Monetary/Fiscal Interactions with Forty Budget Constraints*

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Abstract

It is well known that monetary and fiscal policy are connected by a common budget constraint. In this paper, we study how this manifests itself in the context of the Eurozone, where that connection links the European Central Bank, the 19 national central banks, the Treasuries of 19 countries, and the European Union. Our goal is twofold. First, we wish to clarify how seigniorage flows from the monetary authority to the budget of each country. Second, we seek to answer the question of how the taxpayers of each country are affected by a default of one of the participants to the union. In answering this question, we analyze the mechanisms that ensure (or do not ensure) that net liabilities across countries stay bounded, and we establish how the answer depends on the liquidity premium that each category of assets commands (cash, excess reserves within the Eurosystem, and government bonds). We find that the official risk-sharing provisions of the policy of quantitative easing (QE), whereby national central banks retain 90% of the risk intrinsic in bonds of their own country, only holds under restrictive assumptions; under plausible scenarios, a significantly larger fraction of the risk is mutualized.

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1 Introduction

At least since Sargent and Wallace [22], it has been understood that monetary and fiscal authorities are bound together by a common budget constraint, and that this constraint forces some (implicit or explicit) coordination across the two actors. More recently, a large literature on the fiscal theory of the price level has developed to study the implications of the way this coordination takes place,[1] and the potential role that de jure separate budget constraints between a nation's central bank and its Treasury might have,[2] with an eye to political-economy stories where this separation might affect the bargaining power of the different players.[3] These papers have focused on the interaction between a single fiscal and a single monetary authority. This is because currency issue and monetary policy is typically done by a national central bank, even in federal countries, and the relationship between the national central bank and the Treasury occurs at the level of the central government.

In this paper, we revisit monetary/fiscal interaction in the context of the Eurozone. While monetary policy is conducted under the control of the European Central Bank (ECB), the European Union has been until now a minor fiscal player with limited revenues and has mostly relied on transfers from the national governments, that retain the ultimate power to tax in their jurisdiction. Moreover, the budgetary interaction between these national governments and the ECB is mediated by the national central banks (NCBs) of each member country, each with its own separate budget. This distinction has taken particular significance since the ECB engaged

[1] This literature started with Leeper [18], Sims [23], and Woodford [30]. More recent contributions that have emphasized the alternation between different regimes include Davig and Leeper [14, 15], Chung, Davig, and Leeper [9], Bianchi and Melosi [5, 6], Bianchi, Melosi and Rottner [7], and Bianchi, Faccini and Melosi [4]. Cochrane [10, 11, 12, 13] has argued that active fiscal rules provide a more convincing source of determinacy within new Keynesian models than active monetary policy rules.

[2] The separation of the budget constraints plays a prominent role in Sims [24, 25], Bassetto and Messer [3], Hall and Reis [17] and Reis [21].

[3] The analysis of monetary-fiscal games is the subject of a smaller literature. Bassetto [2] provides theoretical underpinnings for the fiscal theory of the price level, but he does not describe the objectives that lead fiscal and monetary authorities to choose their strategies. A few papers that have attempted such a description are Niemann [19], Barthélemy and Plantin [1], and Camous and Matveev [8].

in quantitative easing (QE), purchasing large amounts of debt issued by national governments. Given the very heterogeneous risks of default across Eurozone countries, a simple pooling of all assets, income, and losses at the level of the ECB would represent an implicit insurance offered by the citizens of the more stable countries to those that are most likely to default. Realizing this, QE has been structured so that each NCB retains 90% of the risk arising from movements in the price of their country's bonds.[4] We then ask the following question: if monetary and fiscal policy are inevitably intertwined by their common budget constraint, under what assumptions is there truly a wall between the budgets of each nation within the Eurozone? Is there still the potential for losses and gains to spill over from one country to another in potentially unintended ways?

Sims [25] characterized the ECB as a "model E" central bank, where there is a stark separation with fiscal authorities and a presumption of no fiscal backing, to contrast it with "model F" central banks (like the Federal Reserve System), where lines are more blurred. Once the Eurosystem (formed by the ECB and its member NCBs) started engaging in large-scale purchases of government debt, our findings suggest that the conditions under which the separation of the budgets of each country holds are quite restrictive. In practice taxpayer risks are pooled to a greater extent than it would be the case de jure. We distinguish between two broad cases. First, if the Eurozone excess reserves do not command a special liquidity premium, but rather pay the same interest rate as other nominally risk-free assets, then separation can be enforced to the extent that the ECB can prevent each NCB from operating with arbitrarily negative capital and it can also prevent each national Treasury from recapitalizing its NCB with assets that represent pure bookkeeping entries, such as the Federal Reserve's gold certificates. Second, when excess reserves command a liquidity premium and pay a correspondingly lower interest rate, even prohibition of negative capital is not sufficient to avoid that a default by one country spills over to the taxpayers of other countries through the budget constraints of their NCBs, beyond the small percentage that has been agreed ex ante.

Our paper emphasizes the role of the Target 2 system in representing the link in the budget

[4]The appendix contains a more extensive description of the specific arrangements about income and loss pooling across the Eurosystem.

constraints across countries. In this, we join the literature that has discussed the role of Target 2 within the Eurozone, alternatively criticizing it[5] or defending it.[6] Critics of the Target 2 system worry about the consequences of Target 2 imbalances in the event of a breakup of the European Monetary Union, wondering whether those imbalances would ever be repaid; they also have studied the relationship between movements in Target 2 balances, international capital movements within the Eurozone, and current-account imbalances across countries. Compared to previous work, our analysis focuses entirely on quantitative easing, but it concentrates its attention to the role of the budget constraint of the *fiscal* authorities, in addition to monetary authorities. Cast in this light, the Target 2 system is simply one manifestation of the link in the budget constraint of the monetary authority, which is supposed to act at the European level, and that of the national Treasuries, that are supposed to remain independent. We thus highlight how fragile this arrangement looks from the perspective of studies of monetary/fiscal interactions, and how a similar link would inevitably emerge in different ways as long as the ECB faces national fiscal authorities and purchases their debt in the conduct of its monetary policy.

2 The setup

Our model starts from Bassetto and Messer [3], whose notation we follow. As in their paper, the model is stylized and based on an economy that features flexible prices and special assumptions about preferences, but this is done purely for simplicity and does not affect the central message of our paper. Most of our equations are based on present-value relations that would be true under much more general circumstances.

The economy features a continuum of private households that live in one of two countries, A and B. Each one of the two countries has its own Treasury and a national central bank (NCB), but the two NCBs are joined in a currency union which we call the Eurosystem. Assuming only two countries has no effect other than simplifying notation. We abstract from the budget of the European Union, who would be a separate player. In practice the budget of the EU is

[5]See e.g. Sinn and Wollmershäuser [28], Sinn [26, 27], and Perotti [20]

[6]See e.g. DeGrauwe and Ji [16], Whelan [29]

small relative to that of the national governments; the important assumption here is that we do not allow transfers from the EU to national governments to depend on the creditor/debtor position of national treasuries and central banks. While the European Stability and Growth Pact in principle allows for fines, these have never been applied and, to the best of our knowledge, nothing in European law allows for targeted transfers based on the creditor/debtor position vis-à-vis the Eurosystem. Other arrangements, such as the European Stability Mechanism (ESM), may be a more relevant source of pooling of fiscal revenues, but they remain limited and are not the focus of our analysis anyway. However, it might be worth noting that such mechanisms would be one way in which the imbalances that we identify in our analysis are eventually resolved if the tension arising from keeping them implicit within the budget of the central banks becomes untenable. Finally, we also abstract from the budget of the European Central Bank (ECB), since our considerations can be cast purely in terms of the relation between NCBs. In practice, the Target 2 balances that play a prominent role in what follows are mediated through the ECB rather than being bilateral positions.

The Treasury of each of the two countries issues one-period bonds.[7] Country A's debt is safe, while country B's debt is potentially subject to default. We denote by γ_t the (exogenous) probability that country B's debt will be defaulted in period $t+1$, and we assume an exogenous haircut δ upon each default. B_t^i is the nominal amount of one-period bonds that are issued by country i's Treasury in period t and need to be repaid in period $t+1$, and R_t^i is the promised nominal interest rate between periods t and $t+1$. To repay its debts, country i's Treasury has the power to levy (lump-sum) taxes on the residents of the country; let T_t^i be their nominal amount in period t. The Treasury also receives transfers S_t^i from its NCB, with $S_t^i < 0$ corresponding to a recapitalization of the NCB by the Treasury. We abstract from government spending.[8]

On a period-by-period basis, the budget constraint for country i's Treasury is given by the

[7]Bassetto and Messer [3] analyze long-term bonds, since their emphasis is on interest-rate risk. Since we are interested in default risk instead, we neglect them.

[8]Equivalently, we assume that public goods are perfect substitutes for private consumption, in which case transfers and spending are equivalent, as long as the nonnegativity constraint on private consumption is not binding, which we assume.

following:

$$B^i_{t-1}(1-\delta I_t) = \frac{B^i_t}{1+R^i_t} + S^i_t + T^i_t, \tag{1}$$

where I_t is an indicator function that takes the value of 1 for country B if the country defaults at t and zero otherwise.[9] At each period t, the left-hand side of equation (1) represents the Treasury's repayment commitments: B^i_{t-1} to the holders of debt, scaled down by δ if default occurs. The right-hand side represents the sources of funds: taxes from the private sector seigniorage transfers from the central bank to Treasury, and new issuance of debt.

In this theoretical section, we focus on the monetary-policy and quantitative easing roles of the central bank and we thus neglect other assets and liabilities that are not connected to it.[10] As a whole, the Eurosystem has liabilities in the form of currency and reserves, and assets in the form of loans to banks and government bonds. In our model, we abstract from banks, so both reserves and loans are directly with the Eurozone residents. We distinguish between currency and reserves because the former pays a zero nominal interest rate. In normal times, when the nominal risk-free interest rate is positive, the spread between the nominal interest rate and the zero rate on currency is a source of profits for the Eurosystem. Reserves may pay an interest rate, which we normally think of being positive, but can also be negative, both in principle and in practice.

We adopt the following notation:

- M_{t-1} represents currency outstanding at the beginning of period t issued by the Eurosystem as a whole, and M^i_{t-1}, with $i \in \{A, B\}$ is the amount of the liability allocated to the NCBs of countries A and B.

- X_{t-1} represents reserves outstanding at the beginning of period $t-1$, with a similar split denoted by X^i_{t-1}.

- A_{t-1} represents loans to private households, which are then also split into A^i_{t-1}.

[9] I_t is always zero for country A.

[10] One example is foreign-currency reserves. Quantitatively, we concentrate on the larger items of the balance sheet.

- $\bar{B}_{t-1}^i$ represents holdings by the Eurosystem of government bonds issued by country i. To keep notation simple, we assume here that each NCB only purchases the bonds of its country. This can be generalized; what is important for our analysis is that the NCB of each country purchases a disproportionate amount of the bonds of its Treasury, which is a key characteristic of the current QE program in the Eurosystem and is supposed to limit the mutualization of default risk.

- Finally, τ_{t-1}^i represents the Target 2 balance of the NCB of country i.

Government bonds of countries A and B carry a different interest rate due to default risk. We assume that private citizens cannot default on their loans from the Eurosystem. Since our emphasis is on the assets and liabilities of the central bank, in this version we abstract from the liquidity role that government debt may play, and simply assume that country A's risk-free debt pays the same rate of return as private securities. In particular, this will imply that, in the equilibrium we will describe, this interest rate exceeds the growth rate (which we will normalize to zero). We will include a discussion of liquidity services of government debt in future versions.[11] We assume that reserves pay interest at the rate R_t^X; reserves may or may not provide liquidity services, so in equilibrium we will obtain $R_t^X \leq R_t^A$.

A central role in our paper is played by the budget constraints of the NCBs, but for now we start with the budget constraint of the Eurosystem as a whole. The flow budget constraint is

$$M_t - M_{t-1} + \frac{X_t}{1+R_t^X} - X_{t-1} = \frac{\bar{B}_t^A + A_t}{1+R_t^A} + \frac{\bar{B}_t^B}{1+R_t^B} - A_{t-1} - \bar{B}_{t-1}^A - \bar{B}_{t-1}^B(1-\delta I_t) + S_t^A + S_t^B. \quad (2)$$

On the left-hand side of equation (2), the Eurosystem raises funds by issuing new currency or reserves beyond those previously issued. On the right-hand side, the new funds are used to purchase new government securities of either country (beyond rolling over principal and interest), or to transfer seigniorage to either government.

[11] Allowing governments to reap seigniorage from being able to issue debt at low interest rates would not interact with our considerations, except that we usually would expect governments not to default while the interest rate that they pay is below the growth rate of the economy, so that the burden of debt service remains effectively negative.

The economy starts at time 0 with some initial stock of bonds, money, and excess reserves, described by $(B^i_{-1}, \bar{B}^i_{-1}, A_{-1}, A^i_{-1}, X_{-1}, X^i_{-1}, M_{-1}, M^i_{-1})_{i=A,B}$.

We relegate the household problem to the appendix. For our purposes, the key equation that emerges in a competitive equilibrium is the consolidated present value budget constraint of the government, which is also known as the government debt valuation equation in the literature on the fiscal theory of the price level:

$$\begin{aligned} & B^A_{-1} - \bar{B}^A_{-1} - A_{-1} + (B^B_{-1} - \bar{B}^B_{-1})(1 - \delta I_0) + M_{-1} + X_{-1} = \\ & T^A_0 + T^B_0 + M_0 \frac{R^A_0}{1 + R^A_0} + X_0 \left(\frac{1}{1 + R^X_0} - \frac{1}{1 + R^A_0} \right) \\ + & E_0 \sum_{s=1}^{\infty} z_{0,s} \left[T^A_s + T^B_s + M_s \frac{R^A_s}{1 + R^A_s} + X_s \left(\frac{1}{1 + R^X_s} - \frac{1}{1 + R^A_s} \right) \right]. \end{aligned} \tag{3}$$

In equation (3), $z_{0,s}$ is the nominal stochastic discount factor between periods 0 and s. This equation states that the liabilities of the Eurozone as a whole at the beginning of period 0 must be equal to the present value of taxes levied by all the governments in the union, plus the present value of all the seigniorage revenues arising from the fact that cash and reserves may pay a lower interest rate than implied by the stochastic discount factor due to their liquidity provision. This equation emerges from market clearing and from the transversality condition of the households: if government liabilities were not matched by appropriate tax revenues, debt would explode over time, and households would find it optimal to spend some of their exploding wealth rather than continuing to purchase ever-increasing amounts of government bonds (or money).

3 The present-value budget constraint of the Eurosystem

Using the no-arbitrage relations emerging among asset prices in a competitive equilibrium, we can similarly sum forward the budget constraint of the Eurosytem, equation (2), and we obtain the following:

$$
\begin{aligned}
&\bar{B}^A_{-1} + A_{-1} + \bar{B}^B_{-1}(1-\delta I_0) - M_{-1} - X_{-1} + M_0\frac{R^A_0}{1+R^A_0} + X_0\left(\frac{1}{1+R^X_0} - \frac{1}{1+R^A_0}\right)\\
&+E_0\sum_{s=1}^{\infty} z_{0,s}\left[M_s\frac{R^A_s}{1+R^A_s} + X_s\left(\frac{1}{1+R^X_s} - \frac{1}{1+R^A_s}\right)\right]\\
&=S^A_0 + S^B_0 + E_0\sum_{s=1}^{\infty} z_{0,s}(S^A_s + S^B_s) + \lim_{s\to\infty} E_0[z_{0,s}(\bar{B}^A_{s-1} + \bar{B}^B_{s-1}(1-I_{s-1}))].
\end{aligned}
\tag{4}
$$

The left-hand side of (4) represents the assets of the Eurosystem as of time 0: its holdings of government bonds and private debt, plus the present value of seigniorage revenues. The right-hand side represents the disposition. The first part is standard, and represents the present value of seigniorage transfers to governments. The final term represents the fact that nothing prevents the Eurosystem from accumulating exploding amounts of government debt. While private households would never do that, as they would rather increase their consumption, the central bank is not an agent maximizing its consumption and nothing prevents a policy of indefinite accumulation.[12] If the Eurosystem faced a single fiscal authority, a Modigliani-Miller theorem would be at work and this position would be irrelevant. To better illustrate it, consider the consolidated present-value budget constraint of the fiscal authorities of the Eurozone:

$$
\begin{aligned}
&B_{A,-1} + B_{B,-1}(1-\delta I_0) = T^A_0 + T^B_0 + S^A_0 + S^B_0 + E_0\sum_{s=1}^{\infty} z_{0,s}\left[T^A_s + T^B_s + S^A_s + S^B_s\right]\\
&+\lim_{s\to\infty} E_0[z_{0,s}(\bar{B}_{A,s-1} + \bar{B}_{B,s-1}(1-\delta I_{s-1}))].
\end{aligned}
\tag{5}
$$

Notice that the limit in (6) only contains bonds held by the Eurosystem, because the limit is zero for all holdings by private actors. Whether the central bank remits its profits to the Treasury or keeps them in ever-increasing amounts of debt is irrelevant from the perspective of equations (4) and (6), as well as for all the other competitive-equilibrium conditions, which only depend on the bonds in the hands of the private households. Of course, in practice the net position of the central bank might matter in political-economy models in which there is a conflict between the

[12]Throughout our analysis, we assumed that $\lim_{s\to\infty} E_0[z_{0,s}A_{s-1}] = 0$. Since we impose a lower bound on the private-sector real net debt position, this is equivalent to ruling out a situation in which the private sector accumulates an explosive amount of government debt financed by exploding loans from the central bank.

fiscal and monetary authorities. These equations are useful to understand the policy implications of the fiscal authorities' attempt to directly or indirectly seize some of the assets of the central bank. A recent example of such a policy in the Eurosystem is the proposal to cancel some of the debt held by the Eurosystem that the countries accumulated in their fight against COVID. To the extent that this leads to lower future remittances or a lower limit accumulation of assets by the Eurosystem, the proposal would be neutral, but it is rather viewed as a way of pressuring the Eurosystem to increase seigniorage revenues (and thereby inflation). Similarly, during the Great Depression, the Treasury seized the gold of the Federal Reserve System, replacing it with "gold certificates," an asset bearing no interest and an indefinite maturity.[13]

While there are many historical examples of policies of redistribution of assets between fiscal and monetary authorities, what is unique about the Eurosystem is the fact that many different countries are participating, which raises the possibility that the indefinite accumulation of assets may be asymmetric across countries. To address this, we now consider the present-value budget constraints of national central banks and national Treasuries within the Eurosystem.

4 The budget constraints of national Treasuries and Central Banks

Splitting the budget constraint of each national Treasury is straightforward, owing to the weak links across different fiscal authorities in the Eurozone. Summing (1) forward, we obtain

$$B_{i,-1}(1-\delta I_0) = T_0^i + S_0^i + E_0 \sum_{s=1}^{\infty} z_{0,s} \left[T_s^i + S_s^i\right] + \lim_{s\to\infty} E_0[z_{0,s}(\bar{B}_{i,s-1}(1-\delta I_{s-1}))], \quad i = A, B, \tag{6}$$

[13]It is worth noting that these gold certificates are not an entitlement to gold, so that they do not necessarily appreciate at the same rate as gold. The Federal Reserve System carries them on the book at their historical value.

with the usual proviso that $I_t \equiv 0$ for country A by assumption.[14] Equation (6) assumes that the Treasury of country i does not participate in the market for country j's debt, or at least that its position does not explode, similar to the position of the private sector.

The flow budget constraint of country i's NCB is given by

$$M_t^i - M_{t-1}^i + \frac{X_t^i - \tau_t^i}{1 + R_t^X} - X_{t-1}^i + \tau_{t-1}^i = \frac{\bar{B}_{i,t}}{1 + R_t^i} + \frac{A_t^i}{1 + R_t^A} - \bar{B}_{i,t-1}(1 - \delta I_t) - A_{t-1}^i + S_t^i. \tag{7}$$

We consider the allocation of cash and purchases of private securities to be part of "ordinary monetary policy," and are split between the two NCBs according to an exogenous capital key α^i. In contrast, the composition of liabilities between reserves and the Target 2 balance depends on the counterparty of asset purchases conducted by the Eurosystem. When the Eurosystem buys an asset from a resident of country i, the NCB of country i issues new reserves. To the extent that this asset is purchased by the NCB of country $j \neq i$, the NCB of country i is compensated by a matching Target 2 credit. To be concrete, if the NCB of country B purchases one unit of government bonds of country B from residents of country A in period t, it acquires an asset worth $1/(1 + R_t^B)$ and a matching Target 2 liability worth the same. The NCB of country A acquires a Target 2 credit worth $1/(1 + R_t^B)$ and a matching liability in the form of extra reserves. We have imposed that Target 2 balances pay the same rate as reserves, as is the case in practice.[15]

Rolling forward equation (7), we obtain

$$\begin{aligned}
&\bar{B}_{i,-1}(1 - \delta I_0) + A_{-1}^i - M_{-1}^i - X_{-1}^i + \tau_{-1}^i + M_0^i \frac{R_0^A}{1 + R_0^A} + X_0^i \left(\frac{1}{1 + R_0^X} - \frac{1}{1 + R_0^A} \right) \\
&+ E_0 \sum_{s=1}^{\infty} z_{0,s} \left[M_s^i \frac{R_s^A}{1 + R_s^A} + (X_s^i - \tau_s^i) \left(\frac{1}{1 + R_s^X} - \frac{1}{1 + R_s^A} \right) \right] \\
&= S_0^i + E_0 \sum_{s=1}^{\infty} z_{0,s} S_s^i + \lim_{s \to \infty} E_0 [z_{0,s} (\bar{B}_{i,s-1}(1 - \delta I_{s-1}) + \tau_s^i)].
\end{aligned} \tag{8}$$

[14] We neglect bonds issued by the European Union and other arrangements such as the ESM. These are a further potentially important source of mutual insurance, but are not at the heart of our research question, and they all implicitly or explicitly include limits that would ensure that the transversality condition is satisfied.

[15] More precisely, the interest rate on Target 2 balances is tied to the ECB's Main refinancing rate, which is the bottom of the corridor system. In our analysis, we neglect the technical details that lead to the emergence of a corridor of interest rates.

We wish to study the consequences on this budget constraint of a default by country B's Treasury in period 0. Such a default causes a shortfall in the assets of country i's CB on the right-hand side.

Consider first the case in which central bank reserves do not provide special liquidity, so that they pay the same rate of return as other nominal risk-free claims: $R_t^X = R_t^A$. If the Eurosystem as a whole controls the evolution of monetary policy, and it does not react by altering the path of seigniorage on cash, there are only two possibilities:

- **The Intended Adjusted Mechanism**. Faced with a smaller net worth, and correspondingly smaller current and future profits, country B's NCB reduces the present value of the stream of remittances to the Treasury of country B. Ceteris paribus, this will force the Treasury to raise taxes on country i's residents, keeping the credit risk confined to country B. If the default is sufficiently large so as to make the left-hand side of equation (8) negative, this might require negative values of S_t in some periods: this would correspond to a recapitalization of the NCB by its Treasury. What would such a recapitalization entail in practice? How willing would a government that has just defaulted on its debt be to find the resources for this to happen?

- **Alternative Shenanigans**. A government in default might be tempted to continue to receive its transfers from its NCB, and let the NCB operate with smaller and eventually negative capital. In the absence of a lower bound on the Target 2 liability, the NCB is able to operate in this regime indefinitely, relying on the explosive limit on the right-hand side as a source of funding for its seigniorage transfers even when its assets have fallen in value. An equivalent alternative would be for the Treasury to recapitalize its NCB with non-interest bearing assets of infinite maturity, such as the "gold certificates" (or the more-recently discussed "platinum coin.") Such an arrangement would avoid the embarrassment of taking money out of a NCB that has negative book value, but would not alter the economic problem, since these assets would not generate income and would thus not appear in the economically relevant budget constraint. This prospect causes a conundrum for country A's central bank. Since Target 2 liabilities sum to zero within the

Eurosystem, an exploding liability for country B implies an exploding asset for country A, which detracts from the present value of seigniorage transfers that country A's CB can remit to its own Treasury. This is the most transparent manifestation of the fact that there is effectively a single common budget constraint, and a need to coordinate remittance policies. If country B refuses to undergo what we labeled as the "intended adjusted mechanism," it remains unclear in the current circumstances how country A could force an adjustment. If country A insisted on maintaining its stream of seigniorage transfers, the inevitable forces of the budget constraint would force an increase in seigniorage (and the accompanying higher inflation).

Next, consider how the conclusion that we reached above changes when reserves play a liquidity role, so that $R_t^X < R_t^A$. To further simplify the proof, assume the slightly stronger condition $(1+R_t^X)/(1+R_t^A) < \theta < 1$, that is, the value of liquidity services provided by reserves have a uniform lower bound. Suppose that, following a default by country B in period 0, country B's NCB does not alter any of its policies, but simply relies on rolling over an increased Target 2 liability. Using equation (7), we observe that the change in the Target 2 position in period t will be given by

$$\Delta\tau_t^i = -\bar{B}_{B,-1}\delta\prod_{s=0}^{t}(1+R_t^X). \tag{9}$$

From the household optimality conditions, we obtain

$$\frac{1}{1+R_t^A} = E_t z_{t,t+1} \Longrightarrow (1+R_t^X)E_t z_{t,t+1} < \theta.$$

Using the law of iterated expectations, it then follows that

$$\lim_{t\to\infty} E_0 z_{0,t}\Delta\tau_t^i = 0 : \tag{10}$$

in this case, a policy of indefinite rollover does not even lead to an explosive path for Target 2 balances! Depending on the specific value of R_t^X, it may lead to a balance that is growing slower than the private rate of interest, or even shrinking in real terms. How is this possible? Equation (8) provides the answer: in this case, the NCB earns seigniorage profits in the amount of $\frac{1}{1+R_t^X} - \frac{1}{1+R_t^A}$ on its Target 2 *liabilities*, so that higher liabilities effectively shift seigniorage from country A to country B. Of course, uless country A reduces its own seigniorage redistribution, the present value of the Eurosystem as a whole is not in balance, so that some other adjustment will need to take place. This example illustrates once more how the presence of a common budget constraint causes makes it difficult to define where fiscal risk arises upon a country's default.

5 Some Numerical Illustrations

(Work in progress)

In this section we explore some numerical implications of the model under alternative scenarios. In the current version, we focus on plausible scenarios that are fairly favorable to the central bank, in that the present value of seigniorage profits is large compared to the size of the default.

We take the period to be 1 year. We consider an economy in which consumption grows at a constant rate, so that the real interest rate on government debt and private assets is also constant and equal to 2%. We assume that the economy grows at 1% per year, and we study paths in which the central bank successfully keeps inflation stable at 2%.

We follow the official profit distribution rule of Bank of Italy and apply it to both country A and country B. Specifically, accounting profits are distributed to the Treasury for 60% and retained as reserves for 40%.

Country A and country B are treated symmetrically, except for two aspects:

- Country B is subject to a one-time possibility of default in period 2, while country A never defaults.
- Country B represents 15% of the GDP of the currency union, roughly the size of Italy in the Eurozone.

Symmetry implies that the demand for cash and bank reserves (after adjusting for size) is the same in the two countries.

To compute seigniorage, we posit a log-log demand for cash given by

$$M_t/(P_tY_t) = \phi \left(R^A\right)^{\lambda},$$

with $\phi = 0.0096$ and $\lambda = -0.61$, and Y_t is real GDP. This is chosen so that cash over GDP is 6% when the nominal interest rate is 5% and 4.5% when the nominal rate is 8%, in line with the historical experience of the United States.

Similarly, we assume that reserves are given by

$$X_t/(P_t Y_t) = \phi^X \left(\frac{1+R^A}{1+R_t^X} - 1 \right)^\lambda .$$

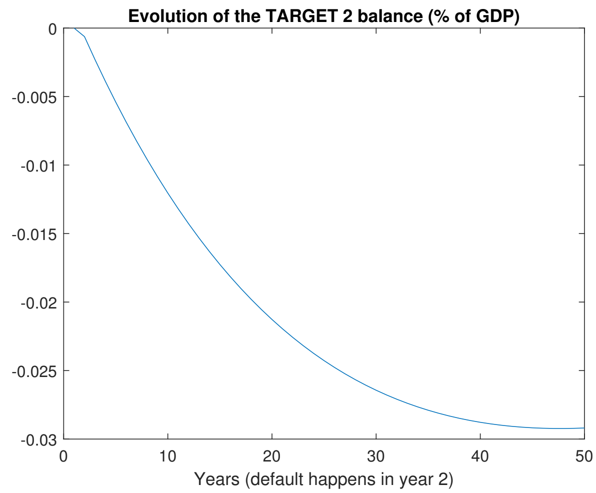
We use the same value of λ as for cash, and we choose $\phi^X = 0.0045$ so that in the initial steady state the central bank has assets in the amount 25% of GDP. On the liability side, in addition to cash (about 6.8% of GDP), the central bank has about 7.4% of GDP of bank reserves.[16]

We start the economy from the asset position that the central bank would have in a steady state in which it only bought private assets. In period 0, the CB engages in "quantitative easing," purchasing government bonds of both countries in the amount of 25% of GDP; this is a one-time purchase and is then reabsorbed through growth and inflation over time. As mentioned in the model, each national CB buys the bonds of its own government.

Country B may or may not default in period 2 (it will not default in any other period). We set the probability of default at 2%; our results are not sensitive to this parameter. Upon default, country B imposes a 50% haircut on its debt, which represents thus a loss of 12.5% of GDP for the CB. This is a fairly benign scenario: the CB starts with a net reserve position of about 11% of GDP, so it barely reaches negative capital. Furthermore, given the relatively low real interest rate, the present value of seigniorage is large, at 31% of GDP (26% coming from cash and 5% from bank reserves).

Even in this benign scenario, 9% of the fiscal cost of the default is born by the taxpayers of country A. To understand how this happens, Figure **??** shows the evolution of country B's Target 2 balance. In our experiment, the effect of default on the Target 2 balance is limited on impact. In our environment, Target 2 imbalances emerge over time. In the absence of a default, the CB would be using some of its profits to reabsorb the reserves issued through quantitative easing. When a default occurs, the missing interest payments on the defaulted debt reduce the resources available to reabsorb reserves, leaving the Eurosystem with more bank reserves than

[16]The balance of assets minus liabilities represents accumulated reserves.



would have happened otherwise. Since bank reserves pay the same interest rate in both countries and we assumed symmetry, some of the greater reserves will transfer to banks in country A, so that country B incurs a Target 2 liability. As we previously discussed, in this environment a Target 2 liability is a way for the CB of country B to appropriate a greater part of the seigniorage raised by the Eurosystem, leading to some mutualization of risk.

We considered two alternative scenarios. First, suppose that QE is larger, at 50% of GDP. While in the baseline case the CB incurs losses only in the period of default and starts earning profits from its net interest margin immediately in the period after default, in this case the net interest payments remain negative for 38 years. In the initial years, the net position of the CB of country B is paying interest on reserves and Target 2 liabilities that exceeds its interest earnings on assets, even though the interest rate on the latter is higher. Without an interest rate differential, the CB of country B would be engaging in a Ponzi scheme and the Target 2 liability would explode. Nonetheless, the seigniorage earned from cash as well as the lower interest rate paid on reserves and Target 2 liabilities compared to assets eventually is enough to restore balance and bring the CB back to profitability. The length of the period in which the CB of country B has negative capital implies a greater temptation for its government to engage in creative accounting and thereby attempt to seize an even greater share of seigniorage.

Finally, suppose that in period 1, prior to a default, the Treasury of country B raids the reserves of its central bank. In this case, the proportion of costs shifted to the taxpayers of country A rises to 16%, and the Target 2 balance reaches a minimum of -18% of GDP.

It is worth noting that, even in this last experiment, the movement in the Target 2 balance is not as large as the one that we already observed in the data. This is likely to be the case because of the symmetry assumption: the prospect of a default is not accompanied by movements of bank deposits across countries.

A The Household Problem

In each country i the representative consumer's preferences are given by[17]

$$u(c_0^i) + v(\omega_0^i) - \phi y_0^i + E_0 \sum_{t=1}^{\infty} \beta^t [u(c_t^i) + v(\omega_t^i) - \phi y_t^i],$$

where c_t is consumption of residents of country i in period t that is paid out of cash, ω_t^i is consumption paid out of reserves, and y_t^i is labor supplied in period t.[18] There is a technology with constant returns to scale that produces one unit of either consumption good for each unit of time worked.

In each period, each household cannot consume what it produces, but it rather has to purchase its consumption from an anonymous market; in some markets only cash is accepted, and in others only reserves, so that the following constraints must hold:

$$m_t^i \geq P_t c_t^i$$

and

$$x_t^i \geq P_t \omega_t^i$$

where m_t^i and x_t^i are money and reserve balances held by the individual household.

[17] Bassetto and Messer [3] allow for periods in which the discount factor is greater than one, so that the zero bound on nominal interest rates may be binding for a central bank that attempts to target stable prices. We neglect this element here. While Bassetto and Messer lump required reserves with cash and assume no liquidity role for excess resrves, for our purposes it is better to separate the two and lump together all reserves, that may provide a liquidity role separate from that of cash.

[18] Lowercase variables represent choices by the households, while uppercase variables represent choices by a government agency, either the Treasury or a central bank.

Capital markets are integrated, so that households can save in bonds of either country, borrow from the central bank, or invest in state-contingent private securities α_t. Define w_t as the nominal wealth in the hands of households at the beginning of period t and ω_t its net asset position against other households. We have

$$w_t = b_{A,t-1} - a_{t-1} + b_{B,t-1}(1 - \delta I_t) + m_{t-1} + x_{t-1} + P_{t-1}(y_{t-1} - c_{t-1} - \omega_{t-1}) + \alpha_t. \tag{11}$$

The different time subscripts represent the fact that public bonds are nominally risk free (other than for the event of a default), so that their promised repayment in period t is set in period $t-1$, while α_t is contingent on time-t shocks (and consequently so is w_t).

Defining $z_{t,s}$ as the stochastic discount factor between periods t and s (representing the intertemporal prices in the market for private loans), the wealth of the households evolves according to the following equation:

$$\begin{aligned} &E_t\left[z_{t,t+1}\left(w_{t+1} - b_t^A + a_t - b_t^B(1 - \delta I_{t+1}) - m_t - x_t - P_t(y_t - c_t - z_t)\right)\right] \\ &+\frac{b_t^A - a_t}{1 + R_t^A} + \frac{b_t^B}{1 + R_t^B} + m_t + \frac{x_t}{1 + R_t^X} + T_t \leq w_t \end{aligned} \tag{12}$$

Households are also subject to a lower bound on real wealth $w_t/P_t \geq \underline{w}$, which is not binding in any period, but prevents Ponzi schemes.

The necessary and sufficient conditions for household optimality require

$$u'(c_t) = \phi(1 + R_t^A), \tag{13}$$

$$v'(\omega_t) = \phi\frac{1 + R_t^A}{1 + R_t^X}, \tag{14}$$

$$z_{t,t+1} = \frac{\beta P_t(1 + R_{t+1}^A)}{P_{t+1}(1 + R_t^A)}, \tag{15}$$

$$E_t z_{t,t+1} = \frac{1}{1 + R_t^A} \Longrightarrow 1 = \beta E_t\left[\frac{P_t(1 + R_{t+1}^A)}{P_{t+1}}\right], \tag{16}$$

$$\frac{1}{1 + R_t^B} = \beta E_t\left[z_{t,t+1}(1 - \delta I_{t+1})\right], \tag{17}$$

and the present-value budget constraint

$$\begin{aligned} &w_0 \geq T_0 + m_0\frac{R_0^A}{1 + R_0^A} + x_0\left(\frac{1}{1 + R_0^X} - \frac{1}{1 + R_0^A}\right) \\ &+\sum_{s=1}^{\infty} z_{0,s}\left[T_s + m_s\frac{R_s^A}{1 + R_s^A} + x_s\left(\frac{1}{1 + R_s^X} - \frac{1}{1 + R_s^A}\right) + P_{s-1}(y_{s-1} - c_{s-1} - \omega_{s-1})\right], \end{aligned} \tag{18}$$

where no arbitrage implies $z_{0,s} := \prod_{t=1}^{s} z_{t-1,t}$.

The competitive equilibrium conditions are the same as above, plus market clearing, which requires $y_t = c_t + \omega_t$ and that the household demand for government bonds is equal to their supply. Using market clearing, in equilibrium equations (18) and (11) yield (3) in the main text.

B A brief overview of ECB's monetary policy operations: implementation and risk sharing agreements

Most of the Eurosystem's monetary policy operations are carried out in a decentralised way, however their implementation and risk sharing agreements differ from program to program.

During standard open market operations (MROs, LTROs, fine tuning, and structural operations) and non-standard longer term refinancing operations (TLTROs and three years LTROs) each NCB collects bids for central bank liquidity from local institutions and manages the collateral provided (the ECB provides a list of eligible assets) keeping them in their balance sheets. Despite their decentralized nature, the risk associated with all these refinancing operations is fully shared among the Eurosystem's NCBs in proportion to their capital key (article 32.4 of the ESCB Statute).

In quantitative easing programs (the Asset Purchase Programme started in 2014 and the recent Pandemic Emergency Purchase Programme), the Eurosystem expands its global balance sheet buying asset-backed securities (ABSPP), covered bonds (CBPP3), corporate sector bonds (CSPP), and public sector securities (PSPP and PEPP).

The PSPP (approximately 85% of the whole APP) and the PEPP are, in terms of magnitude, the most relevant. Under the PSPP and the PEPP the Eurosystem buys sovereign bonds from euro-area governments according to each country's NCB share of the ECB's capital ('capital key'), and securities from european institutions and national agencies. Purchases are carried out by both the ECB (20% of the total), and each of the NCBs (the remaining 80%). NCBs focus exclusively on their home market, and thus hold only their own country's debt. From a risk sharing perspective, PSPP and PEPP are different from open market operations, as the sovereign bonds default risk is not shared: each NCB bears in full the risk on the bonds it has on its balance sheet, that represent the 90% of the total sovereign bonds purchased (the other 10% is held by the ECB). In terms of profits, when it comes to compute the monetary income to be pooled and shared, these holdings are considered to bear interest at the marginal rate used by the Eurosystem for MROs, any extra profit remains therefore to the NCB.

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