (-18.41)

\(^2\) In contrast to Jovanovic and Rousseau (2001), we do not assume that dividends will be reinvested when calculating the real return to the S&P 500.
4. Evidence on the Variability of the Stock of Public Debt Securities

Table 1 illustrates the correlations of monthly $g^M_1$ growth and growth in the amount of government debt securities outstanding $g^{BS}_t$ with the monthly real return on three-month treasury bills $r_{t,t+1}$ and the correlations of monthly M1 growth and bond supply growth with monthly three-month nominal treasury bill yields $r_{t,H}$ for the sample from 1980 to 2002. The real and nominal returns of the upcoming three months are chosen for the reason that afterwards the situation of primary dealers and investors who buy three-month treasury bills and hold them until maturity will be analysed. The fact that primary dealers commit funds to bond auctions before they know the exact amount that will be auctioned and, thus, before they know the price and the yield of the bonds to be auctioned makes them subject to the bond-supply risk which they then pass on to the investors on the secondary market. Shocks to the monthly amount of government debt securities outstanding might imply lower bond prices and primary dealers and investors might react in demanding higher yields when buying bonds at the beginning of each three-month holding period. Therefore, on the one hand, one would associate growth in the net bond supply with higher short-term nominal and real interest rates while, on the other hand, one would expect growth in the money supply to be negatively correlated with short-term real and nominal interest rates. Looking at table 1 containing the correlations, Germany, France and Spain display the expected negative correlation between the growth rate of money M1 and the nominal short-term rate, while Belgium and Italy display positive correlations. The real short-term rate, instead, is negatively correlated with monetary growth in all countries with the only exception being Italy. Concerning the bond supply growth, it is positively correlated with the real short-term rate only in Belgium and Italy and it is positively correlated with the nominal rate in Belgium, Italy and France. In contrast, the bond supply growth in Germany displays a clearly negative correlation with both, real and nominal short-term rates.

The liquidity effect seems to be at work in Germany, Spain and France where we find a negative correlation between M1 and the short-term nominal interest rate but not in Belgium and in Italy. Belgium and Italy could be an interesting case to study because they are the only two countries which display the wrong - positive - sign for the correlation between monetary growth and nominal short-term interest rates on the one hand, paired with the presumably correct, i.e. positive, correlation between bond supply growth and real and nominal short-term rates on the other hand. The positive and, therefore, intuitively wrong correlation between the nominal short-term interest rate and money M1 for Belgium and Italy could imply that these countries are special in the sense that in these countries variations in the bond supply, which is displaying at least the correct sign in contrast to the variations of money supply, might have more explanatory power for the fluctuations in nominal interest rates than variations in the money supply have. On the other hand, the positive
The correlation between M1 growth and the nominal short-term rates could as well be due to private sector shocks that have nothing to do with monetary policy shocks. Private sector shocks could be at the heart of increases to money demand and faster growth in broad monetary aggregates like M1 and, thus, drive up short-term interest rates. Therefore, one needs to disentangle monetary policy shocks from private sector monetary shocks.

The same caveat is obviously in place regarding the positive correlations between the bond supply growth and the three-month nominal and real return in Belgium and Italy. The positive correlations could be due to private sector shocks which have nothing to do with structural shocks to the bond supply. Therefore, one needs to identify the structural shocks in the economy in order to be capable of making assertions on the causal relationship between bond supply risk and the ex-post real return on three-month treasury bills. Doing exactly this in a structural BVAR for Italy, we find evidence that shocks to the bond supply raise the real return of three-month treasury bills. For France and Germany, however, shocks to the bond supply seem to decrease the real return. Only Belgium and Spain follow Italy in the presence of the liquidity effect in the bond market up to a certain degree. For Belgium and Spain we find evidence for a slight increase of the real returns in response to shocks of the bond supply.

Table 1: Correlations of treasury securities’ and M1’s monthly growth rates with three-month real and nominal returns

<table>
<thead>
<tr>
<th></th>
<th>BE</th>
<th>DE</th>
<th>ES</th>
<th>FR</th>
<th>IT</th>
</tr>
</thead>
<tbody>
<tr>
<td>corr(r_{t+1}, g_{t}^{RS})</td>
<td>0.04</td>
<td>-0.14</td>
<td>-0.03</td>
<td>-0.11</td>
<td>0.06</td>
</tr>
<tr>
<td>corr(r_{t+1}, g_{t}^{M1})</td>
<td>-0.11</td>
<td>-0.18</td>
<td>-0.23</td>
<td>-0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>corr(i_{t+1}, g_{t}^{BS})</td>
<td>0.10</td>
<td>-0.27</td>
<td>-0.06</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>corr(i_{t+1}, g_{t}^{M1})</td>
<td>0.06</td>
<td>-0.14</td>
<td>-0.08</td>
<td>-0.15</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Figure 1: Twelve-month rolling standard deviations of monthly growth rates of real M1 and real treasury securities in Italy
Of course shocks to the bond supply can only be relevant in explaining interest rate fluctuations if the growth rate of the amount of government securities outstanding is not simply constant but has a certain degree of variability. Here, it is interesting to compare the variability in the bond supply to the variability in the money supply as money is usually considered the variable to have the most immediate effect on short-term interest rates.

Figures 1 and 2 illustrate the monthly volatility of the real M1 and the real treasury securities growth rates exemplary for Italy and for Germany. It can be seen that especially in Germany the volatility of the growth rates of treasury securities has a magnitude in the order of the volatility of monetary growth rates. Despite of this, the volatility in the bond supply is a phenomenon that has been rarely analysed as to date.

**Figure 2**: Twelve-month rolling standard deviations of monthly growth rates of real M1 and real treasury securities in Germany

![Chart showing the volatility comparison between real M1 and real treasury securities in Germany](chart.png)

**Table 2**: Monthly growth rates of real M1 and real treasury securities

<table>
<thead>
<tr>
<th>Country</th>
<th>BE</th>
<th>DE</th>
<th>ES</th>
<th>FR</th>
<th>IT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{M1}^H$</td>
<td>0.31</td>
<td>0.43</td>
<td>0.28</td>
<td>0.09</td>
<td>0.69</td>
</tr>
<tr>
<td>$L_{HS}^H$</td>
<td>0.59</td>
<td>0.75</td>
<td>1.52</td>
<td>1.02</td>
<td>0.44</td>
</tr>
<tr>
<td>$C_{M1}^H$</td>
<td>1.54</td>
<td>1.38</td>
<td>0.86</td>
<td>0.78</td>
<td>1.41</td>
</tr>
<tr>
<td>$C_{HS}^H$</td>
<td>3.06</td>
<td>1.14</td>
<td>0.20</td>
<td>7.33</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Table 2 displays the means and standard deviations of monthly growth rates of real M1 and real treasury securities for all five countries of our study from 1980 to 2002. For most countries in our sample the mean and the standard deviation of the monthly growth rates of treasury securities have been exceeding the ones of M1.

3 We apply the Hodrick-Prescott filter on these two series.
Figure 3 depicts how the monthly growth rates of real treasury securities compare in the US, in Italy and in Germany. The graphs imply that in all three countries there is considerable variability in the amount of treasuries outstanding. This variability could put significant upward pressure on the real returns of the treasury securities. In fact [15] find that in the US shocks to the bond supply cause positive shocks on the real returns on three-month treasury bills and in this paper we will illustrate that in Italy shocks to the total amount of treasuries outstanding lead to slight increases in the real return on three-month treasury bills. This might be an exclusively Italian phenomenon because the variability in the growth rate of treasury bills outstanding might historically have been higher in Italy than it has been in other euro area countries and the share of treasury financing needs covered by issuing treasury bills might have been higher in Italy than for example in France or in Germany.

**Figure 3:** 12 month moving average of the monthly growth rates of treasury securities outstanding in the US, in Italy and in Germany

For Belgium and for Spain we find similar results like for Italy. Bond supply shocks seem to exert an upward pressure on the ex-post real returns of three-month treasury bills in these countries, too.
5. Money Supply Shocks

What does the evidence on the traditional liquidity effect of shocks to monetary aggregates look like for the five euro area countries Belgium, Germany, France, Italy, and Spain? We will look at a four-variable structural VAR from Leeper et al. [17]. In order to identify the VAR, we impose one further homogeneous restriction, i.e. $\alpha_{21} = 0$ which implies that price shocks have no contemporaneous effect on output. This restriction is motivated by the existence of a certain lag in private agents’ decisions in reaction to CPI shocks.

For the general motivation of this identification scheme please refer to the section 2 where we give a detailed explanation of the identification scheme of Leeper et al. [17]. The lagged reactions of the monetary authorities to private sector variables and the sluggish reactions of private agents to money and interest rates give rise to the following contemporaneous restrictions on the coefficients of the variables:

$$
\begin{pmatrix}
1 & \alpha_{12} & 0 & 0 \\
0 & 1 & 0 & 0 \\
\alpha_{21} & \alpha_{22} & 1 & \alpha_{34} \\
0 & 0 & \alpha_{43} & 1
\end{pmatrix}
\begin{pmatrix}
\epsilon_t^{CPI} \\
\epsilon_t^{FP} \\
\epsilon_t^{TB3m} \\
\epsilon_t^{M1}
\end{pmatrix}
= 
\begin{pmatrix}
\nu_t^{CPI} \\
\nu_t^{FP} \\
\nu_t^{TB3m} \\
\nu_t^{M1}
\end{pmatrix}
$$

(11)

Although our main objective is to analyse the effect of shocks to the supply of treasury securities on the ex-post real return of three-month treasury bills we begin to estimate the four-variable structural model from Leeper et al. [17] for the Italian data to get evidence on the traditional liquidity effect of monetary innovations on short-term interest rates. To this end, we use the three-month treasury bill yield TB3m instead of the real return and we leave aside the amount of treasuries outstanding for the time being.

Figure 4 shows the impulse responses for this model for the case of Italy. Consumer prices react positively to output and as well to the interest rate - this is the price puzzle. Italy is the only country in our sample which manifests the price puzzle. In all other four countries prices show a negative reaction to interest rate shocks. For Spain, however, the reaction is quite weak.

Italian output initially does not react much either to the interest rate or to M1. However, it shows a slightly positive reaction to money after several periods. This is very similar to the reactions in Belgium, Germany and France but in contrast to Spain, where output reacts negatively to M1 shocks.

In Italy the interest rate displays a strong liquidity effect when M1 is shocked but it hardly reacts to the other variables. However, M1 shows a strong reaction with the wrong sign to the interest rate - the liquidity puzzle.

The liquidity effect for the other countries can be read off the tables 3 and 4 displaying structural one standard deviation innovations to three-month treasury bill rates and M1 with their respective
standard errors in parenthesis. For France and Belgium the three-month rate decreases when M1 is shocked. In Germany and Spain instead, the three-month return responds positively to monetary shocks. This could happen via an expectations effect when markets expect higher monetary growth to feed through to higher inflation and interest rates rise in anticipation of higher policy rates.

Table 3: Impulse responses of the three-month interest rates to one standard deviation innovations in M1

<table>
<thead>
<tr>
<th>Period</th>
<th>BE</th>
<th>DE</th>
<th>ES</th>
<th>FR</th>
<th>IT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.242518</td>
<td>0.258199</td>
<td>0.343984</td>
<td>-0.358103</td>
<td>-0.670219</td>
</tr>
<tr>
<td></td>
<td>(0.02034)</td>
<td>(0.01231)</td>
<td>(0.02432)</td>
<td>(0.03049)</td>
<td>(0.02612)</td>
</tr>
<tr>
<td>6</td>
<td>-0.379753</td>
<td>0.256907</td>
<td>0.293130</td>
<td>-0.304091</td>
<td>-0.519617</td>
</tr>
<tr>
<td></td>
<td>(0.04501)</td>
<td>(0.02475)</td>
<td>(0.05052)</td>
<td>(0.06382)</td>
<td>(0.06673)</td>
</tr>
<tr>
<td>12</td>
<td>-0.267166</td>
<td>0.191344</td>
<td>0.232406</td>
<td>-0.260976</td>
<td>-0.404966</td>
</tr>
<tr>
<td></td>
<td>(0.06019)</td>
<td>(0.04176)</td>
<td>(0.06450)</td>
<td>(0.09194)</td>
<td>(0.10020)</td>
</tr>
<tr>
<td>18</td>
<td>-0.172810</td>
<td>0.111064</td>
<td>0.189012</td>
<td>-0.248911</td>
<td>-0.296320</td>
</tr>
<tr>
<td></td>
<td>(0.07187)</td>
<td>(0.04432)</td>
<td>(0.07362)</td>
<td>(0.10331)</td>
<td>(0.11719)</td>
</tr>
<tr>
<td>24</td>
<td>-0.101270</td>
<td>0.047377</td>
<td>0.110291</td>
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<td>-0.198957</td>
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<tr>
<td></td>
<td>(0.07497)</td>
<td>(0.04182)</td>
<td>(0.07779)</td>
<td>(0.10149)</td>
<td>(0.12604)</td>
</tr>
</tbody>
</table>

A second explanation could be that in Germany and Spain private demand shocks are responsible for the positive effects of money shocks on the interest rate. Private demand shocks could raise money demand and, therefore, increase interest rates. In France and Belgium the traditional liquidity effect seems to be at work like in Italy. Here, money supply shocks are the dominant force and lower the short-term nominal interest rate. For a one percent shock to monetary growth the three-month treasury bill rate decreases about one percentage point. In Germany and Spain, however, it increases by roughly one percentage point.

Regarding the shock of the interest rate on M1 we find that the shock lowers M1, as it should do, only in Belgium, Germany and Spain. In France and Italy interest rate shocks increase M1. [[Due to increase in demand for sight deposits which pay interest rates in France and in Italy? The higher money demand dominates higher money supply in France and Italy.]] By the same token, this would imply that in Belgium, Germany and Spain money supply shocks dominate money demand shocks and, thus, lead to lower short-term interest rates following monetary shocks.
6. Shocks to Government Debt and Real Returns

We analyse the effects of shocks to government debt on the real ex-post return of three-month treasury bills of the five euro area countries with the biggest absolute amount of government debt outstanding, namely, Belgium, Germany, France, Italy and Spain at a monthly frequency.

Figure 4: Four-variable structural VAR for Italy
Table 4: Impulse responses of M1 to one standard deviation innovations in the three-month interest rate

<table>
<thead>
<tr>
<th>Period</th>
<th>BE</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>-0.011820</td>
<td>-0.005362</td>
<td>0.007193</td>
<td>0.012798</td>
</tr>
<tr>
<td></td>
<td>(0.00661)</td>
<td>(0.00050)</td>
<td>(0.00034)</td>
<td>(0.00042)</td>
<td>(0.00060)</td>
</tr>
<tr>
<td>5</td>
<td>-0.010449</td>
<td>-0.009704</td>
<td>-0.005672</td>
<td>0.006469</td>
<td>0.007437</td>
</tr>
<tr>
<td></td>
<td>(0.00105)</td>
<td>(0.00139)</td>
<td>(0.00163)</td>
<td>(0.00101)</td>
<td>(0.00112)</td>
</tr>
<tr>
<td>12</td>
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<td>-0.005319</td>
<td>0.005020</td>
<td>0.004902</td>
</tr>
<tr>
<td></td>
<td>(0.00221)</td>
<td>(0.00193)</td>
<td>(0.00240)</td>
<td>(0.00145)</td>
<td>(0.00184)</td>
</tr>
<tr>
<td>18</td>
<td>-0.005073</td>
<td>-0.006296</td>
<td>-0.005085</td>
<td>0.003323</td>
<td>0.003004</td>
</tr>
<tr>
<td></td>
<td>(0.00302)</td>
<td>(0.00232)</td>
<td>(0.00330)</td>
<td>(0.00179)</td>
<td>(0.00219)</td>
</tr>
<tr>
<td>24</td>
<td>-0.007317</td>
<td>-0.005976</td>
<td>-0.007848</td>
<td>0.002845</td>
<td>0.001623</td>
</tr>
<tr>
<td></td>
<td>(0.00639)</td>
<td>(0.00239)</td>
<td>(0.00417)</td>
<td>(0.00191)</td>
<td>(0.00227)</td>
</tr>
</tbody>
</table>

Even if the amount of securities outstanding might not be the most sophisticated measure of market liquidity from a market microstructure perspective, choosing the five countries with the biggest amount of government securities outstanding in the euro area allows us to abstract at least to a certain degree from microstructure issues, which, by having an impact on yields, could distort our analysis.

Bond supply shocks are caused by the nature of the way in which ministries of finance and debt management agencies auction and syndicate government paper. When bonds are to be auctioned, auction schedules are typically released only one week prior to auctions indicating the quantity to be auctioned. Due to rollover plans from private agents and from domestic and foreign authorities whose rollover plans are not common knowledge or, in some countries, due to securities purchased directly by national central banks, the scheduled quantity could differ substantially from the actual quantity allotted. Even if the quantity announced and the quantity allotted were identical, agents still would be subject to supply-risk at a monthly frequency because the amounts to be auctioned typically are only released few days prior to the auctions and, therefore, agents still face a certain degree of uncertainty about the amounts to be auctioned at the beginning of any specific month.

Ideally, we would like to measure the shocks to only the amount of three-month treasury bills outstanding and analyse their impact on investors’ required real returns. This would provide us with a measure of how costly high variance in amounts outstanding or to be issued could be. A lack of transparency regarding the issuance amounts of treasury bills could be costly for public debt financing if it drives up yields. An elevated cost in public debt financing could manifest itself in investors demanding higher yields when facing higher supply risk on primary and secondary markets in the presence of shocks to the amounts of securities issued and in the presence of auctioning or syndication methods that are characterised by a lack of transparency or reliability. However, constructing time series on the outstanding amount of specific maturities of treasury bills would be possible only at prohibitive cost. Therefore, we need to content ourselves with measuring shocks to
the total amount of government bonds and bills outstanding and the implications they have for real ex-post returns on three-month treasury bills.

6.1 The Data

For Italy, ITRR is the monthly real ex-post return of an agent that has bought an Italian treasury bill with a three-month remaining maturity on the primary market and holds the bill until maturity. The real return is constructed as the difference between the average monthly gross allotment rate for three-month maturities - calculated by the Bank of Italy - and the three-month inflation rate measured by the seasonally adjusted consumer price index from the Italian National Institute of Statistics (ISTAT):

\[
ITRR_t = (1 + \frac{IT3m_t}{100}) - ((1 + \frac{ITCPI_{t+1} - ITCPI_{t-1}}{ITCPI_{t-1}})^4 - 1)),
\]

(12)

Regarding the other variables used, ITM1 is the logarithm of the real value of the seasonally adjusted money supply M1 for Italy retrieved from Datastream. ITBS stands for the log of real general government debt outstanding, which includes short-term and long-term public debt securities outstanding as well as loans and other forms of debt. Although it would have been preferable to use only the marketable Italian government debt outstanding, debt securities outstanding are the major chunk of total government debt in Italy and in the other countries we analyse and correlations between the two measures of debt are very high where available. ITIP is the log of seasonally adjusted real Italian industrial production, which we use instead of real GDP because it is readily available as a monthly series. ITP is the logarithm of the seasonally adjusted Italian consumer price index including tobacco. Industrial production and consumer prices are from ISTAT. The IMF commodity price index and the German one year bond yield will be treated as exogenous variables in the VAR. The world commodity price index contains important information on the future path of inflation and the German interest rate at least for the period before the introduction of the single currency in 1999 contained important information on the future course of Italian interest rates.

For the other countries the yields of three-month treasury bills and the amounts of government securities outstanding were retrieved from the national central banks’ websites, while data on consumer prices, monetary aggregates and industrial production were taken from Datastream. After the introduction of the euro in 1999 the respective countries’ national contributions to the money supply M1 in eurozone becomes our monetary variable M1.
6.1.1 Choleski Identification

We kick off our analysis of the effects of shocks in government debt outstanding with a simple Choleski identification scheme estimating a VAR in Italian industrial production, the Italian real stock of debt securities, Italian real M1, the monthly yield on an Italian treasury bill with three months remaining maturity and the Italian consumer price index. For now, we include the nominal three-month treasury bill yield, rather than the ex-post real return - to be introduced later - in order to compare the impulse responses for the Italian data to the benchmark models of Leeper et al. [17] and we use industrial production rather than output because of its availability as a monthly series. The quarterly series for GDP carry too much noise into the impulse responses when converted into monthly frequencies. The comparison to models like the one of Leeper et al. [17] could already reveal the possible opportunities from introducing the variable bond supply in VARs analysing monetary shocks and interest rate fluctuations.

A Choleski decomposition of these variables with the Choleski-ordering ITBS, ITIP, ITM1, IT3m yields the impulse responses shown in figure 5. The amount of government securities outstanding BS is ordered first because usually it does not respond within the period to the other macro variables. The same is true for industrial production and consumer prices which react only with a certain lag to variables like M1 and the three-month interest rate. The IMF commodity price index and the German one year nominal interest rate are included as exogenous variables in the system.

The Italian stock of government debt reacts negatively to industrial production but does not seem to react to shocks in any of the other variables. In some countries the bond supply reacts to some of the other variables, too. However, no general pattern can be established of how the bond supply reacts to prices, interest rates or money.

Industrial production shows hardly a reaction to M1 Italy. This seems to reject the monetarist view that monetary aggregates are capable of moving production. Neither does industrial production initially respond to an interest rate shock. It displays the expected negative reaction only from the 6th period onwards. Leeper et al. [17] have suggested a negative shock of output, the variable they use instead of industrial production, to shocks in the federal funds rate in a four-variable model including CPI, output, the federal funds rate and M1. This seems to be a more straightforward result.

In the other countries the reaction of industrial production to the interest rate is similar to the one in Italy and industrial output declines after six periods. The notable exception is Germany where it first increases and then begins to decline after ten periods. In all four other countries industrial output reacts positively to M1.
While in Italy one percent shocks to M1 increase industrial production only by 0.1%, in the other countries industrial production goes up by between 0.3% and 0.45%.

The CPI reacts positively to the bond supply after three to four periods and negatively to M1. There is a negative reaction of the CPI to the interest rate for two or three periods only. Afterwards the CPI displays the price puzzle. The price puzzle is no exclusively Italian phenomenon. It shows up in the other four countries, too. Consumer prices react positively to interest rate shocks, while they would be supposed to display negative reactions.

Italian M1 reacts negatively to industrial production, to the bond supply, to the three-month interest rate and to the price level. The impulse responses to shocks in industrial production and the price level display, however, quite large error bands. The contraction of M1 in response to the interest rate is strong (at 0.4% after 10 periods) and persistent. This liquidity effect has the correct sign in contrast to the one that Leeper et al. [17] find for the US.
In the other four countries M1 reacts positively to shocks in industrial production but the responses to other variables vary from country to country. Of particular interest are the responses of M1 to interest rate shocks. M1 contracts in all countries even if with a smaller magnitude and with less persistency than for the Italian case. The contraction to one percentage point shocks to the interest rate is —0.18% in Belgium, —0.25% in France, —0.26% in Germany and —0.30% in Spain.

Finally, the Italian three month interest rate hardly reacts to industrial production but it displays a clearly positive reaction to the bond supply after being initially inert for four months. After five periods a one percentage point bond supply shock raises the three-month rate by some 35 basis points. The interest rate initially reacts positively to M1 but after two months it displays the expected negative reaction. It hardly reacts to industrial output and to consumer prices. The liquidity effect of shocks to the monetary aggregate seems to be rather small for Italy. A one percentage point shock to M1 leads to a decline of the three-month rate of roughly 15 basis points only after nine periods. For Italy the short-term interest rate is more sensitive to bond supply innovations than it is to monetary innovations.

With the exception of Germany, the other countries replicate the negative reaction of the interest rate to monetary shocks. In Belgium the reaction is —20 bp, in France —22 bp and in Spain —66 bp. Regarding the reaction to bond supply shocks, interest rates react negatively in Germany, Spain and France but do not display any significant response in Belgium.

The most striking result is that the Choleski identification scheme creates a prize puzzle. When interest rates are shocked, the CPI goes up. This is in contrast to the Leeper et al. [17] model presented above which generates the correct responses of the CPI to interest rate shocks. Another possibility would be that the introduction of the new variable government bond supply causes the prices to react in the wrong way. Nice in the Choleski scheme is that industrial production goes down due to the interest rate shock instead of staying unchanged or going up as in the four-variable structural VAR before. Another positive feature of the model is that for Italy and France the reaction of M1 to the interest rate now comes in with the right sign, so that finally all countries display the correct reaction of M1 within the framework of the Choleski identification. Furthermore, the scheme generates the correct liquidity effect of M1 on interest rates with the exception of Germany where the liquidity puzzle found in the above structural VAR continues to persist.

6.2 Structural VAR

After introducing the bond supply into the model we proceed to develop a structural VAR to identify the structural shocks of the bond supply, the monetary aggregate M1 and the short-term interest rate to the system. The Choleski identification scheme presented above was too rigid in the sense that it restricted the interaction between the three-month interest rate, M1 and the bond supply too much.
without allowing for contemporaneous feedback between these variables, especially between the interest rate and M1.

The nominal yield on three-month treasury bills TB3m, money M1, the government bond supply BS, industrial production IP and the consumer price index P constitute the structural model

\[
    \begin{pmatrix}
        TB3m_t \\
        M1_t \\
        BS_t \\
        IP_t \\
        P_t
    \end{pmatrix}
    =
    \begin{pmatrix}
        TB3m_{t-1} \\
        M1_{t-1} \\
        BS_{t-1} \\
        IP_{t-1} \\
        P_{t-1}
    \end{pmatrix}
    +
    \begin{pmatrix}
        u^T3m_t \\
        u^M1_t \\
        u^BS_t \\
        u^IP_t \\
        u^P_t
    \end{pmatrix},
    \quad (13)
\]

where the matrix \( A \) defines the contemporaneous interaction between the variables of the model and \( C(L) \) is a matrix lag polynomial.

\( u^T3m_t, u^M1_t, u^BS_t, u^IP_t \) and \( u^P_t \) are the structural disturbances to the model’s variables. The matrix \( B \) defines which structural shocks will hit which variable in the system.

The reduced form of the structural model (13) can be written as

\[
    \begin{pmatrix}
        TB3m_t \\
        M1_t \\
        BS_t \\
        IP_t \\
        P_t
    \end{pmatrix}
    =
    A^{-1}C(L)
    \begin{pmatrix}
        TB3m_{t-1} \\
        M1_{t-1} \\
        BS_{t-1} \\
        IP_{t-1} \\
        P_{t-1}
    \end{pmatrix}
    +
    \begin{pmatrix}
        \epsilon^T3m_t \\
        \epsilon^M1_t \\
        \epsilon^BS_t \\
        \epsilon^IP_t \\
        \epsilon^P_t
    \end{pmatrix},
    \quad (14)
\]

where the vector \( \epsilon^t = [\epsilon^T3m_t \, \epsilon^M1_t \, \epsilon^BS_t \, \epsilon^IP_t \, \epsilon^P_t] \) contains the VAR residuals.

The identification of this structural model is achieved by orthogonalising the structural disturbances, imposing the theory-based restriction that macroeconomic variables do not contemporaneously react to monetary or financial market variables and imposing the restriction that the policy makers and private agents react only with lags to macroeconomic variables. These restrictions are in line with models in the monetary policy literature which study effects of monetary policy on macroeconomic variables with datasets of monthly frequency.

Thus, the relationship between the VAR residuals and the structural disturbances can be written as
\[ A e_t = B u_t, \quad (15) \]

where \[ A e_t = \begin{pmatrix}
1 & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} \\
\alpha_{21} & 1 & \alpha_{23} & 0 & 0 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 1
\end{pmatrix} \]

and \[ B u_t = \begin{pmatrix}
\beta_{11} & 0 & 0 & 0 & 0 \\
0 & \beta_{22} & 0 & 0 & 0 \\
0 & 0 & \beta_{33} & 0 & 0 \\
0 & 0 & 0 & \beta_{44} & 0 \\
0 & 0 & 0 & 0 & \beta_{55}
\end{pmatrix} \]

correct paragraphs: The first equation in the system posits that money contemporaneously affects the interest rate—this is the liquidity effect. Furthermore, the interest rate on T-bills is affected by bond supply changes. In the special case that bond supply changes constitute mainly changes in long-term bonds rather than changes in T-bills the effect on the short-term interest rate can, however, be expected to be very limited. Furthermore, the interest rate is contemporaneously shocked by industrial production and by consumer prices.

As can be seen from the second equation, money does react to the interest rate and to the bond supply within the period.

The third equation in the system implies that the bond supply is contemporaneously only influenced by its own shocks. The interest rate, money, industrial production and the CPI do not contemporaneously affect the bond supply because the quantity of new government bonds issued does not vary due to these variables at high frequencies. The assumption that the debt issuing agency does not react to shocks to the interest rate might be true up to a certain extent because once an auction and the amount of T-bills to be auctioned have been decided upon and announced it is very unlikely that the auction will be cancelled or the amount to be auctioned will be modified on the account of an interest rate shock. At most there might be small adjustments in the amount to be auctioned in order to accommodate developments in the markets.
The fourth equation restricts the contemporaneous reaction of private agents to the interest rate, to money, to the bond supply and to the CPI to zero. Due to costly and time-intensive dispositions in the private sector industrial production does not react contemporaneously to interest rates, money, the bond supply and the CPI.

Finally, the fifth equation reflects the consensus view in the empirical monetary transmission literature that the aggregate price level responds very little to monetary contractions and expansions. In this equation sluggishness in the private sector motivates the restrictions that the price level does not react to interest rates, money, the bond supply and industrial production.

Figure 6: Structural VAR for Italy including the nominal yield on Italian three-month treasury bills

The commodity price index is an exogenous variable in the structural VAR as it contains information on the future course of inflation. Due to its importance in accounting for Italian short-term interest rates, the German one-year interest rate figures as exogenous variable in the system. The German interest rate is added to the VARs of the other countries with the exception of Germany, too.
Figure 6 displays the impulse responses for this model. The interest rate reacts negatively to shocks to money M1 and it reacts positively to bond supply shocks. In the other four countries only in France there is a liquidity puzzle in the sense that the nominal short-term rate reacts positively to interest rate shocks. After some periods M1 in Italy displays the correct sign in its reaction to the interest rate shock. This can not be said for Belgium, Germany and Spain where money now reacts positively to interest rate shocks. The consumer price index displays a positive reaction to interest rate shocks. This price puzzle manifests itself in the other four countries, too.

Real returns
Now it is time to introduce the ex-post real return instead of the nominal yield into the model. The difference between the two measures being the change in the consumer price index during the three months in which an agent holds the treasury bill. The contemporaneous interaction between the real return and the other four variables of the model could be different from the interaction of the three-month nominal yield with the four variables.

The real return for an investor in a buy-and-hold strategy is defined by the yield to maturity at the purchase of a new three-month treasury bill and the inflation in the following three months. An investor that buys a new issue in an auction or on the secondary market will, therefore, react to information on the possible future path of inflation. News about the commodity price index, the CPI, industrial production and M1 will influence his perception about possible levels for future inflation and, therefore, the yield which he will require from his investment. Information on possible shocks in the bond supply will influence his valuation of the bond he is about to acquire independently of the expected inflation path.

The contemporaneous shocks given to the real return are identical to the ones to the nominal yield of treasury bills. The real return is contemporaneously shocked by the commodity price index, by M1, by the bond-supply and the consumer price index but not by industrial production. A shock to M1 will most likely lead to higher prices of treasury bills and lower nominal and real returns. Shocks to the bond supply could push down bond prices on secondary markets or, when they are caused by roll-over decisions, on primary markets and, therefore, push up yields and real returns. These reactions could, however, depend on the question where on the maturity curve the supply shocks takes place. Supply shocks on the long end may not have as strong effects on short-term rates as supply shocks on the short end would have. Finally, a rise in the CPI implies higher future inflation and should raise nominal yields, but investors that have already taken a long position in the market will see their real returns decrease by inflation surprises.

Therefore, the identifying restrictions are identical to the ones in system (15). The corresponding impulse responses are displayed in figure 7.

The real return reacts negatively to M1 and displays a slightly positive reaction to the bond supply after a lag of eight months.
Figure 7: Structural VAR for Italy including the real return on Italian three-month treasury bills.

Although not being significant in this model, the lagged reaction of the real return to bond supply shocks reminds of the lag in the impulse response of the nominal yield to the bond supply in figure 6 and the reaction in the Choleski identification scheme in figure 5. M1 increases as a reaction to interest rate shocks. The bond supply displays a positive reaction to interest rate shocks and monetary shocks.

By and large, the models in the nominal and in the real return deliver the same qualitative results for Italy. Even with the very high inflation at the beginning of the Italian sample in the second half of the 1980s the impulse responses of the real and the nominal models are very similar.
7. Government Debt Shocks and the Bayesian VAR Approach

The number of coefficients in a VAR grows as a quadratic function of the number of variables included. Therefore, even VARs with only five or six variables are heavily parametrised models. Heavily parametrised models in conjunction with scant sample information which is very random, however, cause an overfit and result in models that reflect random noise rather than systematic empirical variability. The application of arbitrary exclusion restrictions founded on economic theory or the use of the Bayesian approach to estimation represent potential solutions to this over-parameterisation problem of a VAR.

A priori one often does not know whether it is feasible to set values for specific coefficients equal to zero. However, there are many situations in which knowledge of model coefficients is not totally absent. In this case the Bayesian approach avoids too many zero restrictions and allows the available information to be expressed more realistically through allocation of probability distributions to the model’s different coefficients.

In the Bayesian approach each of the model’s coefficients are assigned probability distributions. Mean and variance of these distributions control the likelihood of a given coefficient taking on a particular value. Hence, stochastic prior information on coefficients allows a reasonable range of uncertainty about parameter values.

In order to overcome the overparametrisation problem and to get rid of an excess of random noise in the impulse response functions of our structural VAR we employ a Bayesian VAR (BVAR) to analyse the effects of bond supply shocks on the three-month real returns of treasury bills.

7.1 The Minnesota prior

A Minnesota prior incorporates the fact that a random walk is a good proxy for the behaviour of economic variables over time and the prior takes into account the fact that a more recent path of a variable yields more information about its behaviour than its more distant past. Normal distributions are assigned to each coefficient of a lag so that the mean is one for the coefficient of the first own lag and zero for the other lags. Coefficients on longer lags are more likely to be close to zero than coefficients on shorter lags. The variance will be lower for other lags than for own lags of and will decrease for more distant lags.

However, the specification of a complete normal prior on a VAR would be intractable and a few well-chosen hyperparameters are used instead. The hyperparameters of which we make use are the mean vector of coefficients on the first own lags, the importance of other lags with respect to own lags and the lag decay.

When variable $j$ refers to the $j$th variable in the VAR and equation $i$ to the equation whose dependent variable is $i$, the information needed to construct the prior is:
First, the mean of the prior distribution for the first own lag in each equation. We use a mean of zero for the prior on all coefficients except the first own lag in each equation on which a prior mean of one is placed. The reason for this is that many economic time series follow a random walk process. The alternative is a mean of zero on series which can be represented by white noise. In our system we do not have any variables that behave like white noise.

Second, the standard deviation $S(i, j, l)$ of the prior distribution for lag $l$ of variable $j$ in equation $i$ for all $ij$ and $l$. The standard deviation is scaled by the standard errors of variable $j$ in equation $i$ to control for the different scale of the variables in the system. The standard priors restrict the standard deviation function to the form:

$$S(z, j, l) = \{\gamma g(l) f(z, j)\} s_i / s_j,$$

where $\gamma$ is the overall tightness, which is the standard deviation on the first own lag and $g(l)$ is the tightness on lag $l$ relative to lag 1. The lag tightness expresses the importance of longer lags relative to the first lag.

Third, $f(i, j)$ is the tightness on variable $j$ in equation $i$ relative to variable $i$. This means that $f(i, j)$ stands for the importance of lags of other variables relative to the importance of own lags of the dependent variable in each equation.

The literature has shown that a reasonable procedure is to set the parameter for overall tightness to something in the order of 0.1 or 0.2. Tightness controls the importance of variables own lags relative to the lags of the other variables in the system. Setting it too high eliminates the Bayesian part of the system. On the other hand, setting the value for tightness too low forces the own lags of a variable too close to the prior mean of the lags of the other variables. We stick to the value of 0.2 on overall tightness.

Regarding the tightness of own lags, we set the decay factor for own lags to $g(l)$ to 1.5. Setting the value for the tightness of other lags $f(i, j)$ to 1.0 gives a standard VAR. On the other hand, setting this value very low gives little weight to interaction of any one variable with the other variables' lags and, therefore, eliminates the "vector" part of the VAR and yields an univariate model. This might be a feasible option if single equations in the VAR will turn out to be univariate autoregressions rather than equations interacting with the variables in the system. We set the importance of lags of other variables relative to the own lags of the dependent variable initially to 0.5. However, the bond supply equation turns out to come close to an univariate auto-regressive process in our Italian data. None of the other lags have significant t-statistics in this equation. Furthermore, in the equations for the CPI and industrial production only few lags of the real return are significant. Therefore, it seems to be reasonable to give a lower weight to the lags of the other variables. We find that the range of 0.3 to 0.4 does fine in the sense that impulse response functions are smoother and deliver more reasonable results than a higher value would do. Taking care of the fact that the bond supply, the consumer price index and industrial production come
near to univariate auto-regressions we, therefore, set the value for the importance of other lags to 0.35. For countries other than Italy we choose the same values for the hyperparameters.

7.2 The Results of the BVAR

7.2.1 Italy

The identification scheme for the structural BVAR is the one elaborated in system (15). Real ex-post return of three-month treasury bills. In the run-up to the introduction of the euro (1985-1998): As displayed in figure 8, the Italian real return reacts positively to shocks of the amount of government securities outstanding ITBS as has already been indicated in the first structural model above (see figure 6 and figure 7). Regarding the magnitude of this liquidity effect, a one percentage point shock in the bond supply leads to an immediate six basis point increase in the three-month real return and to a nine basis point increase after five periods. After two years the ex-post real return still stays eight basis points higher compared to its pre-shock level. These increases in the real return might be considered as being very small but certainly they are worthwhile to study. With government securities outstanding for amounts of between 300 billion euro in Belgium and 1500 billion euro in Italy, differences of only very few basis points become relevant for the costs of public debt financing.

The real return shows as well the expected negative reaction to M1. A one percentage point monetary shock lowers the real return by twelve basis points after six periods. Although the effects of M1 shocks on the fluctuations in the real short-term rate seem to be slightly bigger than the effects of shocks to government debt levels BS, the latter still put an upward pressure on real returns.

M1 Money initially shows a positive response to interest rate shocks but then declines after four periods. Two years after the shock money is still lower than prior to the shock.

Bond supply The bond supply reacts positively to the real interest rate and to the consumer price index but it reacts negatively to industrial production.

Industrial production Industrial production reacts slightly negative to interest rate shocks and slightly positive to monetary innovations.

Consumer prices Consumer prices show hardly a reaction to the interest rate but a very persistent and positive reaction to the bond supply. Higher prices probably are a reaction to higher expected interest rates in consequence to the bond supply shock.
Figure 8: BVAR Italy. Sample June 1985 - December 1998

Table 5: Structural Variance Decomposition of the Italian Real Return 1985-1998

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>ITRR</th>
<th>ITM1</th>
<th>ITBS</th>
<th>ITIP</th>
<th>ITP</th>
</tr>
</thead>
<tbody>
<tr>
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<td>79.6</td>
<td>0.0</td>
<td>0.1</td>
<td>1.0</td>
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<tr>
<td>8</td>
<td>0.0040</td>
<td>20.5</td>
<td>73.6</td>
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<td>0.3</td>
<td>2.8</td>
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<td>16</td>
<td>0.0042</td>
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<td>68.6</td>
<td>2.6</td>
<td>0.3</td>
<td>3.2</td>
</tr>
<tr>
<td>24</td>
<td>0.0043</td>
<td>26.9</td>
<td>66.8</td>
<td>2.6</td>
<td>0.3</td>
<td>3.3</td>
</tr>
</tbody>
</table>
Table 6: Structural Variance Decomposition of the Italian Real Return 1999-2009

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>ITRR</th>
<th>ITM1</th>
<th>ITBS</th>
<th>ITIP</th>
<th>ITP</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.0012</td>
<td>4.6</td>
<td>94.7</td>
<td>0.0</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>8</td>
<td>0.0027</td>
<td>7.9</td>
<td>84.3</td>
<td>0.5</td>
<td>1.5</td>
<td>5.8</td>
</tr>
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<td>16</td>
<td>0.0031</td>
<td>9.8</td>
<td>77.1</td>
<td>1.1</td>
<td>4.7</td>
<td>7.3</td>
</tr>
<tr>
<td>24</td>
<td>0.0033</td>
<td>11.7</td>
<td>71.5</td>
<td>1.6</td>
<td>7.0</td>
<td>8.2</td>
</tr>
</tbody>
</table>

According to the variance decomposition in table 5 the bond supply makes some contribution to the variance of the real return in Italy which increases with the forecast horizon while the immediate major contributions come from M1 and the real return itself.

**After the introduction of the euro** After the euro introduction the reaction of the ex-post real return of Italian three-month T-Bills to shocks in the amount of government paper outstanding is still present but the magnitude of the reaction is close to zero basis points (see 9). The evolution in the variance decomposition of the real return shows that after the introduction of the euro the shocks to the amount of government securities ITBS contribute as well less to the forecast error variance of the real return than before the introduction of the single currency (see 6 compared to 5).
Computation of Confidence Bands in the BVAR

Regarding the computation of the confidence bands for the BVAR, Sims and Zha [28] illustrate that the construction of classical confidence intervals for impulse responses in dynamic multivariate linear models is problematic because impulse responses are highly nonlinear functions of the underlying autoregressive reduced form parameters. Classical confidence bands restrict themselves to probability statements based on pre-observation probability distributions while the confidence bands for overidentified Bayesian VARs suggested by Sims and Zha [28] use probability statements about the parameters conditional on the observed data. Classical confidence regions mix information about parameter location with information about model fit and can be misleading. Error bands that illustrate the statistical reliability of estimated impulse responses should be based on the shape of the likelihood function. Therefore, we are using a RATS code from the Estima website which is based on Sims and Zha [28] in order to calculate the confidence intervals.

7.2.2 Germany

The structural model for Germany, France, Belgium and Spain is identical to the model (15) for Italy.

Real ex-post return of three-month treasury bills

In the run-up to the introduction of the euro (1980-1998): The German real return displays a very slight positive response to M1 shocks. This liquidity puzzle which is in contrast to the Italian evidence is, however, small with a response of the real return of only eight basis points to one percentage point shocks in M1. The second major contrast to the Italian data manifests itself in the negative reaction of the real return to bond supply shocks.

Furthermore, the real return shows positive reactions to industrial production and to consumer prices. The response of the short-term real rate to consumer price shocks is particularly strong, probably reflecting the prompt responses of the Bundesbank to inflationary pressures.

M1

Money responds negatively to interest rate shocks and to shocks in the CPI. M1 reacts positively to bond supply shocks and to industrial production. M1 reacts negatively to the interest rate after two periods and to consumer prices after six periods.

Bond supply

The bond supply reacts positively to the real return and to the consumer price index. It reacts negatively to M1. In all three cases the elasticities amount approximately to unity.

Industrial production

Industrial production hardly reacts to interest rate shocks and to some of the other shocks but shows a negative response to consumer prices.
**Figure 10: BVAR Germany. Sample July 1980 - December 1998.**

**BVAR Germany: Impulse responses to shocks of**

<table>
<thead>
<tr>
<th>DERR</th>
<th>DEM1</th>
<th>DEBS</th>
<th>DEIP</th>
<th>DEP</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Consumer prices** Consumer prices display the correct negative reaction to the interest rate and a strong positive reaction to M1. The impulse responses correspond to an elasticity of —0.30% with respect to the interest rate and 1.3% with respect to M1. The consumer prices show a positive and lagged reaction to industrial production.

Table 7 shows that for Germany the bond supply contributes between two and five percent to the forecast error variance of the real return between 1980 and 1998. The contribution of the bond supply and of M1 to the variance decomposition is much less pronounced than for the case of Italy.

**Table 7: Structural Variance Decomposition of the German Real Return 1980-1998**

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>DERR</th>
<th>DEM1</th>
<th>DEBS</th>
<th>DEIP</th>
<th>DEP</th>
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<tr>
<td>8</td>
<td>0.0006</td>
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<td>3.8</td>
<td>6.2</td>
<td>40.1</td>
</tr>
<tr>
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<td>0.0007</td>
<td>42.9</td>
<td>2.5</td>
<td>5.1</td>
<td>13.6</td>
<td>35.6</td>
</tr>
<tr>
<td>24</td>
<td>0.0007</td>
<td>40.2</td>
<td>4.3</td>
<td>5.4</td>
<td>15.7</td>
<td>34.4</td>
</tr>
</tbody>
</table>
In contrast to Italy, the real returns evolve much more exogenously in the case of Germany even though industrial production and the CPI make an important contribution to the forecast error variance. Striking is the high contribution of consumer prices at all horizons. This reflects probably the high commitment of the Bundesbank to anti-inflationary monetary policy.

**After the introduction of the euro** After the euro introduction the reaction of the real return of German three-month Schatz bills to shocks in the stock of government paper outstanding seems to have become slightly negative some months after the shock, however, even after six months, when the negative reaction reaches its maximum, the magnitude is equivalent to just less than a one basis point decline (see figure 11).

### Table 8: Structural Variance Decomposition of the German Real Return 1999-2009

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>DERR</th>
<th>DEM1</th>
<th>DEBS</th>
<th>DEIP</th>
<th>DEP</th>
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</thead>
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</tr>
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<td>0.0020</td>
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<td>13.3</td>
<td>27.3</td>
<td>6.9</td>
<td>31.6</td>
</tr>
</tbody>
</table>
Figure 12: BVAR France. Sample February 1980 - November 1998.

BVAR France: Impulse responses to shocks of

Real ex-post return of three-month treasury bills in the run-up to the introduction of the euro (1980-1998): The French data replicates the liquidity puzzle we found for Germany. A one percentage point shock to M1 raises the real return by roughly 25 basis points although this shock displays a very low persistence. In contrast to Italy, the real return reacts negatively to shocks in the bond supply. A one percentage point shock to the bond supply lowers the real return by roughly 25 basis points. The real return responds positively to consumer price shocks. Here the reaction of roughly 70 basis points is quite strong.

Table 9: Structural Variance Decomposition of the French Real Return 1980-1998

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>FRRR</th>
<th>FRM1</th>
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<th>FRIP</th>
<th>FRP</th>
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<td>0.1</td>
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<td>5</td>
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</tr>
<tr>
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<td>0.0013</td>
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<td>1.3</td>
<td>28.0</td>
</tr>
<tr>
<td>24</td>
<td>0.0013</td>
<td>39.2</td>
<td>8.3</td>
<td>23.5</td>
<td>1.6</td>
<td>27.3</td>
</tr>
</tbody>
</table>
M1 Money shows a slightly negative response to interest rate shocks with an elasticity of 0.15% and reacts positively to industrial production shocks. It reacts negatively to bond supply shocks and to CPI shocks.

Bond supply The bond supply reacts negatively to the real return and to M1. It reacts positively to industrial production.

Industrial production Industrial production displays a slightly negative reaction to interest rate shocks which manifests itself in an elasticity of —0.1% after five periods and a positive reaction to money with an elasticity of 0.3% after 14 periods. It reacts positively to the bond supply.

Consumer prices Consumer prices show the expected negative reaction to the interest rate and decline by 0.6% four periods after the shock and are down by 0.9% two years after a monetary shock. They show a clearly positive reaction to the bond supply with an elasticity of 0.6% two years after the shock.

In France the bond supply is a sizeable component of the forecast error variance of the real return. The variance decomposition in table 9 states that the bond supply contributes roughly between two and twenty-four percent to the variance of the real return at different horizons. In analogy to Germany and in contrast to Italy, the French bond supply and consumer prices are an important source of fluctuations in real short-term rates while M1 does not contribute much to the variance in real short-term rates.

After the introduction of the euro After the euro introduction the reaction of the real return of three-month T-bills to shocks in the stock of government paper outstanding seems to have become slightly positive but like for the example of Germany the magnitude of the reaction seems to be absolutely negligible (see figure 13).

Figure 13: BVAR France. Sample January 1999 - November 2009.
7.2.4 Belgium

Real ex-post return of three-month treasury bills In the run-up to the introduction of the euro (1980-1998). Like in the case of Italy, we find evidence for the liquidity effect in the bond market for Belgium in the period from 1980 to 1998 (see figure 14). The real ex-post return of Belgian three-month treasury bills increases slightly in reaction to shocks to the Belgian bond supply. Unitary shocks to the stock of government bonds outstanding push the real return immediately thirteen basis points higher. After two years the real return still stays three basis points higher compared to its pre-shock level. On the other hand, the monetary shock generates a liquidity puzzle because it sends the real return initially 86 basis points higher. After four periods this response becomes negative with minus eight basis points and after two years the real return is still down by two basis points. While the monetary shock initially creates the wrong reaction on the real return the bond supply shock creates the correct reaction and is slightly more persistent than the monetary shock. This suggests that bond supply shocks are at least as important as money supply shocks in order to explain fluctuations of real short-term interest rates in Belgium.

In addition, the Belgian real return hardly responds to industrial production shocks but immediately goes up 25 basis points to consumer price shocks.

**M1** Money immediately declines by about 0.8% due to interest rate shock. This response is very persistent so that money stays down 0.7% two years after the shock. M1 reacts positively to the industrial production shock but reacts negatively to consumer prices.

**Bond supply** The bond supply reacts slightly positively to the real return, to M1 and to the price level but negatively to industrial production.

**Industrial production** Industrial production reacts positively to the real interest rate and the bond supply but negatively to M1.
Consumer prices  Consumer prices show the correct negative reaction to the interest rate with an elasticity of $-0.6\%$ after three periods. After two years following an one percentage point real interest rate shock prices are even down by 1.5%. Consumer prices show strong negative responses to M1 and to the bond supply, too.

The results of the variance decomposition for Belgium are roughly comparable to the Italian results. The bond supply contributes between one and ten percent to the variance of the real return at different horizons. M1 and the real return are the other important variables and M1 makes the higher contribution of the two.

After the introduction of the euro  After the euro introduction the reaction of the real return of Belgian T-Bills to shocks in the government debt levels has become practically zero (see figure 15).

**Table 11: Structural Variance Decomposition of the Belgian Real Return 1980-98**

<table>
<thead>
<tr>
<th>Period</th>
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<th>BERR</th>
<th>BEM1</th>
<th>BEBS</th>
<th>BEIP</th>
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</table>
Figure 15: BVAR Belgium. Sample January 1999 - November 2009.

Table 12: Structural Variance Decomposition of the Belgian Real Return 1999-2009

<table>
<thead>
<tr>
<th>Period</th>
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<th>BEM1</th>
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<td>1.7</td>
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</table>
7.2.5 Spain

Real ex-post return of three-month treasury bills. In the run-up to the introduction of the euro (1988-1998): Like in the case of Italy and Belgium, we find evidence for the liquidity effect in the bond market for Spain. The real return increases initially by ten and after three periods by twenty basis points in reaction to shocks to the amount of Spanish bonds outstanding. However, the traditional liquidity effect is at work, too. The real return displays a negative response to M1 shocks, decreasing by 47 basis points in response to monetary shocks. The monetary shocks are, however, less persistent than bond supply shocks. Two years after a monetary shock the real return is even ten basis points higher than before the shock. Besides, the real return shows a strong negative reaction to consumer price shocks.

**M1** Money displays a wrong reaction to interest rate shocks. Money goes up 0.5% due to one percentage point interest rate shocks. It reacts positively to the bond supply and industrial production and negatively to consumer prices.

**Bond supply** The bond supply reacts slightly positively to the real return, to M1 and to industrial production. It reacts negatively to the price level.
Table 13: Structural Variance Decomposition of the Spanish Real Return 1988-1998

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
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<td>13.2</td>
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<td>35.3</td>
</tr>
</tbody>
</table>

Figure 17: BVAR Spain. Sample January 1999 - November 2009

**Industrial production** Industrial production reacts positively to the real return, M1 and the bond supply. It displays a negative response to price shocks.

**Consumer prices** Consumer prices show the wrong reaction to the interest rate. The price puzzle manifests itself in a 0.2% increase of the consumer price index following a 100 basis point shock to the real return. The price level displays a negative reaction to M1 and industrial production shocks.

In Spain the price level plays a very important role for the forecast error variance of the real return. The same can be said for the bond supply which at longer horizons makes the same contribution to the variance of the real return like M1.

**After the introduction of the euro** In Spain the reaction of three month ex post real returns to shocks in government debt levels increases even after the introduction of the euro.
Table 14: Structural Variance Decomposition of the Spanish Real Return 1999-2009

<table>
<thead>
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<th>Period</th>
<th>S.E.</th>
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<th>ESBS</th>
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<tr>
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<tr>
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<td>48.8</td>
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<td>20.9</td>
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</table>

The initial impact is a roughly 40bp rise in the real return but after three to four months the real return is actually 40bp down compared to the equilibrium level before the debt shock before levelling out over an horizon of roughly one year.
8. Conclusions

We study the effects of bond supply shocks on the real ex-post return of three-month treasury bills in a structural VAR and a Bayesian VAR framework for the five euro area economies with the biggest amount of government securities outstanding. Namely, these are Belgium, France, Germany, Italy and Spain. Besides variation in monetary aggregates, variations in the bond supply should help to explain movements in nominal and real short-term interest rates at high frequencies. This phenomenon is worthwhile to analyse as, historically, the empirical literature gives no unanimous verdict on the existence, the magnitude and the sign of the traditional liquidity effect of monetary innovations. This leaves a vacuum in the explanation of short-term interest rate movements which could be partly filled up by the implications of the bond supply risk. As indicated by Jovanovic and Rousseau [15], the interest rate being the rate of return on bonds rather than the return on money, one should look at the bond market rather than on monetary aggregates in order to find explanations for interest rate fluctuations.

In order to capture the dynamics between the real return on three-month treasury bills, the monetary aggregate M1 and shocks to total government debt we employ a semi-structural VAR. Imposing contemporaneous restrictions on the interaction of the variables, the VAR identifies the structural shocks of the bond supply, defined as the stock of government debt securities outstanding, of a monetary aggregate and of the real ex-post return on three-month treasury bills. On account of the well-known over-parametrisation problems of classical VARs we estimate the structural models for our five euro area economies in a Bayesian VAR framework.

Based on our Bayesian VARs, there seems to be a tendency that in countries in which treasury bills traditionally form a substantial part of the total amount of government securities outstanding bond supply shocks led to higher real returns between 1980 and 1998 as investors which were faced with increasing uncertainty in bond auctions tended to demand higher real yields. In Belgium, Italy and Spain treasury bills represent a relatively high share of total treasury securities outstanding4. The same is true for the US, where the government debt agency gives a great weight to treasury bills instead of long-term bonds in the maturity structure of government securities outstanding and where Jovanovic and Rousseau [15] find that bond supply shocks raise real ex-post three-month returns.

Our BVAR shows that, in the two decades before the introduction of the single European currency, in Italy a bond supply shock of one percentage point pushes up the three-month real return immediately by six basis points. In Belgium the real return increases by thirteen and in Spain by ten basis points in response to a bond supply shock. Two years after the bond supply shock real returns are still up by three basis points in Belgium, eight basis points in Italy and even ten basis points in Spain. In Belgium and in Spain the responses of the real returns to the bond supply shocks are more persistent
than the responses to the monetary shocks even if, at least at short horizons, the magnitude of the monetary shocks is higher. At long horizons, however, the magnitude of the bond supply shocks is higher which implies that a contraction in M1 has a stronger upward effect on the real return than an expansion in the bond supply of the same magnitude. In Belgium the monetary shock initially even has the wrong sign. Only in Italy the monetary shock is stronger than the bond supply shock at all horizons and the monetary shock displays a higher persistence as well. As reported by Jovanovic and Rousseau [15], this is in contrast to the US where in some sub-samples the bond supply has a stronger effect on interest rates than M1 has.

A notable exception might be France. In France treasury bills make up a high share of total government securities outstanding, too. However, we find no evidence that shocks to government debt levels push up the three-month ex-post real return in France. In France and in Germany bond supply shocks seem to lower real returns while, strangely enough, monetary shocks can not explain short-run interest rate fluctuations because the two countries experience the liquidity puzzle. Shocks in M1 lead to higher interest rates. Certainly the liquidity effect in the bond market, even with the wrong sign, has still important implications for these two countries because in both countries the liquidity puzzle is accompanied by bond supply shocks whose effects have a bigger magnitude on real returns than money supply shocks have.

Although we find that government bond supply shocks raise real returns in Belgium, Italy and Spain and that, at medium horizons of about two years, bond supply shocks have bigger effects on real short-term interest rates than money supply shocks in all of our countries with the exception of Italy, we can not yet make out a pattern to group countries according to the sign of the traditional liquidity effect, the sign of the liquidity effect in the government bond market or according to the relative magnitudes and the persistence of these two effects as this, if possible, would require a more detailed study of the debt structure of the countries involved.

These results have displayed the potential of the liquidity effect in the euro area government bond markets in explaining movements in ex-post three-month real returns in the five countries analysed. One possible drawback of our work might be that, due to the scarcity in the availability of data, we use the shocks to the total amount of government debt outstanding instead of the shocks to the net bond supply which would exclude the amounts of securities held by the respective central banks. To our understanding, excluding the amounts in the portfolios of the central banks and, thus, using only the amounts actually being available for trading to the public should, however, further strengthen the role played by the liquidity effect in the bond supply in explaining short-term interest rate movements.

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4 According to the ECB Securities Issues Statistics as of June 2003 the proportions of general government securities with maturities of up to one year on the total amount of general government securities were 13.4% for Belgium, 12.7% for France, 12.3% for Spain, 12.2% for Italy and 3.3% for Germany.
Therefore, in future studies it would be desirable to prove that using the net bond supply will strengthen the relationship between the liquidity effect in the euro area government bond market and euro short-term rate fluctuations.

Furthermore, it would be interesting to analyse whether and how the upward pressure, which shocks in the bond supply exert on real returns in some countries is related to the maturity structure of the government securities of these countries.

The introduction of the euro in 1999 has probably caused a statistical break in the intricate relationship between monetary aggregates, government debt levels and real returns of T-Bills. Apparently, in our BVARs for the 1999-2009 period we do not find much evidence for a positive relationship between shocks to the level of government debt securities outstanding and the real returns of short-term government paper.

One of the more obvious reasons for this disconnect might be the fact that a certain degree of macroeconomic and financial convergence in the run-up to EMU has contributed to a collapse in the country risk premia in the period between the two EMS crisis and the actual introduction of the euro in 1999. Subsequently, the collapse in the country risk premia and the foundation of the European Central Bank - together with initially sounder fiscal policies - have concurred to increase financial stability in the EMU periphery and probably have led as well to very strong correlations of the three-month treasury bill yields across eurozone and - in some cases - to a certain decoupling of treasury bill yields with macroeconomic fundamentals which only came to the forefront in the recent crisis.

The fact that the econometric relationship between shocks to government debt levels and real yields on treasury bills broke down for the period from 1999 to 2009, obviously does not imply that shocks to debt levels, shocks to amounts of public debt securities outstanding and shocks to auction schedules have no importance any more in the eurozone. Rather the breakdown of this relationship might be due to the fact that eurozone had been characterised by extraordinary levels of financial stability, unheard of in most periphery countries, and simply the number of monthly time series observations since the start CDS and bond spread widening in eurozone is just too short to measure the effects of the recent crisis.

The bottom line for public refinancing needs is that financial institutions working closely together with public debt management agencies need to do their utmost to help the sovereign agencies to auction and syndicate public debt in the most transparent fashion possible, so as to reduce public financing costs in times of financial stress and ratings pressure.
References


