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UNION DEBT MANAGEMENT

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1 Introduction

The role of debt management (DM) in macroeconomic models with distortionary taxation and the optimal maturity structure of debt has been studied extensively in the last years. Central to these studies is the role of the fiscal hedging channel of DM that leverages on the negative covariance between long bond prices and government deficits. Angeletos (2002) and Buera and Nicolini (2004) (hereafter ABN) reach the conclusion that governments should issue only long term debt. Buera and Nicolini (2004) and Faraglia et al (2010) find that the optimal portfolios emerge from these models feature large long bond positions financed through investments in short term assets. In Chari and Kehoe (1999) and Siu (2004) governments can smooth taxes, even when they borrow short, because debt is nominal and inflation is effective in absorbing fiscal shocks. On the other hand, Lustig et al (2008) show, also using a model with nominal assets, that financial market frictions coupled with sticky prices restore the optimality of long term debt.

All these papers consider DM in a closed economy setting. It is however not clear that their conclusions apply when we consider an open economy, and more so when we are concerned with the optimal structure of government debt in a currency union. There are two main issues to consider: firstly, the role of inflation in stabilizing macroeconomic variables, such as public debt, is limited in currency areas in the presence of idiosyncratic shocks and, secondly, bond prices and spending shocks may not sufficiently covary in equilibrium in a currency area when cross border arbitrage constrains the behavior of asset prices, especially under asymmetric shocks.

In this paper we study optimal DM in a currency union, both empirically and theoretically, focusing on whether debt portfolios can help governments hedge against fiscal shocks. In Section 2 we lay out our empirical analysis which tests formally for the presence of fiscal hedging in Euro Area government bond markets. We present a novel dataset, assembled for this paper, which contains information on bond prices and quantities of all types of debt in the portfolios of five Euro Area governments since 1998. We first look at the composition of the public debt in the Euro Area and find that governments have issued debt in a wide range of maturities including large amounts of long term bonds, and have mainly focused on issuing nominal debt.

We then estimate a series of panel VARs to identify the effects of fiscal shocks on the holding period returns of government portfolios. We propose a novel identification strategy to separate idiosyncratic and aggregate spending shocks and study their impact effects on the holding period returns. If the impacts are negative, then a rise in spending levels leads to a drop in government liabilities, which enables governments to partly transfer the burden to bond holders. This is the fiscal hedging channel of DM.

Our empirical findings suggest that bond returns responded strongly to spending shocks during 1999-2008, the period considered in our analysis. However and most importantly, this only holds for shocks which affect the average level of spending in the Euro Area, the aggregate shocks according to our identification scheme, whereas shocks which do not affect average spending and which we consider idiosyncratic, do not have any effect on bond returns. Hedging against the latter types of shocks through DM therefore seems to have been nearly impossible.

In Section 3 we turn to a formal model of optimal DM in a currency union to ask whether theory can shed light on our empirical findings, but also to investigate what types of debt instruments governments should use if they want to take full advantage of fiscal hedging. We setup a model in which two countries, members of a currency area, face fiscal shocks and finance them through distortionary taxes and through debt portfolios. Key features of our model are monopolistic competition and sticky prices (e.g. Siu (2004) and Lustig et al (2008)), private sector preferences which exhibit a *mild bias* towards home goods, but also that government consumption is allocated in home goods (e.g. Gali and Monacelli (2008)). Using this model we study the optimal policy assuming that a benevolent planner with full commitment sets taxes and the debt portfolio in both countries to maximise the joint welfare of their citizens. The assumption of a benevolent planner that maximises joint welfare is common in the international macro literature (e.g. Gali and Monacelli (2008) and Fahri and Werning (2017)) and extends the optimal DM literature to a currency area (ABN, Faraglia et al (2010), Siu (2004) and Lustig et al (2008)).

We first build our Ramsey program assuming that the planner can issue state contingent debt. Then, we attempt to decentralize the optimal complete market allocation using non-state contingent assets and in particular nominal bonds of different maturities, as seen in the data. Using the same definition of aggregate and idiosyncratic shocks as in the empirical model of Section 2, we show that a government that issues nominal debt can hedge against aggregate shocks, however in the presence of idiosyncratic shocks the complete market outcome cannot be attained.

To understand this prediction of our model notice that, in a currency union and under complete financial markets, the efficient allocation equates the ratio of marginal utilities across countries to the consumption based real exchange rate, in our case the ratio of consumer price indices. Under this condition the price of a nominal asset that promises to pay one unit of income in some future period cannot vary in equilibrium with idiosyncratic shocks. If it did, then bonds of equal maturity issued by different governments would need to carry different returns; however, consumers have essentially the same asset pricing kernel and thus would want to buy only one of these assets bringing the other asset's market in disequilibrium. In equilibrium, nominal assets have the same price and yield the same holding period returns; at the same time, however, idiosyncratic shocks to spending impact government deficits. Thus, the covariance between realized returns and deficits is zero.

Which kind of bonds can therefore help the government to implement the complete market allocation irrespective of the type of shocks? In Section 4 we show that this can be achieved through issuing inflation indexed debt, since the covariance between real bond prices and government deficits is negative in our model. Moreover, to fully exploit the negative covariance governments should issue long term bonds similar to Angeletos (2002), Buera and Nicolini (2004) and Faraglia et al (2010). We show that this result is robust across different parametrisations of the model. We, then, turn again our attention to our dataset to document the behavior of the shares of long term inflation indexed debt in the five Euro Area countries in our sample since the introduction of the common currency. We note that the shares, which were zero or close to zero in 1999, increased substantially over the period considered for many of the countries in our sample. This change in the structure of debt in the Euro Area brings actual DM policies closer to the optimum identified by our model.

This paper brings several new insights to the literature and relates to several strands. First, our empirical exercise in Section 2 is complementary to related empirical papers on fiscal hedging, for example Brendt et al (2012) and Faraglia et al (2008). Brendt et al (2012) use post World War II US data, identifying fiscal shocks as innovations to defense spending, and find a significant impact on holding period returns. Faraglia et al (2008) provide evidence of the presence of fiscal insurance in a panel of OECD countries studying the covariance between deficits and bond returns over the period 1970-2000. Our empirical analysis validates the fiscal hedging channel of debt management focusing on the Euro Area.

A recent stream of papers (see for example Fahri and Werning (2017), Dmitriev and Hoddenbagh (2015), Auclert and Ronglie (2014)) studies optimal fiscal transfers in models of currency unions (essentially fiscal unions). Transfers can improve risk sharing across countries and can stabilize government budgets. Debt management policies in our model play a similar role, they enable governments to share fiscal risks efficiently with other governments, i.e. across countries. If we allow for transfers in our model then the optimal portfolios are not defined and the fiscal burden can be distributed across countries (just like in our second best program, either through transfers or through debt management we achieve the same effect). This highlights an additional reason for which DM in currency areas is important, as one can think of various frictions in the presence of which fiscal transfers become difficult to implement. Admittedly, various financial market frictions, which our paper abstracts from, may limit the scope of DM. We thus view our approach as complementary to the recent literature on fiscal transfers. The interplay between transfers and DM is interesting and remains to be explored.

Finally, our findings are relevant for the literature on the so called 'equity home bias puzzle' in DSGE models[1], especially the recent strand in this literature which considers bonds and equities

[1] See for example Baxter and Jermann (1997), Coeurdacier et al (2010), Coeurdacier and Gourinchas (2017), Devereux and Sutherland (2007, 2008), Engel and Matsumoto (2009) and Coeurdacier and Rey (2013) amongst

together (see for example Coeurdacier and Gourinchas (2017) and Coeurdacier and Rey (2013) and references therein). In these models households choose portfolios to hedge consumption against real exchange rate and non tradable income risks. However, the hedging motives of governments have not been yet considered in this context. Since governments are an important supplier of debt, accounting for their behavior explicitly seems a meaningful next step in the agenda.

2 Fiscal Insurance in the Euro Area

In this section we provide a formal test for the presence fiscal insurance in the Euro Area. We employ panel SVARs estimating the responses of bond returns to government spending shocks. Our sample covers five Euro Area countries: Belgium, France, Germany, Italy and Spain which account for roughly 80 percent of aggregate output and spending in the Euro Area. In Section 2.1 we describe the new data set that we have gathered for this empirical analysis and the variables that enter in the SVARs. In section 2.2 we present the identification strategy that we employ to separately identify the effects of aggregate spending shocks and the effects of idiosyncratic shocks. Our empirical results are described in subsections 2.3 and 2.4. Our key finding is that aggregate shocks impinge large changes on bond returns, whereas we find little evidence of fiscal insurance against idiosyncratic shocks.

2.1 Data and Variables

2.1.1 Data

Bond Quantities and Prices. Our novel dataset contains information on every outstanding security issued by the central governments of the countries considered over the period 1998 to 2016. For each asset we can identify the type, nominal or real, the maturity, from 1 quarter to 30 years, as well as the principal and the coupon payments. These observations have been gathered separately for each country and for brevity we list our data sources in the online appendix. The uniqueness of this dataset lies on the fact that it determines the maturity structure of each country's government debt taking into account each bond issued and it does not rely on any of the aggregated official time series publicly available.

All countries issued bonds maturing in less than a year after issuance and which do not pay coupons. These are called Treasury Certificates or Bills in the case of Belgium, Bubills in Germany, Letras in Spain, BOTs in the case of Italy, or BTFs in France. In general, their share fluctuates around 10 percent of all outstanding debt for each country, except for Germany where Bubills always represent less than 5 percent of total sovereign debt.

The rest of debt is long and several types of assets have been used by different countries. There are medium-term bonds typically maturing 5 years after issuance and that pay coupons: Bobls in Germany, BTAN in France, Bonos in Spain, etc. There are also many types of long-term bonds: OLOs in Belgium, OATs in France, Bunds in Germany, etc. In general, these instruments pay fixed coupons but Italy, for instance, issue CTZs that do not pay coupons, and CCTs which are floating rate bonds. Moreover, some medium- and long-term bonds are indexed to inflation. The only country that does not use this instrument is Belgium where all debt is nominal (see the discussion in section 4 for further details).

If we take into account all payment obligations implied by these bonds (both principal repayment and coupons) and their remaining life (i.e. residual maturity instead of their maturity at issuance), we find that the share of outstanding debt due in less than a year fluctuates around 20 percent in each country. This measure of short-term debt is largest for Italy and peaks at around 30 percent. The country which records the lowest values is Germany. Overall, the shares of short (long) debt in government portfolios are positive for all countries and are stable over the time period considered. In general, the average remaining life of all payment obligations in each country ranges between 6

numerous others.

and 8 years, showing a stable and increasing trend until 2007, when they flatten or, in the case of Italy and Spain, drop slightly.

Finally, nominal bond prices (for zero coupon bonds) are obtained from the BIS database which publishes yield estimates. Because prices of real bonds are not provided and not all countries used this type of instrument, we restrict our empirical analysis to nominal assets.

GDP, Prices and Spending. Our SVARs will include government spending, output and price variables. We retrieve real GDP, price indices (GDP deflator) and government spending for all countries considered from the OECD database. Government spending corresponds to consumption of final goods and services by the central government and thus excludes transfers and public investment. Over the period considered mean spending levels range between 21 percent of GDP, in the case of France, to 17 percent, in the case of Spain. Spending varies considerably over time; for example, in Belgium expenditures account for 17 percent of the variability of GDP (i.e. in terms of the ratio of standard deviations), and in Germany for 10 percent.

Sample Selection. Our sample covers the period 1998 (Q2) to 2008 (Q2). We exclude the 'turbulent years' of the financial and sovereign debt crises since we wish to focus on years when the markets perceived government default as extremely unlikely for all countries in our sample as it is assumed in the DM literature. We thus truncate our sample in the second quarter of 2008 just before Lehman-Brothers filed for bankruptcy in September 2008. Moreover, we start the sample 2 quarters before January 1st 1999, the date of the official introduction of the Euro, as our VARs will have two lags.

2.1.2 Bond Return Variables

In our empirical analysis we run panel VARs to identify the effects of fiscal shocks on holding period returns. This section describes how we have constructed the holding period returns from our data.

First we convert all non-zero coupon bonds in our data set into zero-coupon bonds; this procedure gives us face values of debt of maturity $j = 1, 2, ..., 120$ where j denotes quarters. We price the zero coupon bond quantities with the zero-coupon yields from the BIS database, to obtain market values of debt. We finally use the market values along with the holding period returns on zero coupon bonds to create composite returns of portfolios of various maturities. The composite returns are the bond return variables that will enter in our VARs.

More specifically, let $q_t^{i,j}$ be the price of a zero coupon bond and P_t^i the GDP deflator in country i in period t. We define the holding period return for a security of maturity j as

$$R_{t-1,t}^{i,j} = \frac{q_t^{i,j-1}}{q_{t-1}^{i,j}} \frac{P_{t-1}^i}{P_t^i} - 1.$$

In words, $R_{t-1,t}^{i,j}$ is the payoff of buying a zero coupon bond of maturity j in $t-1$, at price $q_{t-1}^{i,j}$, then selling it back in t at price equal to $q_t^{i,j-1}$ (at which point obviously the maturity of the security has decreased by one quarter), adjusted for realized inflation between $t-1$ and t. With $R_{t-1,t}^{i,j}$ at hand we construct the following return variables:

$$\mathscr{R}_{t-1,t}^{i,\underline{j},\overline{j}} \equiv \frac{\sum_{j=\underline{j}}^{j=\overline{j}} R_{t-1,t}^{i,j} w_{t-1}^{i,j}}{\sum_{j=\underline{j}}^{j=\overline{j}} w_{t-1}^{i,j}}$$

where $w_{t-1}^{i,j}$ is the share of the market value of debt of maturity j over the total market value of debt issued by government i in $t-1$. $\underline{j}$ and $\overline{j}$ are the lowest and upper bounds of maturities included in the composite return $\mathscr{R}_{t-1,t}^{i,\underline{j},\overline{j}}$.

In our empirical analysis below we will run separate VARs assuming different values for $\underline{j}$ and $\overline{j}$. Our baseline model sets $\underline{j} = 1$ and $\overline{j} = 120$ and $\mathscr{R}_{t-1,t}^{i,1,120}$ denotes the return on the overall portfolio of government i. We also experiment with the following values for $\{\underline{j}, \bar{j}\}$: $\{1,4\}$, $\{5,16\}$, $\{17,28\}$, and $\{29,120\}$ corresponding to short, medium, long and very long maturities respectively. This enables us to identify the effects spending shocks on different maturity segments.

2.2 Identification of Aggregate and Idiosyncratic Spending Shocks

Our goal is to quantify the response of holding returns to government spending shocks and simultaneously to separately identify the impact of aggregate and idiosyncratic shocks. We thus make two identification assumptions. The first assumption serves to identify spending shocks in general and the second, to separate the effects of aggregate shocks from the effects of idiosyncratic shocks. To identify spending shocks, we follow Blanchard and Perotti (2002), Burriel et al (2010), Beetsma and Giuliodori (2011) among others) and assume that government consumption reacts with lags to innovations in output.[2] To separately estimate the impact of aggregate and idiosyncratic shocks, we assume that country specific spending does not impact instantaneously the average spending level of the five countries in our sample.

Formally, let $\mathscr{X}_t^i \equiv \left(\widetilde{g}_t^a, \widetilde{g}_t^i, \widetilde{Y}_t^i, \widetilde{P}_t^i, \mathscr{R}_{t-1,t}^{i,\underline{j},\bar{j}}\right)$ denote the vector of variables that enter in the VAR, where $\widetilde{g}_t^a$ denotes the log of the weighted average spending in t (with weights corresponding to relative GDPs), $\widetilde{g}_t^i$ is the log of real government consumption in i[3], $\widetilde{Y}_t^i$ the log of real GDP, $\widetilde{P}_t^i$ the log of the GDP deflator. We detrended each of these variables using a one-sided Hodrick-Prescott filter with a smoothing parameter of 8330, following Berndt et al. (2012).[4]

Our baseline specification is the following pooled panel VAR:

$$\mathscr{X}_t = \mathscr{B}(L)\mathscr{X}_{t-1} + \nu_t, \quad \nu_t = \mathscr{M}\epsilon_t \tag{1}$$

where $\mathscr{X}$ stacks the $\mathscr{X}^i$ matrices, ν_t represents the reduced form innovations, ϵ_t are the structural shocks which have diagonal variance-covariance matrix $\mathscr{D}$. $\mathscr{B}(L)$ is the lag polynomial in the reduced form VAR. Identification of the structural shocks is achieved through the choice of the square matrix $\mathscr{M}$ that maps the errors ϵ_t to the reduced form errors ν_t.

We use the Choleski decomposition and assume that $\mathscr{M} = \mathscr{L} \cdot \mathscr{D}^{1/2}$ where $\mathscr{L} \cdot \mathscr{D}^{1/2}$ is a lower diagonal matrix. Given the ordering of the variables in the VAR, our approach is therefore to identify the aggregate spending shock as the shock that impacts all variables instantaneously and the idiosyncratic spending shock as the shock that does not impact (within the period) average spending. Both spending shocks are identified as in Blanchard and Perotti (2002) assuming that spending responds with lags to innovations in prices and output.[5] The return series enters last in $\mathscr{X}$ since both output shocks and price shocks impact returns instantaneously.[6]

[2]Because our data is quarterly assuming more than one lag is sensible. This for example is argued in Ravn et al (2012). Born and Mueller (2011) show that Blanchard and Perotti's identification scheme also works with annual data.

[3]Note that as in Perotti (2004) and Burriel et al (2010) we adjusted spending by adding deviations of the deflator of spending from its trend and assuming an elasticity of 0.5. The trend is obtained through a standard HP filter. In this way we cleaned the government consumption series from cyclical variations in prices.

[4]Notice that the value 8330 is equivalent to removing frequencies of around 15 years. Given our short timespan, we use a pre-sample from 1981(Q1) to detrend the series. In the online appendix we show that our results are robust towards alternative values of the smoothing parameter.

[5]Our identification is similar to the one employed by Bernardini et al (2017) who estimate spending multipliers in US states. Their first variable in the VAR is aggregate spending and the second variable is a redistribution index which measures state specific shocks that leave total government spending unchanged. Identification of both aggregate and idiosyncratic shocks is made through the Blanchard and Perotti (2002) scheme.

[6]Our focus is on identifying the effects of spending on returns and therefore, the exact ordering of variables 3 to 5 should not matter significantly for our findings. Indeed we tested this and found that our results below do not change when, for instance, returns are the third variable in the VAR.

2.3 Baseline Estimates

2.3.1 Estimates from a SVAR: All Shocks Together

Before considering separately idiosyncratic and aggregate shocks, it is instructive to consider in a first stage the effects of total spending on holding period returns. For this exercise we run model (1) removing average spending from the state vector and letting $\mathscr{X}_t^i \equiv (\widetilde{g}_t^i, \widetilde{Y}_t^i, \widetilde{P}_t^i, \mathscr{R}_{t-1,t}^{i,\underline{j},\bar{j}})$.[7] Notice that in this way our estimates will pull together both the aggregate and idiosyncratic shock components, since each of the series $\widetilde{g}_t^i$ is influenced by both types of shocks. Given the ordering, we continue to identify the shocks to spending through the Blanchard and Perotti (2002) scheme.

Applying the usual information criteria, our reduced form estimates indicate that including two lags in the polynomial $\mathscr{B}(L)$ is appropriate. In Figure 1 we show the impulse responses of each of the variables to a one standard deviation shock in 'total' spending in a VAR with $\mathscr{R}_{t-1,t}^{i,1,120}$ as the last variable. The top left panel plots the response of spending, the top right output, the bottom left the price level and on the bottom right we plot the response of returns. The dashed lines in each plot indicate the one standard error confidence intervals (equivalent to the 16th and 84th percentiles as is typical in the literature).[8]

Following a shock to spending, prices increase and output increases albeit not substantially. Notice, however, that the estimated response of real output falls within the range of previous estimates in the literature, which typically give a multiplier close to one for the Euro Area.[9]

Figure 1 About Here

Focusing on the bottom right panel of Figure 1, we find that the return variable drops by roughly 34 basis points (bps) on impact, and this drop is statistically significant. This constitutes a large impact effect of spending on returns.[10] The effect can be interpreted as follows: when spending levels rise, the payout of government debt is lowered and governments enjoy capital gains (equivalently investors suffer capital losses). This provides *strong evidence of fiscal insurance* in the Euro Area.

Table 1 About Here

In rows 2 to 5 of Table 1 we investigate the effect of varying the maturity of debt on our estimates. The second row reports the magnitude of the response of returns of maturity less than or equal to one year. The remaining rows report the impact effects of the shock on maturities between 1 and 4 years, 4 and 7 and above 7 years respectively. All responses are large and statistically significant. Moreover, the impact effect is larger the longer the maturity of the bonds included in $\mathscr{R}$. This finding in line with the theoretical models of optimal DM.[11]

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[7] A similar exercise has been performed by Beetsma and Giuliodori (2011) with Euro Area data to identify the effects of spending on output. Their state vector includes spending, output, long term rates and real exchange rates. Their identification assumption is the same as the one employed here.

[8] See for example Blanchard and Perotti (2002) or Beetsma and Giuliodori (2011). The confidence intervals are computed assuming normality of errors and using Monte Carlo simulations (1000 replications). We apply this procedure to all estimates reported in this section.

[9] See for example Burriel et al (2010)). Since spending is about 20 percent of output in our sample, we have that a spending shock equivalent (in magnitude) to one percent of GDP increases output by close to one percentage point. We thus obtain a multiplier slightly smaller than one.

[10] Though $\mathscr{R}$ continues to respond to the shock even after the initial period, our focus here is on the initial impact. This is because of the way we have constructed the returns $\mathscr{R}$ using time varying portfolio weights. For the impact effect the weights are predetermined (see previous derivations) but for subsequent periods the weights may adjust to the shock. This could be for example because debt management offices adjust the maturity of new issuances in response to the slope of the yield curve, i.e. issue more of a cheaper security and so on.

Focusing on initial period responses we can avoid this problem.

[11] It is not surprising that even assets of maturity less than or equal to 1 year give a strong and statistically significant impact. Since our horizon is quarterly the prices of 6 monthly and yearly nominal debt respond to the shock. Changes in P also exert an influence since we adjusted returns by inflation.

2.3.2 Fiscal Hedging against Aggregate and Idiosyncratic Shocks

We now turn our attention to the main focus of our exercise: to identify separately the impacts of aggregate and idiosyncratic shocks on holding period returns. Table 1 summarises the results from the estimation of the VAR in (1) with $\mathscr{X}_t^i \equiv \left(\widetilde{g}_t^a, \widetilde{g}_t^i, \widetilde{Y}_t^i, \widetilde{P}_t^i, \mathscr{R}_{t-1,t}^{i,\underline{j},\overline{j}}\right)$, as defined in Section 2.2. The second column of the table measures the impact effect on the returns stemming from an aggregate spending shock, the third column shows the estimates for the idiosyncratic shock. The first row of the table shows the impact on the 'overall portfolio' that is assuming $\underline{j} = 1$ and $\overline{j} = 120$. The results are as follows: first, in response to an aggregate shock holding period returns drop significantly. The estimated impact is roughly equal to 81 bps, more than twice the impact estimated in the previous subsection. Second, the estimated impact in the case of idiosyncratic shocks is roughly 14 bps, however, it is not statistically significant. This suggests that fiscal hedging is powerful, but only in the case of aggregate shocks.

From rows 2-5 in Table 1 we see that the above findings hold also for each of the maturity segments considered. Across all segments aggregate spending shocks have strong negative effects on returns, and the effects are statistically significant. For idiosyncratic shocks, the impact effects are small and are significant only in the case of short and medium term bonds.

2.4 Robustness

The evidence presented so far has two important implications for debt management in the Euro Area. First, fiscal hedging exerts a powerful influence on the behavior of returns on government debt and second, this influence is mainly accounted for by shifts in aggregate spending. We now turn to alternative specifications of our empirical model to test the robustness of our findings. We consider here three different versions of the model: first, we replace the pooled VAR in (1) with separate VARs for each country employing the identification strategy of Section 2.2 but now averaging the estimates over the five countries in our sample. Second, we replace the average spending level (the first variable in the pooled VAR in (1)) with the first principal component of the spending series of the countries and run another pooled panel. Third, we run again model (1) replacing returns $\mathscr{R}$ with holding period returns not adjusted by inflation.

2.4.1 Evidence from Separate VARs

Since our sample contains 41 observations for each country, the advantage of a pooled VAR is that it limits the number of parameters that need to be estimated. On the other hand, a pooled VAR can be criticized for imposing too much structure and restrictions on the estimated coefficients. In this section we put aside the efficiency gains of the pooled panel and allow for heterogeneity in the estimated coefficients. We run the following model:

$$\mathscr{X}_t^i = \mathscr{B}^i(L)\mathscr{X}_{t-1}^i + \nu_t^i, \quad \nu_t^i = \mathscr{M}^i\epsilon_t^i \tag{2}$$

where superscript i denotes a country. The state vector $\mathscr{X}^i$ is as defined before. The lag polynomials $\mathscr{B}^i(L)$ are again of second order. After estimating model (2) we again apply the Cholesky decomposition to identify the structural innovations to spending. In Table 2 we report the results. The impact effects now correspond to the average responses from the five VARs.[12]

Table 2 About Here

In column 2 of the table we report the impacts of aggregate shocks.[13] Notice that aggregate shocks continue to yield considerable impacts on returns, the coefficients are in fact larger now than

[12] The averages are weighted by relative GDP. Recall that we had constructed $\widetilde{g}^a$ in this fashion.

[13] For completeness column 1 reports the estimated responses for total spending as in Section 2.3.1, now allowing for heterogeneous coefficients across countries.

those reported in Table 1. This confirms our previous findings that movements in aggregate spending in the Euro Area lead to debt devaluations.

Column 3 shows the analogous impacts of idiosyncratic shocks. Notice that now all coefficients are insignificant and moreover, they have the 'wrong sign', returns increase in response to spending shocks so that governments experience capital loses. This holds for the overall portfolio as well as for the different maturity segments considered in the second to fifth rows of the table.

Our previous findings are therefore confirmed when we allow for heterogeneity in the estimated parameters. Aggregate shocks are the key driving force behind fiscal hedging in the Euro Area.

2.4.2 Using First Principal Component for Aggregate Shocks

Our identification of aggregate and idiosyncratic shocks relied on the assumption that idiosyncratic disturbances do not influence the average spending series. In Section 3 we will use a theoretical model to show that shocks which do not influence average spending are not insurable when governments issue nominal bonds. The identifying assumption we employed will thus match the model's definition of aggregate and idiosyncratic shocks. Nevertheless, in an empirical section devoted to fiscal hedging, it is important to establish robustness towards using alternative series as first variables in the VAR. We experiment with using the first principal component ($\mathscr{P}$) of the spending series of the five countries in our sample. We run a panel VAR as in (1) with $\mathscr{X}_t^i \equiv \left(\mathscr{P}_t, \widetilde{g}_t^i, \widetilde{Y}_t^i, \widetilde{P}_t^i, \mathscr{R}_{t-1,t}^{i,\underline{j},\bar{j}}\right)$.

Table 3 About Here

The results are shown in the first two columns of Table 3. For brevity we only report here the impacts of aggregate and idiosyncratic shocks separately. As the table shows the estimated responses are similar to those reported in Table 2. This holds for both aggregate and idiosyncratic shocks. Therefore, using the first principal component, as opposed to the weighted average of spending as first variable in the VAR, makes very little difference for our findings.

For completeness, columns 3-4 of Table 3 estimate the model of subsection 2.3.1 which allows for heterogeneity in coefficients. The results are similar to the ones reported in Table 2. We continue to find very strong evidence of fiscal hedging against aggregate shocks and little evidence against country specific shocks.

2.4.3 Returns not Adjusted by Inflation

As explained in section 2.1.2 to construct $\mathscr{R}$ we divided the return from buying a nominal asset in $t-1$ and selling it in t by the rate of inflation. In order to isolate the impact of spending shocks on nominal bond prices we now run VAR (1) replacing $\mathscr{R}$ with holding period returns not adjusted by inflation. The results are shown in Table 4. Notice that now the estimated coefficients are smaller in absolute value, they remain strongly significant in the case of aggregate shocks and become insignificant in the case of idiosyncratic shocks (except for maturities shorter than one year).

Therefore, part of the response of bond returns $\mathscr{R}$ to spending shocks is accounted for by inflation but aggregate shocks have substantial impacts on nominal bond returns.

Table 4 About Here

The online appendix presents several robustness checks of the results reported in this section.

3 Model / Ramsey Policy

3.1 Model

The empirical findings of the previous section indicated that debt management in the Euro Area benefited from fiscal insurance against spending shocks. However, this only held for aggregate shocks. Governments could not insure against idiosyncratic shocks through nominal assets.

We now turn to the theory and use a theoretical model in the spirit of the DM literature to interpret our empirical results but also to investigate what types of debt are optimal in a currency union. Our baseline model is a Ramsey policy equilibrium in a currency area which consists of two countries, A and B. It can be seen as a variant of (adding another country to) the models of Angeletos (2002) and Buera and Nicolini (2004). We assume that a benevolent planner under full commitment sets taxes and issues debt to finance exogenous shocks to government spending. Markets are complete. In addition, the model features monopolistic competition and sticky prices as in Siu (2004) and Lustig et al (2008). In this section we first derive the equilibrium and setup the planning problem under the assumption governments can issue debt in state contingent securities. Then, we ask if the optimal allocation can be decentralized through DM.

3.1.1 Uncertainty

Uncertainty in our model derives from fluctuations in the spending levels of the two countries. Let G_t^i denote the level of exogenous government spending in country $i = A, B$. We assume that spending has two components: a common component denoted by g_t^c, which influences the spending levels of the two countries symmetrically, and a country specific component g_t^i, which is i.i.d across countries. We assume $G_t^i = g_t^c + g_t^i$.

G_t^i, g_t^c and g_t^i are first order Markov processes. Let N be the total number of possible realizations of the vector $G_t = [G_t^A, G_t^B]$ of joint spending. This joint process evolves according to the transition matrix $\overline{\mu}$. Finally, let $s_t \in \{s_1, ..., s_N\}$ denote the state in t and s^t represent the history of shocks from dates 0 to t.

The above parameterization of uncertainty is typical in multi-country business cycle models[14] and it is useful to make our theoretical analysis easily comparable to the empirical analysis of the previous section. The spending process assumed has both an idiosyncratic and an aggregate shock component; as in the data, we will identify idiosyncratic shocks taking deviations of G_t^i from the average spending level and aggregate shocks as shocks to average spending.

To clarify this, consider the following example. Suppose we have $N = 4$, g_t^c constant and $g_t^i \in \{\underline{g}, \overline{g}\}$. The vector of possible outcomes is:

$$\left(G_t^A - g^c, G_t^B - g^c\right) \in \left\{ \left(\underline{g}, \underline{g}\right), \left(\overline{g}, \underline{g}\right), \left(\underline{g}, \overline{g}\right), \left(\overline{g}, \overline{g}\right) \right\}$$

and average spending is

$$\frac{\sum_i G_t^i}{2} \in \left\{ g^c + \underline{g}, g^c + \frac{\overline{g} + \underline{g}}{2}, g^c + \frac{\overline{g} + \underline{g}}{2}, g^c + \overline{g} \right\}.$$

In this example, a shock which shifts G_t from state 1 to state 4 is an aggregate shock; the difference between the spending in country i and the average spending, $G_t^i - \frac{\sum_i G_t^i}{2}$, equals 0. A shock which shifts spending from state 2 to state 3 is an idiosyncratic shock, since there is no shift in the average.

3.1.2 Preferences, Aggregators and Price Vectors

Each country is populated by a representative household, and therefore countries are of equal size. Households have identical preferences and for $i = A, B$ the discounted utilities are:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^i, N_t^i), \tag{3}$$

[14]See for example, Krueger et al (2011) for an analogous parameterization of TFP shocks in a multicountry setup.

where C_t^i is consumption in period t in country i and N_t^i denotes aggregate hours. We define C_t^i as

$$C_t^i(s^t) = \left[(1-\alpha)^{\frac{1}{\eta}}\left(C_{i,t}^i(s^t)\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_{-i,t}^i(s^t)\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{4}$$

where $C_{i,t}^i$ is the consumption in country i of a composite bundle of goods produced in i and $C_{-i,t}^i$ is the composite good produced abroad and consumed in i. α governs the degree of home bias in preferences. If $\alpha < \frac{1}{2}$, country i's consumption is biased towards the domestic good. η determines the elasticity of substitution between home and foreign goods.

We assume that $C_{j,t}^i$, $i, j = A, B$, are aggregates over infinitely many varieties of differentiated products with the aggregates defined as:

$$C_{A,t}^i(s^t) = \left[\int_0^1 \left(C_{A,t}^i(s^t,a)\right)^{\frac{\epsilon-1}{\epsilon}} da\right]^{\frac{\epsilon}{\epsilon-1}} \quad \text{and} \quad C_{B,t}^i(s^t) = \left[\int_0^1 \left(C_{B,t}^i(s^t,b)\right)^{\frac{\epsilon-1}{\epsilon}} db\right]^{\frac{\epsilon}{\epsilon-1}},$$

where ϵ governs the elasticity of substitution across differentiated varieties.

Goods a and b have the same price in both countries and thus the law of one price holds. The price indices for the goods produced in countries A and B are:

$$P_t^A(s^t) = \left[\int_0^1 \left(P_t^A(s^t,a)\right)^{1-\epsilon} da\right]^{\frac{1}{1-\epsilon}} \quad \text{and} \quad P_t^B(s^t) = \left[\int_0^1 \left(P_t^B(s^t,b)\right)^{1-\epsilon} db\right]^{\frac{1}{1-\epsilon}}.$$

Standard results give us the following demand functions:

$$C_{A,t}^i(s^t,a) = \left(\frac{P_t^A(s^t,a)}{P_t^A(s^t)}\right)^{-\epsilon} C_{A,t}^i(s^t) \quad \text{and} \quad C_{B,t}^i(s^t,b) = \left(\frac{P_t^B(s^t,b)}{P_t^B(s^t)}\right)^{-\epsilon} C_{B,t}^i(s^t)$$

for generic products a (produced in A) and b (produced in B) consumed in i.

From (4) the optimal choices of the bundles $C_{j,t}^i$ are given by:

$$C_{i,t}^i(s^t) = (1-\alpha)\left(\frac{P_t^i(s^t)}{P_{C,t}^i(s^t)}\right)^{-\eta} C_t^i(s^t) \quad \text{and} \quad C_{-i,t}^i(s^t) = \alpha\left(\frac{P_t^{-i}(s^t)}{P_{C,t}^i(s^t)}\right)^{-\eta} C_t^i(s^t),$$

where $P_{C,t}^i(s^t) = \left[(1-\alpha)P_t^i(s^t)^{1-\eta} + \alpha P_t^{-i}(s^t)^{1-\eta}\right]^{\frac{1}{1-\eta}}$ is the consumer price index in country i.

3.1.3 Asset Markets

Our aim is to characterize policy in an equilibrium with complete markets. As discussed previously, we will first solve the households' and the governments' problems under the assumption that agents trade intertemporally with state contingent assets. Let $D_t(s^{t+1})$ denote a state contingent security bought in t, which pays one unit of income in $t+1$ if history s^{t+1} is realized. $Q_t(s^{t+1})$ is the price of this asset. Moreover, assume that $D_t^{i,G}(s^{t+1})$ denotes the quantity of this state contingent asset purchased by the government in i in period t. Analogously, $D_t^{i,H}(s^{t+1})$ is the quantity bought by the household in i.

We write the budget constraint of the government in country i as:

$$\sum_{s^{t+1}} D_t^{i,G}(s^{t+1})Q_t(s^{t+1}) = D_{t-1}^{i,G}(s^t) + P_t^i(s^t)G_t^i(s^t) - \tau_t^i(s^t)W_t^i(s^t)N_t^i(s^t), \tag{5}$$

where $\tau_t^i(s^t)$ denotes the tax rate levied on the labor income of country is household, $W_t^i(s^t)N_t^i(s^t)$. $P_t^i(s^t)G_t^i(s^t)$ is the nominal value of spending of the government.

The household's budget constraint can be written as

$$P_{C,t}^i(s^t)C_t^i(s^t) + \sum_{s^{t+1}} D_t^{i,H}(s^{t+1})Q_t(s^{t+1}) = D_{t-1}^{i,H}(s^t) + (1-\tau_t^i(s^t))W_t^i(s^t)N_t^i(s^t) + \Pi_t^i(s^t), \tag{6}$$

where $\Pi_t^i(s^t)$ denotes profits from monopolistically competitive firms in country i.[15]

3.1.4 Household Optimization: Choice of Hours and Assets

Households maximize (3) subject to the sequence of budget constraints (6). From the first order conditions of this program, which are standard and we omit for brevity, it is straightforward to show that

$$\frac{W_t^i(s^t)}{P_{C,t}^i(s^t)}(1-\tau_t^i(s^t)) = -\frac{U_{N,t}^i(s^t)}{U_{C,t}^i(s^t)} \tag{7}$$

characterizes the optimal choice of hours and moreover, state-contingent debt prices $Q_t(s^{t+1})$ satisfy

$$Q_t(s^{t+1}) = \beta\frac{P_{C,t}^i(s^t)}{P_{C,t+1}^i(s^{t+1})}\frac{U_{C,t+1}^i(s^{t+1})}{U_{C,t}^i(s^t)}\pi(s^{t+1}|s^t). \tag{8}$$

From (8) we can derive the following risk sharing condition which equates the ratio of marginal utilities to the consumption based real exchange rate under complete markets (see Backus and Smith (1993) and Kollmann (1995)): $\kappa\frac{U_{C,t}^B(s^t)}{U_{C,t}^A(s^t)} = \frac{P_{C,t}^B(s^t)}{P_{C,t}^A(s^t)}$. κ is a constant which reflects the relative wealth endowments of the private sectors in the two countries. For the rest of our analysis we will assume that the two countries have the same initial wealth as we want to focus on symmetric equilibria. We thus set $\kappa = 1$ and

$$\frac{U_{C,t}^B(s^t)}{U_{C,t}^A(s^t)} = \frac{P_{C,t}^B(s^t)}{P_{C,t}^A(s^t)}. \tag{9}$$

3.1.5 Firms: Flexible and Sticky Prices

Aggregate output is composed by a continuum of differentiated intermediate products. Each product is produced by a monopolistically competitive firm operating a linear technology and labor is the sole input in production. We assume that a fraction ν of the intermediate goods firms, in both countries, have to set their prices one period in advance. The remaining firms are flexible price firms and their optimal price is set within the period. To simplify, we denote sticky price firms using a superscript $\mathscr{s}$; $\mathscr{f}$ denotes flexible price firms.

The generic $\mathscr{f}$ type firm, $\imath$, in country i solves a static optimization program, maximizing profits subject to the demand curve given by $Y_{t,\imath}^{i,\mathscr{f}}(s^t) = \left(\frac{P_{t,\imath}^{i,\mathscr{f}}(s^t)}{P_t^i(s^t)}\right)^{-\epsilon} Y_t^i(s^t)$ where $Y_t^i(s^t)$ denotes aggregate output produced in i. The optimal price level is given by

$$P_{t,\imath}^{i,\mathscr{f}}(s^t) = \frac{\epsilon}{\epsilon-1}W_t^i(s^t). \tag{10}$$

$\mathscr{s}$ type firms set prices to maximize profits subject to demand, conditional on date $t-1$ information. For brevity we state this standard program in the appendix where we also show that the optimal price solves:

$$P_{t,\imath}^{i,\mathscr{s}}(s^{t-1}) = \frac{\epsilon}{\epsilon-1}\frac{E_{t-1}\left(\frac{U_{C,t}^i(s^t)}{P_{C,t}^i(s^t)}W_t^i(s^t)Y_t^i(s^t)P_t^i(s^t)^{\epsilon}\right)}{E_{t-1}\left(\frac{U_{C,t}^i(s^t)}{P_{C,t}^i(s^t)}Y_t^i(s^t)P_t^i(s^t)^{\epsilon}\right)}, \tag{11}$$

[15] Notice that we assume complete home bias in equities. This assumption is made for simplicity. It may seem strict for the Euro Area, however, with fiscal shocks being the only source of risk and under complete bond markets, the model does not give an incentive to households to hedge by buying foreign equity. Analogously, the complete market model will have little to say about whether government bonds should be held by domestic or foreign citizens.

where $U^i_{C,t}$ denotes the marginal utility of consumption used by the household to evaluate profits.

Finally, since all flexible (sticky) price firms in country i set the same price level, the price index of goods produced in i, P^i_t is written as:

$$P^i_t(s^t) = \left[\nu P^{i,s}_{t,\imath}(s^t)^{1-\epsilon} + (1-\nu) P^{i,f}_{t,\imath}(s^t)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}.$$

3.1.6 Resource constraints

Following Gali and Monacelli (2008) we assume that government spending is allocated exclusively to domestic goods. Aggregate output in country i is

$$Y^i_t(s^t) = G^i_t(s^t) + C^A_{i,t}(s^t) + C^B_{i,t}(s^t). \tag{12}$$

In equilibrium, output equals total hours. Letting $N^i_t = \left[\int_0^1 \left(N^i_{t,\imath}\right)^{\frac{\epsilon-1}{\epsilon}} d\imath\right]^{\frac{\epsilon}{\epsilon-1}}$ and using the expressions for consumption demands derived previously, we can express (12) as

$$N^i_t(s^t) = G^i_t(s^t) + (1-\alpha)\Phi^i_t(s^t)^\eta C^i_t(s^t) + \alpha\left(\frac{P^{-i}_{C,t}(s^t)}{P^i_{C,t}(s^t)}\right)^\eta \Phi^i_t(s^t)^\eta C^{-i}_t(s^t), \tag{13}$$

where $\Phi^i_t(s^t) \equiv \frac{P^i_{C,t}(s^t)}{P^i_t(s^t)}$.

3.2 Equilibria with Complete Markets/ Ramsey Policies

3.2.1 Implementability

A competitive equilibrium is a set of allocations, prices and tax policies such that households and firms optimize and markets clear. The Ramsey planner chooses from the set of competitive equilibria the one that maximizes welfare. As it is common in the literature (e.g. Lucas and Stockey (1983)), we adopt the primal approach and we simplify the planner's program by dispensing with some variables and constraints. For the sake of brevity, we relegate all derivations to the online appendix. We define here the set of sufficient implementability conditions for the Ramsey program.

Proposition 1: Implementability, Complete Markets
An allocation $\{C^i_t, C^i_{i,t}, C^i_{-i,t}\}$, $\{N^i_t, N^{i,s}_{t,\imath}, N^{i,f}_{t,\imath}\}$, $\{Y^i_t, Y^{i,s}_{t,\imath}, Y^{i,f}_{t,\imath}\}$ *with prices* $\{P^i_{C,t}, P^i_t, P^{i,s}_{t,\imath}, P^{i,f}_{t,\imath}, W^i_t\}$ *and policies* $\{\tau^i_t\}$ *is a competitive equilibrium if and only if the following equations hold:*

$$N^i_t = \begin{cases} G^i_t + (1-\alpha)(\Phi^i_t)^\eta C^i_t + \alpha\omega_t^{-\eta}(\Phi^i_t)^\eta C^{-i}_t & \text{if } i = A \\ G^i_t + (1-\alpha)(\Phi^i_t)^\eta C^i_t + \alpha\omega_t^{\eta}(\Phi^i_t)^\eta C^{-i}_t & \text{if } i = B \end{cases} \tag{14}$$

$$E_0 \sum_{t=0}^{\infty} \beta^t S^i_t = D^{i,G}_{-1} \frac{U^i_{C,0}}{P^i_{C,0}} \tag{15}$$

$$E_0 \sum_{t=0}^{\infty} \beta^t U^i_{C,t}\left(C^i_t + \frac{G^i_t}{\Phi^i_t} - \frac{N^i_t}{\Phi^i_t}\right) = (D^{i,H}_{-1} - D^{i,G}_{-1})\frac{U^i_{C,0}}{P^i_{C,0}} \tag{16}$$

$$E_{t-1}\left(U^i_{C,t} N^i_t \frac{\left(\frac{N^{i,s}_{t,\imath}}{N^i_t}\right)^{\frac{\epsilon-1}{\epsilon}}}{\Phi^i_t}\right) = E_{t-1}\left(U^i_{C,t} N^i_t \frac{\left(\frac{N^{i,f}_{t,\imath}}{N^i_t}\right)^{-\frac{1}{\epsilon}}}{\Phi^i_t} \frac{N^{i,s}_{t,\imath}}{N^i_t}\right) \tag{17}$$

$$\frac{\Phi_t^B(s^{t-1},s_k)}{\Phi_t^B(s^{t-1},s_1)}\left(\frac{N_{t,\not{\imath}}^{B,\jmath}(s^{t-1},s_1)N_t^B(s^{t-1},s_k)}{N_{t,\not{\imath}}^{B,\jmath}(s^{t-1},s_k)N_t^B(s^{t-1},s_1)}\right)^{-\frac{1}{\epsilon}}=\frac{\omega_t(s^{t-1},s_1)}{\omega_t(s^{t-1},s_k)}\frac{\Phi_t^A(s^{t-1},s_k)}{\Phi_t^A(s^{t-1},s_1)}\left(\frac{N_{t,\not{\imath}}^{A,\jmath}(s^{t-1},s_1)N_t^A(s^{t-1},s_k)}{N_{t,\not{\imath}}^{A,\jmath}(s^{t-1},s_k)N_t^A(s^{t-1},s_1)}\right)^{-\frac{1}{\epsilon}}, \tag{18}$$

$k=2,3,..N$ and where $\omega_t \equiv \frac{U_{C,t}^A}{U_{C,t}^B}$ and Φ_t^i in equilibrium is a function of ω_t, $\Phi_t^i=\Phi^i(\omega_t)$.

Proof: See Online Appendix

Let us briefly describe these objects. (14) is the resource constraint of the economy that we obtain from (13) after substituting out prices. (15) is the intertemporal budget constraint of the government, stating that at period 0 the outstanding value of government debt $D_{-1}^{i,G}$ in country i must be equal to the present discounted value of current and future government surpluses, where $S_t^i \equiv (\tau_t^i W_t^i N_t^i - P_t^i G_t^i)\frac{U_{C,t}^i}{P_{C,t}^i}$. Under complete markets (15) is sufficient for the equilibrium, and it is not necessary to keep track of the intertemporal budget constraints after period 0 (see e.g. Buera and Nicolini (2004)). (16) is the 'intertemporal current account constraint' of the household in i.

Finally, (17) is the first order condition of the sticky price firm and (18) is the so called 'sticky price constraint' (see e.g. Siu (2004)) which states that $P_{t,\not{\imath}}^{i,\jmath}(s^{t-1})$ is constant across all s^t given s^{t-1} or that the price of an $\jmath$ type firm set in $t-1$ is fixed and independent of the state s_t.

Since prices are sticky, we cannot dispense with these equations; (17) and (18) are necessary implementability conditions because this is an open economy model. In the closed economy setup these conditions can be satisfied as residuals.[16] However, in the open economy constraints (17) and (18) will not generally be 'slack' and therefore need to be accounted for in Ramsey policy. In the online appendix we demonstrate this property with an analytical example.

3.2.2 Ramsey Policies

The Ramsey planner seeks to maximize:

$$\max_{\left\{C_t^i, C_{i,t}^i, N_{t,\not{\imath}}^{i,\jmath}, N_{t,\not{\imath}}^{i,f}\right\}} \sum_{i=A,B}\sum_{t=0}^{\infty}\sum_{s^t}\mu(s^t)\beta^t\left\{U(C_t^i(s^t),N_t^i(s^t))\right\}$$

subject to the implementability conditions (14) to (18).

For brevity we leave to the appendix the derivation of the Lagrangean for the Ramsey program and the first order conditions, which together with constraints (14) to (18) give us the system of equations that we need to solve to characterize the Ramsey policy. We also discuss in detail the numerical algorithm we employ to approximate the solution to the Ramsey program. A noteworthy feature of the solution is that, since in (17) we have expectations of future variables, the optimal allocation is history dependent. As in Faraglia et al (2010) this makes ours a non-standard application of the complete market model since typically under complete markets allocations are only influenced by the current state s_t (e.g. ABN). In this set up the only case where allocations are history independent is when we assume $corr(G_t^A, G_t^B)=1$, i.e. when shocks are perfectly correlated across countries. Under this assumption our model essentially becomes a closed economy model and constraints (17) and (18) can be dropped.

3.3 Impossibility of Completing the Markets with Nominal Bonds

We now investigate whether the complete market allocation can be decentralized through nominal non-state contingent bonds. The arguments developed in this section follow closely ABN and Faraglia

[16] The reader can verify this by noting that $D_{t-1}^{i,G}(s^t)$ and $D_{t-1}^{i,H}(s^t)$, which satisfy the intertemporal constraints of governments and households, are not uniquely determined, however the ratios $\frac{D_{t-1}^{i,G}(s^t)}{P_{C,t}^i}$ and $\frac{D_{t-1}^{i,H}(s^t)}{P_{C,t}^i}$ are determined. Thus given a price sequence which satisfies (18) we can find values for $D_{t-1}^{i,G}(s^t)$ and $D_{t-1}^{i,H}(s^t)$ to satisfy intertemporal solvency.

et al (2010). We attempt to recover optimal government portfolios solving a linear system of equations which represents the government's intertemporal budget constraints for each possible state of the economy. If we can find a solution to this system in every period t then portfolios of nominal assets can replicate the payoffs of Arrow Debreu securities and markets can be completed. If not, then we cannot decentralize the complete market allocation with non-state contingent nominal debt and conclude that markets are effectively incomplete.

Assume that governments can issue debt in different maturities and that the private sector in each country can buy (or sell) any security. Let $\mathscr{J}$ denote the set of N maturities issued. The number of assets in the market is then equal to the number of the possible realizations of G_t and in theory enough to complete the markets. Let $\mathscr{J}_k$ denote the k-th element of $\mathscr{J}$.

All bonds are nominal. $q_{n,t}^{i,j}$ is the price of a nominal asset, n, which promises one unit of income in period $t+j$ and is issued by the government in country i.

A bond of maturity j issued by a government in country A is priced $q_{n,t}^{i,A} = \beta^j E_t\left(\frac{U_{C,t+j}^A}{U_{C,t}^A}\frac{P_{C,t}^A}{P_{C,t+j}^A}\right)$ by the home household according to his first order condition. The same asset is priced $q_{n,t}^{i,A} = \beta^j E_t\left(\frac{U_{C,t+j}^B}{U_{C,t}^B}\frac{P_{C,t}^B}{P_{C,t+j}^B}\right)$ by the household in country B. Then under no arbitrage this price needs to satisfy:

$$q_{n,t}^{A,j} = \beta^j E_t\left(\frac{U_{C,t+j}^A}{U_{C,t}^A}\frac{P_{C,t}^A}{P_{C,t+j}^A}\right) = \beta^j E_t\left(\frac{U_{C,t+j}^B}{U_{C,t}^B}\frac{P_{C,t}^B}{P_{C,t+j}^B}\right). \tag{19}$$

The same holds for a bond of the same maturity issued by the government in country B. Given that the payoff of the a bond of maturity j is the same, and equal to one, in both countries under no arbitrage the above conditions imply that the price of nominal debt of maturity j issued by each country is equal and $q_{n,t}^{j} = q_{n,t}^{A,j} = q_{n,t}^{B,j}$.

Denote by $B_{n,t}^{i,j}$ the face value of nominal debt, n, of maturity j issued by the government in i in period t. Following ABN, Faraglia et al (2010) and Lustig et al (2008) we assume that all debt is bought back one period after issuance. The period budget constraint of the government in country i is given by:

$$\sum_{j\in\mathscr{J}} q_{n,t}^{j-1} B_{n,t-1}^{i,j} = \sum_{j\in\mathscr{J}} q_{n,t}^{j} B_{n,t}^{i,j} + P_{C,t}^i \frac{S_t^i}{U_{C,t}^i}. \tag{20}$$

According to (20) the government finances its fiscal deficit, $-P_{C,t}^i\frac{S_t^i}{U_{C,t}^i}$, and the outstanding debt level, $\sum_{j\in\mathscr{J}} q_{n,t}^{j-1} B_{n,t-1}^{i,j}$, with a portfolio of newly issued bonds. Iterating forward we can retrieve the intertemporal budget constraint of the government:

$$\sum_{j\in\mathscr{J}} \frac{q_{n,t}^{j-1}}{(1+\pi_t^i)} \frac{B_{n,t-1}^{i,j}}{P_{C,t-1}^i} = E_t \sum_{k=0}^{\infty} \beta^k \frac{S_{t+k}^i}{U_{C,t}^i} \equiv \Upsilon_t^i. \tag{21}$$

Note that this constraint needs to be satisfied for every history s^t. As ABN, Faraglia et al (2010) we use (21) to characterise the optimal government portfolios. The bond quantities need to solve the following systems of equations:

$$\underbrace{\begin{bmatrix} \frac{q_{n,t}^{\mathscr{J}_1-1}(s^{t-1},s_1)}{1+\pi_t^i(s^{t-1},s_1)} & \frac{q_{n,t}^{\mathscr{J}_2-1}(s^{t-1},s_1)}{1+\pi_t^i(s^{t-1},s_1)} & \cdots & \frac{q_{n,t}^{\mathscr{J}_N-1}(s^{t-1},s_1)}{1+\pi_t^i(s^{t-1},s_1)} \\ \vdots & \cdots & & \\ \frac{q_{n,t}^{\mathscr{J}_1-1}(s^{t-1},s_N)}{1+\pi_t^i(s^{t-1},s_N)} & \frac{q_{n,t}^{\mathscr{J}_2-1}(s^{t-1},s_N)}{1+\pi_t^i(s^{t-1},s_N)} & \cdots & \frac{q_{n,t}^{\mathscr{J}_N-1}(s^{t-1},s_N)}{1+\pi_t^i(s^{t-1},s_N)} \end{bmatrix}}_{\mathscr{Q}_{n,t}} \cdot \underbrace{\begin{bmatrix} \frac{B_{n,t-1}^{i,\mathscr{J}_1}(s^{t-1})}{P_{C,t-1}^i(s^{t-1})} \\ \vdots \\ \frac{B_{n,t-1}^{i,\mathscr{J}_N}(s^{t-1})}{P_{C,t-1}^i(s^{t-1})} \end{bmatrix}}_{\mathscr{B}_{n,t}} = \underbrace{\begin{bmatrix} \Upsilon_t^i(s^{t-1},s_1) \\ \vdots \\ \Upsilon_t^i(s^{t-1},s_N) \end{bmatrix}}_{\Upsilon_t}$$

(see ABN and Faraglia et al (2010)). The above system gives a unique solution $\mathscr{B}_{n,t} = (\mathscr{Q}_{n,t})^{-1}\Upsilon_t$ for optimal debt maturities if $\mathscr{Q}_{n,t}$ is invertible. If the solution exists then governments can generate the required state contingent payoffs in t through issuing bonds quantities in $t-1$ and exploiting ex post variation in bond returns in t to complete the markets. We next show that this is not always the case when governments issue nominal bonds.

Proposition 2. *Consider a stochastic process of spending shocks G_t like the one described in Section 3.1, with a common and an idiosyncratic shock component. Then the optimal complete market allocation cannot be decentralized through nominal debt since $\mathscr{Q}_{n,t}$ is not of full rank.*

Proof. The proof requires a straightforward application of (9). Without loss of generality consider the case where $N = 4$ assuming also that spending has only one i.i.d. component across countries.

$$(G_t^A, G_t^B) \in \Big\{ (\underline{g}, \underline{g}), (\overline{g}, \underline{g}), (\underline{g}, \overline{g}), (\overline{g}, \overline{g}) \Big\}. \tag{22}$$

In this case the governments need four assets to complete the markets regardless the maturity. Assume that the maturity structure is $\mathscr{J} = \{\mathscr{J}_1, \mathscr{J}_2, \mathscr{J}_3, \mathscr{J}_4\}$. Then the bond prices matrix $\mathscr{Q}_{n,t}$ of the outstanding debt is:

$$\mathscr{Q}_{n,t} = \begin{bmatrix} \frac{q_{n,t}^{\mathscr{J}_1-1}(s^{t-1},s_1)}{1+\pi_t^i(s^{t-1},s_1)} & \frac{q_{n,t}^{\mathscr{J}_2-1}(s^{t-1},s_1)}{1+\pi_t^i(s^{t-1},s_1)} & \frac{q_{n,t}^{\mathscr{J}_3-1}(s^{t-1},s_1)}{1+\pi_t^i(s^{t-1},s_1)} & \frac{q_{n,t}^{\mathscr{J}_4-1}(s^{t-1},s_1)}{1+\pi_t^i(s^{t-1},s_1)} \\ \frac{q_{n,t}^{\mathscr{J}_1-1}(s^{t-1},s_2)}{1+\pi_t^i(s^{t-1},s_2)} & \frac{q_{n,t}^{\mathscr{J}_2-1}(s^{t-1},s_2)}{1+\pi_t^i(s^{t-1},s_2)} & \frac{q_{n,t}^{\mathscr{J}_3-1}(s^{t-1},s_2)}{1+\pi_t^i(s^{t-1},s_2)} & \frac{q_{n,t}^{\mathscr{J}_4-1}(s^{t-1},s_2)}{1+\pi_t^i(s^{t-1},s_2)} \\ \frac{q_{n,t}^{\mathscr{J}_1-1}(s^{t-1},s_3)}{1+\pi_t^i(s^{t-1},s_3)} & \frac{q_{n,t}^{\mathscr{J}_2-1}(s^{t-1},s_3)}{1+\pi_t^i(s^{t-1},s_3)} & \frac{q_{n,t}^{\mathscr{J}_3-1}(s^{t-1},s_3)}{1+\pi_t^i(s^{t-1},s_3)} & \frac{q_{n,t}^{\mathscr{J}_4-1}(s^{t-1},s_3)}{1+\pi_t^i(s^{t-1},s_3)} \\ \frac{q_{n,t}^{\mathscr{J}_1-1}(s^{t-1},s_4)}{1+\pi_t^i(s^{t-1},s_4)} & \frac{q_{n,t}^{\mathscr{J}_2-1}(s^{t-1},s_4)}{1+\pi_t^i(s^{t-1},s_4)} & \frac{q_{n,t}^{\mathscr{J}_3-1}(s^{t-1},s_4)}{1+\pi_t^i(s^{t-1},s_4)} & \frac{q_{n,t}^{\mathscr{J}_4-1}(s^{t-1},s_4)}{1+\pi_t^i(s^{t-1},s_4)} \end{bmatrix}.$$

As explained in section (3.1.1), idiosyncratic shocks occur in states s_2 and s_3. From (9) $\frac{U_{C,t}^i(s^t)}{P_{C,t}^i(s^t)}$ does not vary across s_2 and s_3 and also the expectations $E_t\left(\frac{U_{C,t+j}^i}{P_{C,t+j}^i}\right)$ for $j = 1, 2, ...$ do not vary across these states. Therefore, nominal bond prices satisfy $q_{n,t}^j(s^{t-1}, s_2) = q_{n,t}^j(s^{t-1}, s_3)$ for all $j \in \mathscr{J}$. Moreover, given the inflation rates, we can write row 3 of $\mathscr{Q}_{n,t}$ as $\frac{1+\pi_t^i(s^{t-1},s_2)}{1+\pi_t^i(s^{t-1},s_3)}$ times row 2. Matrix $\mathscr{Q}_{n,t}$ has two linearly dependent rows and is therefore not invertible. The bond prices cannot exhibit enough variability to achieve the complete market outcome.

The above is easy to generalize to cases where $N > 4$. Proposition 2 sheds light on our empirical findings in Section 2 where we have established that the countries in our sample can hedge only against aggregate shocks and not idiosyncratic shocks since joining the Euro. Note that even though $\mathscr{Q}_{n,t}$ is non-invertible due to the presence of states 2 and 3, the shocks in states 1 and 4 can, in principle, be hedged through issuing nominal debt. The reason is that across these states aggregate (average) spending will vary and so bond prices will also vary.[17] The governments should therefore be able to hedge against these shocks through nominal debt issuances, a pattern which matches our empirical findings in section 2.

Further notice that since the return variables defined in $\mathscr{Q}_{n,t}$ are adjusted by inflation, the impact of idiosyncratic shocks on holding period returns generally may be not zero, since π_t^i may respond

[17] We do not have an analytical proof of this property. However, note that in the case where $N = 2$ and all shocks are aggregate our model will replicate the properties of the ABN model. Under standard preferences long bond prices will comove negatively with aggregate spending.

Increasing the number of states N and introducing idiosyncratic shocks to the model should not impact the properties of asset prices in aggregate shock states.

to the spending shocks. This property is also in line with our data findings in Section 2, where we showed that because inflation responds to idiosyncratic shocks in the Euro Area the real holding period returns respond to these shocks. Nevertheless, as Proposition 2 states, the ex post variability of the returns is not sufficient to complete the markets and governments cannot fully hedge against idiosyncratic shocks.

Finally, Proposition 2 can be generalized to models with more than two countries. Generally, if we increase the number of countries we will expand the number of states which are uninsurable through nominal debt issuances.[18] Our purpose in considering a two country model is precisely to highlight that only part of a shock which is independently distributed across countries can be considered idiosyncratic. Just as in our empirical model in Section 2 also here the idiosyncratic shock is identified as a deviation from the average spending level.

4 Optimal Debt Management with Inflation Indexed Debt

The previous sections demonstrated empirically and theoretically that governments issuing only nominal debt in a currency area cannot fully benefit from fiscal hedging. In this section we use the same model to investigate the properties of optimal DM when the government can now issue inflation indexed (real) debt. Using numerical examples we show that in this case governments can complete the markets, as real bonds can replicate the payoffs of Arrow-Debreu securities. Moreover, we study the maturity structure of government debt and the sensitivity of the optimal portfolio to different parameters of the model. We find that the complete market approach to DM implies that governments should focus on issuing long term inflation indexed bonds in order to take full advantage of fiscal insurance. Finally, we turn again to the empirical evidence and document the use of inflation indexed long debt for the five countries in our sample. We show that, since the introduction of the Euro, almost all the countries have introduced long term inflation indexed bonds. Our model explains this as an optimal response of governments to the introduction of the common currency.

4.1 Introducing Inflation Indexed Debt

A real bond, r, of residual maturity j, issued by country A in period t, is a bond that pays out $(1+\pi^A_{t+1})(1+\pi^A_{t+2})...(1+\pi^A_{t+j})$ at $t+j$, where π^A denotes CPI inflation in country A. From the household's optimization we can show that the price of this bond is $q^{A,j}_{r,t} = \beta^j E_t\left(\frac{U^A_{C,t+j}}{U^A_{C,t}}\right)$ when priced by the household in A. The same bond can be priced also by the household in B and the household in B sets $q^{A,j}_{r,t} = \beta^j E_t\left(\frac{U^B_{C,t+j}}{U^B_{C,t}}\frac{P^B_{C,t}}{P^B_{C,t+j}}\frac{P^A_{C,t+j}}{P^A_{C,t}}\right)$. No arbitrage imposes that prices of the same asset need to be equalised, therefore we have

$$q^{A,j}_{r,t} = \beta^j E_t\left(\frac{U^A_{C,t+j}}{U^A_{C,t}}\right) = \beta^j E_t\left(\frac{U^B_{C,t+j}}{U^B_{C,t}}\frac{P^B_{C,t}}{P^B_{C,t+j}}\frac{P^A_{C,t+j}}{P^A_{C,t}}\right) \qquad q^{B,j}_{r,t} = \beta^j E_t\left(\frac{U^B_{C,t+j}}{U^B_{C,t}}\right) = \beta^j E_t\left(\frac{U^A_{C,t+j}}{U^A_{C,t}}\frac{P^A_{C,t}}{P^A_{C,t+j}}\frac{P^B_{C,t+j}}{P^B_{C,t}}\right) \tag{23}$$

for $j \in \mathcal{J}$. It is easy to show that the risk sharing condition (9) is sufficient to satisfy all the above conditions. In the case of inflation indexed bonds the government's intertemporal constraint becomes

$$\sum_{j\in\mathcal{J}} q^{i,j-1}_{r,t} \frac{B^{i,j}_{r,t-1}}{P^i_{C,t-1}} = E_t \sum_{k=0}^{\infty} \beta^k \frac{S^i_{t+k}}{U^i_{C,t}}, \tag{24}$$

where $B^{i,j}_{r,t-1}$ is the quantity of real bonds, r, of maturity j issued by the government in country i in $t-1$. As in the case of nominal bonds we follow the complete market approach to DM and try to

[18] In the limit, with an infinite number of countries, shocks which are i.i.d are fully idiosyncratic.

find the portfolio that can solve the following system of equations:

$$\underbrace{\begin{bmatrix} q_{r,t}^{i,\mathscr{J}_1-1}(s^{t-1},s_1) & q_{r,t}^{i,\mathscr{J}_2-1}(s^{t-1},s_2) & \dots & q_{r,t}^{i,\mathscr{J}_N-1}(s^{t-1},s_1) \\ \vdots & \dots & & \\ & & & \\ q_{r,t}^{i,\mathscr{J}_1-1}(s^{t-1},s_N) & q_{r,t}^{i,\mathscr{J}_2-1}(s^{t-1},s_N) & \dots & q_{r,t}^{i,\mathscr{J}_N-1}(s^{t-1},s_N) \end{bmatrix}}_{\mathscr{Q}_{r,t}} \cdot \underbrace{\begin{bmatrix} \frac{B_{r,t-1}^{i,\mathscr{J}_1}(s^{t-1})}{P_{C,t-1}^{i}(s^{t-1})} \\ \vdots \\ \frac{B_{r,t-1}^{i,\mathscr{J}_N}(s^{t-1})}{P_{C,t-1}^{i}(s^{t-1})} \end{bmatrix}}_{\mathscr{B}_{r,t}} = \begin{bmatrix} \Upsilon_t^i(s^{t-1},s_1) \\ \vdots \\ \Upsilon_t^i(s^{t-1},s_N) \end{bmatrix}. \tag{25}$$

To gain intuition on why issuing inflation indexed debt may help governments complete the market recall that according to (9), the ratios $\frac{U_{C,t}^i(s^t)}{P_{C,t}^i(s^t)}$ and $E_t\left(\frac{U_{C,t+j}^i}{P_{C,t+j}^i}\right)$ do not vary across idiosyncratic shock states; however, the quantities $U_{C,t}^i(s^t)$ and $E_t(U_{C,t+j}^i)$ may vary across idiosyncratic states and so the expected growth of marginal utility may also vary across these states. Therefore $\mathscr{Q}_{r,t}$ could be inverted and a portfolio could be determined. In the remainder of the section we use numerical methods to solve the model and show that indeed $\mathscr{Q}_{r,t}$ is invertible and optimal portfolios can be determined.

4.2 Calibration

We follow the related DM literature to calibrate the model's parameters (e.g. Buera and Nicolini (2004), Faraglia et al (2010), Siu (2004) and Lustig et al (2008)). To calibrate the open economy dimension of our model we borrow values from Faia and Monacelli (2004). Table 5 summarizes our choices.

[Table 5 About Here]

Each model period corresponds to one quarter. We set the discount rate $\beta = 0.98$ and we assume that household preferences are of the form:

$$\log(C_t^i) - \chi \frac{N_t^{i\,1+\gamma}}{1+\gamma}$$

and choose a value $\gamma = 2$ which gives a Frisch elasticity of 0.5.

We normalize hours to 1/3 of the unitary time endowment in the deterministic steady state. Moreover, we assume that the level of spending equals 20 percent of GDP in steady state. χ is calibrated so that tax revenues balance the governments' budgets in steady state.

We set the home bias parameter $\alpha = 0.4$, the demand elasticity parameter $\eta = 2$ and the elasticity of substitution across varieties parameter $\epsilon = 6$. These values are taken from Faia and Monacelli (2004) and we treat them as our benchmark.

Lustig et al (2008) and Siu (2004) assume fractions of sticky prices ν in their models equal to 0.05 and 0.08 respectively. These values are somewhat low, since the aim of these papers is to show that assuming even mild degrees of price stickiness can have dramatic effects on optimal policy. We consider a wider range of values for parameter ν letting $\nu = 0.05$ be the lowest value in the range considered. This enables us to illustrate the impact of varying the degree of price stickiness on optimal portfolios.

In order characterize the properties of optimal debt management transparently, we consider two cases: the case where governments can issue only two maturities, as in the benchmark of ABN, and the case where they can issue four maturities (as in Buera and Nicolini (2004), Faraglia et al (2010)). In the first case we choose a maturity structure $\mathscr{J} = \{1, 40\}$, with a short bond of one quarter and a long bond of forty quarters. In the second case we choose $\mathscr{J} = \{1, 8, 20, 40\}$.[19]

[19]The results we report below are robust towards assuming other maturity structures.

The government can complete the markets with non state contingent assets only if the number of shock realizations is equal to the number of assets issued. If we use only two maturities then we must set $N = 2$ and we obviously have to consider separately the case where shocks are idiosyncratic and the case where they are aggregate. If shocks are idiosyncratic then the vector of possible outcomes is assumed to be:

$$(G_t^A, G_t^B) \in \Big\{ (\overline{g}, \underline{g}), (\underline{g}, \overline{g}) \Big\}$$

and if shocks are aggregate:

$$(G_t^A, G_t^B) \in \Big\{ (\underline{g}, \underline{g}), (\overline{g}, \overline{g}) \Big\}.$$

When we use four maturities then we set $N = 4$ and the vector of joint spending levels is

$$(G_t^A, G_t^B) \in \Big\{ (\underline{g}, \underline{g}), (\overline{g}, \underline{g}), (\underline{g}, \overline{g}), (\overline{g}, \overline{g}) \Big\}$$

as in (22), that is assuming an i.i.d. spending process for each country.[20] Finally, the Markov transition matrices across (joint) spending states are given by:

$$\Pi_\rho = \begin{bmatrix} \rho & 1-\rho \\ 1-\rho & \rho \end{bmatrix}$$

for the case where $N = 2$. For the case $N = 4$ we create the joint transition matrix $\Pi_\rho \otimes \Pi_\rho$. We set $\rho = 0.95$ as Faraglia et al (2010).

4.3 Results and Extensions

Benchmark Results. We first consider our benchmark case, $N = 2$. The top panel of Table 6 reports the optimal portfolios of country A when shocks are assumed idiosyncratic. The bottom panel reports the portfolios when shocks are aggregate. The portfolios for country B are symmetric and we omit them. The numbers reported are averages of face values over simulations.[21] The columns report the optimal portfolios when we increase the degree of price stickiness.

[Table 6 About Here]

Notice first that regardless the degree of price stickiness or the type of shock the optimal DM strategy features large issuances of long term debt financed through savings in the short term asset. Our model's predictions are therefore similar to those of Angeletos (2002); since bond prices covary negatively with spending in our model, the government finds optimal to issue long term debt to take advantage of fiscal insurance. Moreover, as in Buera and Nicolini and Faraglia et al (2010), the bond positions are several times larger than GDP, which is on average equal to a third in the model.

When shocks are idiosyncratic assuming a higher fraction of sticky prices leads to a fanning out of the positions. In the case where ν equals 5 percent, the government issues roughly 253 times GDP in the long term bond, however, when $\nu = 75\%$ we obtain long bond issuances equal to 421 times GDP. This is due to the fact that a higher degree of price stickiness leads to a smaller impact of spending shocks on consumption (this property follows clearly from (9)). Since after 39 quarters consumption reverts back to its mean value in expectation, most of the variability of real long bond

[20] We assume an i.i.d. process since if we included g^c we would need at least $N = 8$. This would complicate unnecessarily the analysis.

[21] ABN obtain constant portfolios under complete markets. Our portfolios are time varying due to constraint (17). For this reason we summarize the results using simulation averages in the paper. As we show in the online appendix, however, portfolios only change slightly through time, the qualitative features we report here do not change over the cycle.

prices is explained by current consumption. This makes the price of long term inflation indexed debt less responsive to spending shocks, when the degree of price stickiness increases. A government which seeks to take full advantage of fiscal hedging must fan out its position.

When shocks are aggregate portfolios are less extreme as reported in the bottom panel of Table 6. As discussed previously, when shocks are perfectly correlated the model becomes isomorphic to a closed economy model, and therefore it is not surprising that the results of Angeletos, Buera and Nicolini apply. Price stickiness does not exert any influence here. Under aggregate shocks the planner does not find optimal to utilize surprise inflation since inflation distorts the allocation of labor across flexible and sticky price goods and since it is possible to exploit variations in the price of real debt to smooth taxes across time.

Varying the Number of States. We now consider the case $N = 4$ with both aggregate and idiosyncratic shocks. The results are reported in Table 7.

Across all values of ν governments desire to issue long term bonds, with most of the debt being concentrated in either the 20 quarter maturity (when ν is low) or the 40 quarter bond (for high values of ν).[22] The model continues to suggest that the government should issue long term bonds in order to exploit fiscal insurance. As previously, the positions are large multiples of GDP.

[Table 7 About Here]

Varying the Degree of Home Bias. We now study how the optimal portfolio varies when we assume a stronger home bias, decreasing α from 0.4 to 0.2. We assume again that $N = 2$ and that shocks can be only aggregate or only idiosyncratic, as in our benchmark case. Table 8 reports the results.

[Table 8 About Here]

Comparing these results with the benchmark in Table 6, in the case of idiosyncratic shocks, a stronger home bias leads to a slight fanning in of the bond positions. A lower α leads to a larger impact of an idiosyncratic shock to consumption. Therefore, it leads to larger variability in real long bond prices and governments can issue fewer long bonds to hedge against the shock. Notice also that this effect weakens as we increase the degree of price stickiness in the economy, since, as discussed previously, assuming a larger fraction of sticky price firms reduces the responsiveness of consumption to fiscal shocks.

The bottom panel of Table 8 considers the case of aggregate spending shocks. Clearly, in this case α exerts no influence on portfolios since the model is essentially equivalent to the closed economy model.

Our finding that markets can be completed through real debt issuances holds under any $\alpha < \frac{1}{2}$. When α equals a half, the CPIs are equal across countries and an efficient allocation sets the ratio of marginal utilities constant. In this case, consumption does not respond to idiosyncratic shocks and so real debt prices do not vary across idiosyncratic spending states. Without a mild degree of home bias governments cannot complete markets even when they issue inflation indexed debt.

Varying the Elasticity of Home and Foreign Goods. Our baseline calibration has assumed $\eta = 2$ and this assumption follows Faia and Monacelli (2004). Most papers in the open economy DSGE literature assume values in the range $[1, 2]$ and a recent stream of studies[23], which estimate structural DSGEs with Bayesian methods, narrow this range further to $[1.5, 2]$. We choose the lower bound of these estimates and set $\eta = 1.5$ to check the robustness of findings.

[22] It shouldn't be surprising that governments issue small amounts of very short bonds and, in some calibrations, buy the longest maturity available. Faraglia et al (2010) find a similar property in some of the 4 state models they consider, finding also that the portfolios are sensitive to the calibration of the stochastic process of spending; this is one of the key results of their paper, that the complete market approach to debt management leads to bond positions that vary considerably across parameter values and model microfoundations.

[23] See for example De Walque, Smets, and Wouters (2005), Rabanal and Tuesta (2005), Justiniano and Preston (2006).

The results displayed in Table 9 suggest that assuming a lower η increases the variability of bond prices and again governments slightly reduce the size of bond positions. However, the qualitative prediction that governments desire to issue long term debt remains.

[Table 9 About Here]

To summarise, the optimality of issuing long term debt is a robust prediction of our model. We have shown this under a wide range of plausible calibrations of the model, considering alternative values for the degree of price stickiness, the degree of home bias and the elasticity parameter η. Under all cases real bond prices comove negatively with government deficits and this implies that the rows of $\mathcal{Q}_{r,t}$ are linearly independent, so that a solution could be found to system (25) and the optimal portfolios recovered.

Finally, we have seen that the optimal portfolios that emerge from our complete market model are slightly sensitive towards varying the model's parameters and bond positions are large multiples of GDP. These findings are in line with the analogous findings in Buera and Nicolini and Faraglia et al (2010).

Introducing Union Wide Inflation Indexed Debt. As a final numerical experiment we study optimal debt management in the case where governments issue debt indexed to Union wide inflation. As was discussed in Section 2 some of the countries in our sample have issued bonds linked to Euro Area inflation (see also the next paragraph). We therefore find interesting to extend our analysis to consider the effect of issuing these types of bonds in the model. For brevity all details of this version of the model are provided in the online appendix.

Our findings suggest that governments continue to desire to issue long term debt, however the optimal portfolio positions are now even larger than before. For example, in our benchmark calibration, where $N = 2$, $\nu = 0.05$ and shocks are idiosyncratic, long debt is 1065 times larger than GDP. When the prices are stickier and $\nu = 0.75$, the long bond position increases to 2085 times of GDP. This is due to the fact that governments have to leverage more on the size of the positions rather than in the variability of bond prices across states to achieve an optimal fiscal insurance and complete the markets.

When shocks are aggregate, bond positions do not change relative to the benchmark as expected. For brevity we leave the above findings outside the tables.

4.4 Inflation Indexed Debt in the Euro Area

Before concluding our paper in the next section, we turn again our attention to our dataset to document the behavior of the shares of long term inflation indexed debt in the five Euro Area countries in our sample. Figure 2 plots the shares over the period 1998-2016.

Figure 2 About Here

As can be seen from the figure, at the beginning of the sample the shares of 4 out of 5 countries were equal to zero. France started issuing the first inflation indexed bonds in 1998. Between 1998 and 2016 we observe that the shares of Italy and France have increased dramatically and stabilized at around 12 percent of overall debt. In Germany and Spain the shares turned positive in 2007 and 2013 respectively, but remained below 5 percent throughout the period documented. Belgium is the only country whose share equals zero in all of the years covered by our data. All the bonds issued have either long or very long maturity ranging from 5 years to 32 years. Italy and France issued some bonds indexed to the Euro Area HICP as well as bonds indexed to the national CPI. Finally, since 2003 the Euro Area has become the second largest market for inflation indexed debt, both in terms of outstanding volumes and turnover, after the US.

Why would governments want to increase the shares of inflation indexed debt? One of the most cited reasons that we find in the literature is that real bonds are a commitment device against inflating away public debt (see Garcia and van Rixtel (2007) for e review). In the context of the Euro area this is not a very likely scenario since inflation rates have been low and stable for all countries considered even before the official introduction of the Euro.[24] Our paper provides an alternative explanation: long term inflation indexed bonds have a hedging value for governments in a currency area.

5 Conclusions

The complete market model of debt management advises governments in a currency union to issue inflation indexed long term debt. In this way, budgets are insulated from the effects of spending shocks and taxes smoothed, since portfolios absorb a large part of the fiscal shocks. Our paper builds on the insights of the recent macro debt management literature, bringing together its positive and normative elements. Our analysis aims to shed light on the management of government debt in currency areas, which, since recently, has received considerable attention in policy circles, but (in our view) not sufficient guidance from an academic perspective.

A number of fruitful extensions of our framework are worth discussing briefly here. First, our model builds on the presumption that markets can be completed, and thus abstracts from possibly important financial market frictions which governments may find difficult to circumvent when they design policies. A recent stream of papers in the closed economy DM literature has explored the interplay between frictions and optimal maturity (e.g. Faraglia et al (2017), Debortoli et al (2017), Hansen et al (2015)). Useful insights can be drawn from these papers and applied to the Union DM model that we propose. However, in these recent papers the distinction between real and nominal bonds is less crucial than it is in our framework, and therefore it is important to explore whether frictions impact differently nominal and real debt markets. This can be argued for example for the US bond markets, where it has been documented that inflation indexed bonds are less liquid.[25] It would be interesting to know whether higher yields associated with lower liquidity, reduce the attractiveness of these types of assets for debt managers in a currency area.

Second, introducing more shocks to the model is required to study jointly the optimal portfolios of private agents along with the optimal DM by governments, and thus bring together the hedging motives of governments and individuals. This will enable to allow trade in equity into our model and thus draw valuable insights from the vast literature on cross country equity portfolios.

Finally, the interplay between fiscal transfers and DM is also worth exploring.

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[24] Spain and Italy had somewhat high inflation rates in the early 90s. After the mid 90s these countries experienced lower inflation and a reduction in long term nominal interest rates. Gains in credibility derived from keeping the exchange rate with the German and French currencies stable, and not from the issuance of any inflation indexed debt.

Equiza-Goñi (2016) extends the dataset used in this paper to the years before the introduction of the Euro and finds that DM offices in Spain and Italy responded to the flattening of the yield curve, by issuing more long term nominal debt.

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Table 1: **Responses of Real Returns to Spending Shocks (Pooled-Panel VAR)**

	All shocks	**Aggregate**	**Idiosyncratic**
All maturities	$-33.8^{\star}$	$-81.1^{\star}$	-13.8
≤ 1 year	$-18.6^{\star}$	$-17.9^{\star}$	$-19.4^{\star}$
1-4 years	$-29.5^{\star}$	$-57.2^{\star}$	$-17.2^{\star}$
4-7 years	$-47.5^{\star}$	$-120.7^{\star}$	-16.3
> 7 years	$-45.2^{\star}$	$-142.5^{\star}$	-3.6

Notes: The table reports initial period responses (in terms of basis points) of bond returns to a government spending shock (1% increase in government consumption) in pooled panel VARs (see section 2.2 for details). Our data is quarterly and covers the period 1998Q2-2008Q2. All variables (spending, output, prices and returns) are detrended using a one-side HP filter with smoothing parameter of 8330. * denotes that zero is outside the one-standard-deviation confidence interval obtained with Monte Carlo simulations (1000 replications).

Table 2: **Responses of Real Returns to Spending Shocks (Average of Country Responses)**

	All shocks	**Aggregate**	**Idiosyncratic**
All maturities	-17.7	$-98.8^{\star}$	19.1
≤ 1 year	-1.0	-15.1	1.8
1-4 years	-7.7	$-72.8^{\star}$	16.8
4-7 years	-33.4	$-151.2^{\star}$	18.8
> 7 year	-30.5	-166.5	41.9

Notes: The table reports initial period *average responses* of bond returns to government spending shocks. We run a separate VAR for each country, then identified the response of return variables to the shocks and averaged using as weights the relative mean GDP over the sample period. The sample and the identification strategy (ordering of the variables) used are the same as in Table 1. * denotes that zero is outside the one-standard-deviation confidence interval obtained with Monte Carlo simulations (1000 replications).

Table 3: **Responses of Real Returns to Spending Shocks (Principal Components)**

	Pooled Panel		Average	
	Aggregate	**Idiosyncratic**	**Aggregate**	**Idiosyncratic**
All maturities	$-112.1^\star$	-13.8	$-113.8^\star$	-26.9
≤ 1 year	$-22.7^\star$	$-18.4^\star$	$-23.9^\star$	-6.8
1-4 years	$-88.9^\star$	$-14.5^\star$	$-97.0^\star$	-20.6
4-7 years	$-171.4^\star$	-15.9	$-176.2^\star$	-40.2
> 7 year	$-188.9^\star$	-8.9	$-173.4^\star$	-39.3

Notes: We used the same sample and identification strategy (ordering of the variables) as in Table 1. However, the first variable in the panel VAR is now the first principal component of (the log of) government spending series of the countries in the sample. * denotes that zero is outside the one-standard-deviation confidence interval obtained through Monte Carlo simulations (1000 replications).

Table 4: **Responses of Nominal Returns to Spending Shocks (Pooled-Panel VAR)**

	All shocks	**Aggregate**	**Idiosyncratic**
All maturities	$-19.1^\star$	$-67.5^\star$	1.4
≤ 1 year	$-4.1^\star$	$-3.8^\star$	$-3.6^\star$
1-4 years	$-14.8^\star$	$-43.8^\star$	-2.0
4-7 years	$-32.8^\star$	$-107.3^\star$	-1.1
> 7 years	$-30.9^\star$	$-129.3^\star$	11.3

Notes: The table reports reponses of returns to spending shocks identified in a pooled panel VAR as in Table 1, however, the return variables here are not adjusted for inflation. * denotes that zero is outside the one-standard-deviation confidence interval obtained

Table 5: **The Model Parameters**

Parameter	Symbol	Value	Target/Reference
	Preferences and Technology		
Discount Rate	β	0.98	Faraglia et al (2010)
Disutility of Labor (curvature)	γ	2	Elasticity of 0.5
Disutility of Labor (level)	χ		Steady state tax
Time Working	$\overline{h}$	$\frac{1}{3}$	Normalization
Home Bias Parameter	α	0.4	
Substitution / Varieties	ϵ	6	Faia and Monacelli (2004)
Substitution / Domestic vs. Foreign goods	η	2	
Fraction of Sticky Prices	ν	0.05	Siu (2004)
	Spending		
High Spending State	$\overline{g}$	$(1+0.07)g_s$	
Low Spending State	$\underline{g}$	$(1-0.07)g_s$	Faraglia et al (2010)
Persistence	ρ	0.95	

Note: The table summarizes the values of the model parameters under the baseline calibration. The second column gives the symbol used in text and the last column reports the targets or refers to papers followed to set the values. g_s is used to denote the steady state level of spending (20 percent of GDP). See text for further details.

Table 6: **Optimal Portfolios: Baseline Calibration and Effects of Sticky Prices**

% Sticky Prices	$\nu = 5\%$	$\nu = 10\%$	$\nu = 25\%$	$\nu = 50\%$	$\nu = 75\%$
		Idiosyncratic Shocks			
$B_r^{A,1}$	-38.4	-38.9	-42.9	-48.2	-64.1
$B_r^{A,40}$	84.5	85.6	94.5	106.1	140.9
		Aggregate Shocks			
$B_r^{A,1}$	-13.6	-13.6	-13.6	-13.6	-13.6
$B_r^{A,40}$	30.1	30.1	30.1	30.1	30.1

Notes: The table reports optimal portfolios under $N = 2$ (two spending states). The top panel shows the case of idiosyncratic shocks and the bottom panel the case of aggregate shocks. The numbers reported are face values of short- 1 period- debt ($B_r^{A,1}$) and long - 40 quarters- debt ($B_r^{A,40}$).

Table 7: **Optimal Portfolios: Varying the Number of States**

% Sticky Prices	$\nu = 5\%$	$\nu = 10\%$	$\nu = 25\%$	$\nu = 50\%$	$\nu = 75\%$
$B_r^{A,1}$	0.5	0.5	0.5	0.5	0.6
$B_r^{A,8}$	-55.2	-55.2	-55.1	-54.6	-52.8
$B_r^{A,20}$	71.1	69.5	63.4	44.9	-5.44
$B_r^{A,40}$	-2.4	-0.1	8.9	35.7	107.6

Notes: The table reports optimal portfolios under $N = 4$ (four spending states). The numbers reported are face values ($B_r^{A,j}$) of maturities $j = 1, 8, 20, 40$ where j denotes quarters.

Table 8: **Optimal Portfolios: Varying the Degree of Home Bias**

% Sticky Prices	$\nu = 5\%$	$\nu = 10\%$	$\nu = 25\%$	$\nu = 50\%$	$\nu = 75\%$
		Idiosyncratic Shocks			
$B_r^{A,1}$	-32.3	-32.9	-35.2	-42.3	-63.2
$B_r^{A,40}$	71.0	72.4	77.5	93.0	139.1
		Aggregate Shocks			
$B_r^{A,1}$	-13.6	-13.6	-13.6	-13.6	-13.6
$B_r^{A,40}$	30.1	30.1	30.1	30.1	30.1

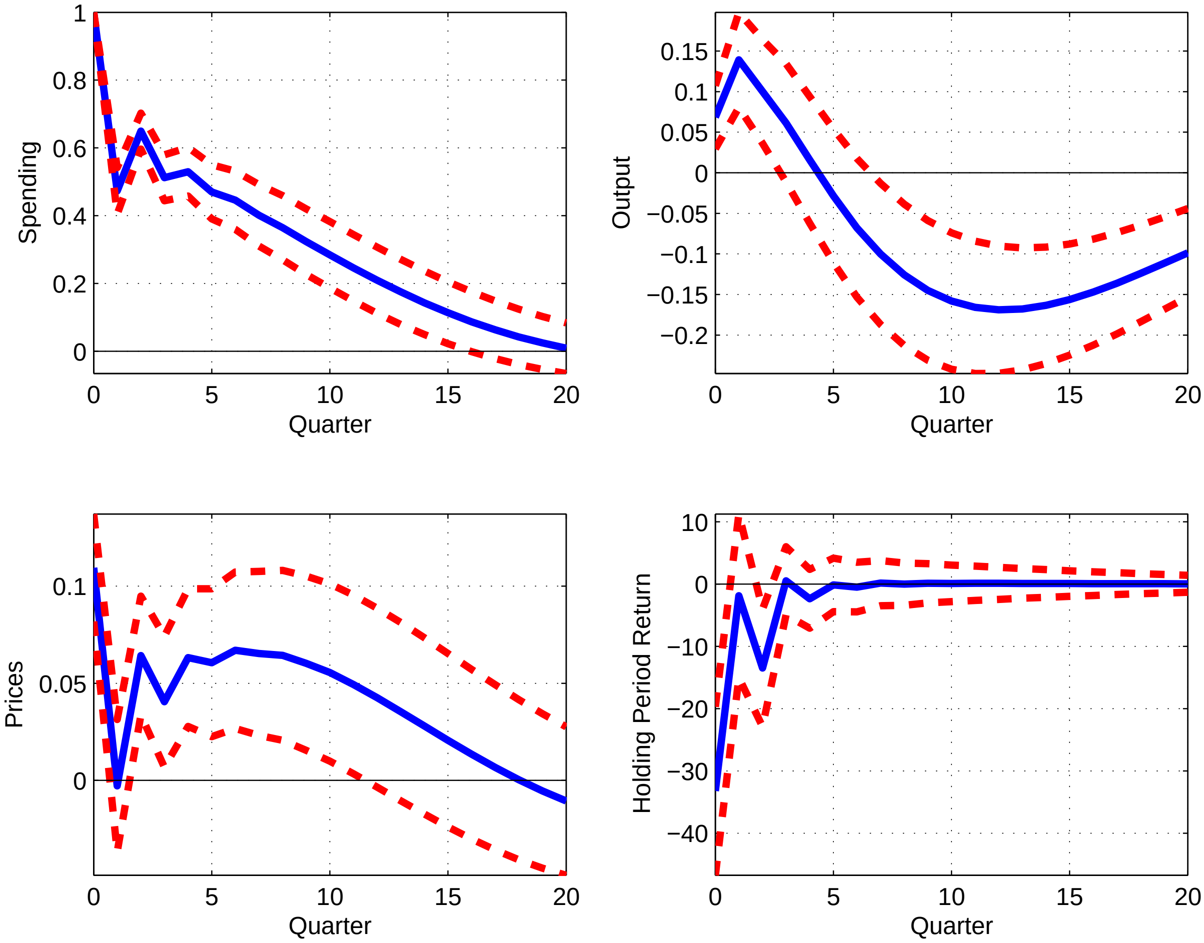
Notes: The table reports optimal portfolios under $N = 2$ (two spending states). The calibration of the model sets $\alpha = 0.2$ (higher degree of home bias). All other parameters are unchanged relative to Table 6.

Table 9: **Optimal Portfolios: Varying the Elasticity of Home and Foreign Goods**

% Sticky Prices	$\nu = 5\%$	$\nu = 10\%$	$\nu = 25\%$	$\nu = 50\%$	$\nu = 75\%$
			Idiosyncratic Shocks		
$B_r^{A,1}$	-28.5	-29.1	-31.5	-38.6	-59.8
$B_r^{A,40}$	62.6	64.0	69.2	84.9	131.6
			Aggregate Shocks		
$B_r^{A,1}$	-13.6	-13.6	-13.6	-13.6	-13.6
$B_r^{A,40}$	30.1	30.1	30.1	30.1	30.1

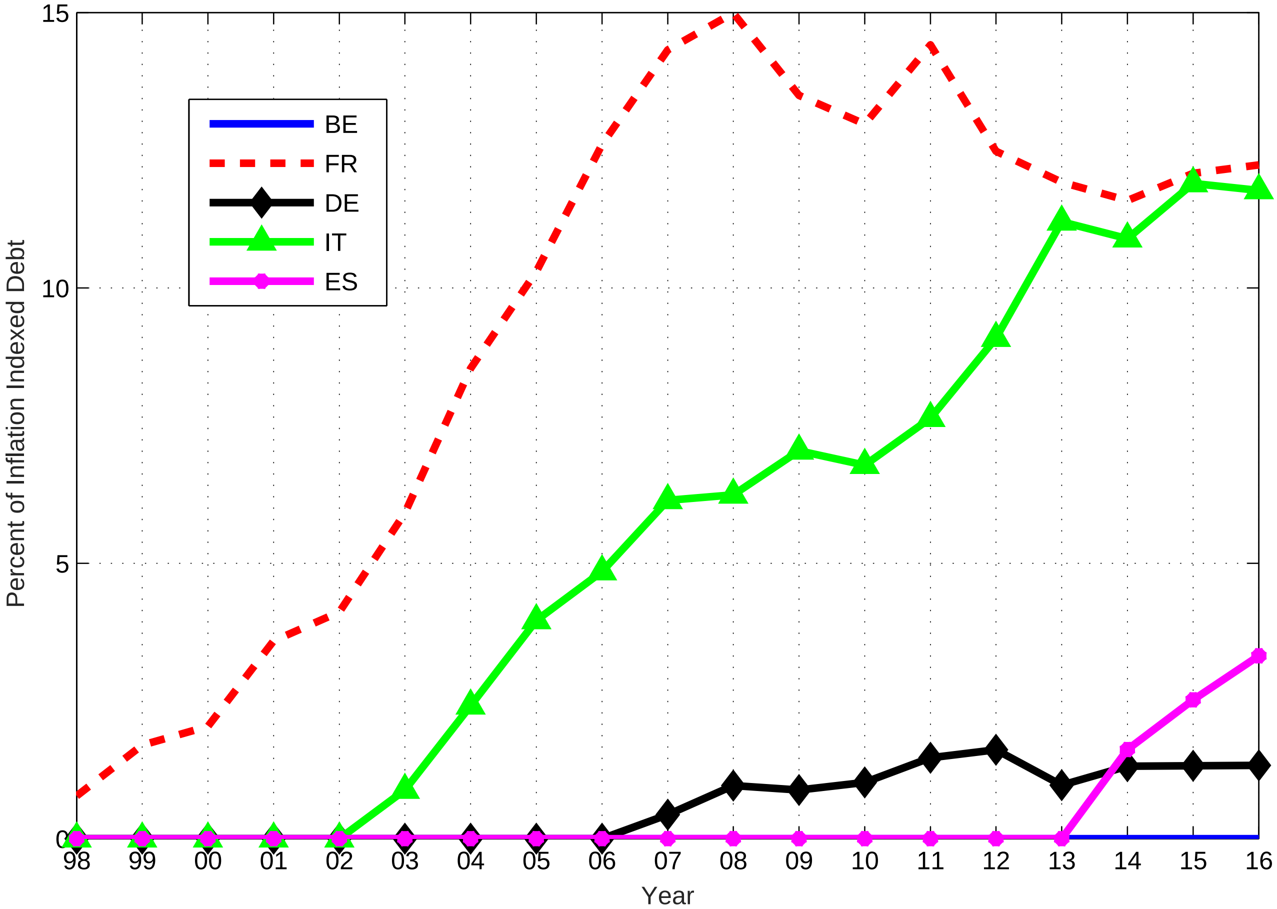
Notes: The table reports optimal portfolios under $N = 2$ (two spending states). The calibration of the model sets $\eta = 1.5$. All other parameters are unchanged relative to Table 6.

Figure 1: **Impulse Responses One Standard Deviation in Spending**



Notes: The figure plots the impulse responses of government spending (top left), output (top right), prices (bottom left) and holding returns (bottom right) to a one standard deviation shock in 'total' spending. The estimates derive from the panel S-VAR in Section 2.3.1. See text for further details.

Figure 2: **Shares of Inflation Indexed Debt in Government Portfolios**



Notes: The figure shows the shares of inflation indexed long maturity debt over total government debt in each country.