



Federal Reserve Bank of Chicago

**Fiscal Consequences of Paying Interest
on Reserves**

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Fiscal Consequences of Paying Interest on Reserves*

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Abstract

We review the role of the central bank's (CB) balance sheet in a textbook monetary model, and explore what changes if the central bank is allowed to pay interest on its liabilities. When the central bank cannot pay interest, away from the zero lower bound its (real) balance sheet is limited by the demand for money. Furthermore, if securities are not marked to market and the central bank holds its bonds to maturity, it is impossible for the central bank to make losses, and it always obtains profits from being a monopoly provider of money. When the option of paying interest on liabilities is allowed, the limit on the CB's balance sheet is lifted. In this case, the CB is free to take on interest rate risk, e.g. by buying long-term securities and financing those purchases with short-term debt that pays the market interest rate. This is a risky enterprise that can lead to additional profits but also to losses. To the extent that losses exceed the profits of the monopoly operations, the CB faces two options: either it is recapitalized by Treasury, or it increases its monopoly profits by raising the inflation tax.

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1 Introduction

The financial crisis of 2008 and its aftermath have brought about dramatic changes in the balanced sheet of the central banks (CBs) of the largest economies in the world. Faced with the inability to wield their traditional policy instrument, which effectively hit the zero lower bound on short-term rates, CBs greatly expanded their balance sheet. While these purchases entailed a variety of assets in the immediate aftermath of 2008, they have since concentrated on bonds (particularly long-term) issued or guaranteed by the governments of their economies; as an example, Figures 1 and 2 show the case of the Federal Reserve in the United States. This expansion

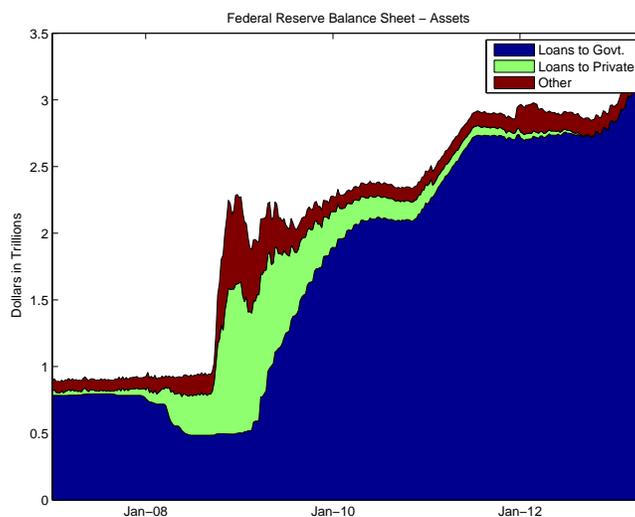


Figure 1: Federal Reserve Assets by Major Category since 2007

was financed in large part by deposits, as shown in Figure 3.¹ At the beginning of the crisis, in September 2008, while the Fed funds rate was still well above zero and the Fed was not yet allowed to pay interest on reserves, these deposits were held by the U.S. Treasury; but since then they have been largely deposits of commercial banks. Not since the Great Depression has the balance of deposits of commercial banks been so large compared to their minimum required reserves. With slight differences in timing, a very similar picture arises in the case of the European

¹See the appendix for definitions.

Central Bank and the Bank of England (Figures 4 and 5 in the appendix).

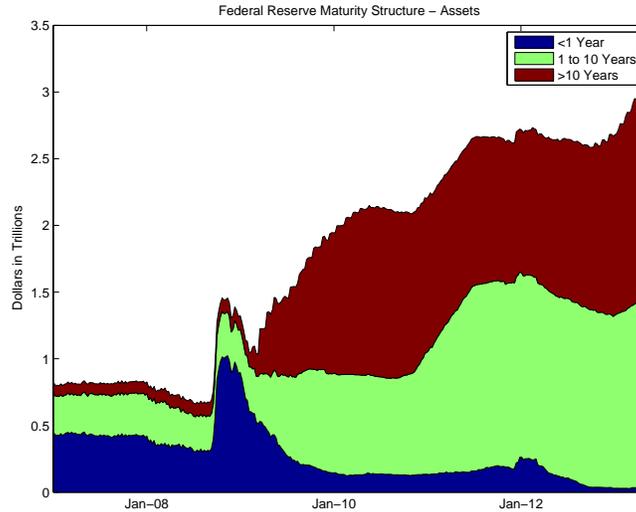


Figure 2: Maturity Structure of Federal Reserve Assets since 2007.²

Just as it took years for the expansion in the CBs’ assets to take place, it is likely that years will also pass before their balance sheet will return to resemble its pre-2008 composition, with liabilities dominated by currency notes.³ During this transition, excess reserves deposited by commercial banks will have to be paid the market short-term rate. If the transition will not be complete by the time when CBs will desire to lift short-term rates from zero to contain inflationary pressures, paying interest on reserves will thus be necessary.

Our goal is not to assess the role that large-scale asset purchases played in the pursuit of monetary policy objectives; indeed, our analysis is based on a simplified model where no such role is present. Our goal is to review instead the *fiscal* implications of such purchases. The starting point of our analysis is Sargent and Wallace’s [14] insight that monetary and fiscal authorities are eventually forced to coordinate because they face a single, consolidated budget constraint, to which seigniorage revenues contribute.⁴ We go beyond Sargent and Wallace by unbundling the

²This graph only includes Liquidity and Credit Facilities, Securities held Outright, TALF, Repurchase agreements, and central bank liquidity swaps, for which maturity data is readily available.

³Bank excess reserves remained elevated into the 1940s in the aftermath of the Great Depression.

⁴The role of nominal debt in this connection has been explored more recently by Leeper [11], Sims [15],

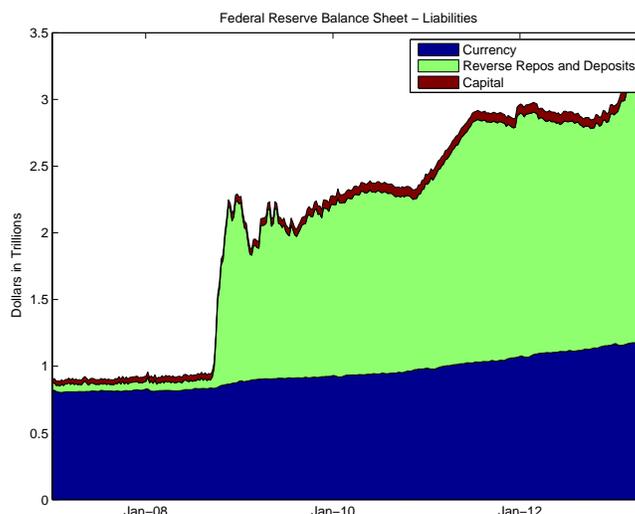


Figure 3: Federal Reserve Liabilities by Major Category since 2007

budget constraints of the government and the CB. In a world in which the latter is simply an agency under direct control of the executive, there is no reason to distinguish between CB and Treasury liabilities. But things change when monetary policy is conducted by an “independent” CB, formally tasked with objectives, such as price and macroeconomic stability, that may conflict with the desires of fiscal authorities. In this case, it is conceivable that the magnitude of its profits and losses, as well as its transfers to fiscal authorities, may ultimately have an effect on the way fiscal-monetary coordination will occur. The CB may find it easier to concentrate on its mandate if it generates a steady stream of profits that can be transferred to Treasury. In contrast, it might find its independence under threat when it books losses, particularly in the extreme case in which these were so large as to require reverse transfers.

To analyze the implications of different asset-management policies of the CB, we rely on a highly stylized, commonly used model of a monetary economy.⁵ After displaying the linkages between the budget constraints of Treasury and the central bank, confirming Sargent and Wallace [14], we focus on the way different balance sheet choices of the CB affect the riskiness of Woodford [18], Bassetto [2, 3], and Cochrane [6], among others. Sims [16, 17] has discussed in greater detail how the balance sheet of the CB affects its ability to achieve price level determinacy.

⁵Our model is based on Lucas and Stokey [12].

its position. Through a sequence of propositions, we show how increasingly aggressive portfolio management strategies by the CB increase the risk of losses that would reduce (and, in extreme circumstances, erase or more than erase) the seigniorage transfers that can be paid to Treasury.

We identify quantitative easing, defined as purchases of long-term bonds financed with the creation of excess reserves, as a qualitative breakpoint in the fiscal risk implied by CB policy. To better understand this breakpoint, an analogy with an individual investor is helpful. An individual investor buying bonds using its own assets may face losses on its portfolio, but may never lose more than the entire value of its initial capital. In contrast, an investor taking a leveraged position in bonds may lose more than its capital (although, of course, such a loss may be extremely unlikely if the leverage ratio is small). Compared to the portfolio of an individual investor, the balance sheet of a central bank is more complicated, in that it involves a significant amount of liabilities (currency) that pay no interest. Moreover, unlike the period of the gold standard, contemporary CBs do not back their currencies with assets, but rather money is irredeemable and takes value simply because of the liquidity services that it provides (money is “fiat”). For this reason, in computing the point at which a CB position becomes leveraged, liabilities in the form of currency (and required reserves) can be neglected.

Our paper is closely related to independent work by Hall and Reis [9], who also identify excess reserves as a force driving the CB to potential losses and study the implications for the conduct of monetary policy; Hall and Reis show that quantitatively the Federal Reserve and the European Central Bank are unlikely to face losses that would threaten their ability to keep prices stable in the absence of a recapitalization.⁶ In our work, we discuss the budget constraints of the fiscal, as well as the monetary authorities, and emphasize the similarity in the debt instruments managed by the central bank and Treasury. We are ultimately interested in the question of how the power to take fiscal risk is allocated across the two agencies, how coordination should be managed, and what institutional rules could foster proper management. Answering this question requires an explicit theory of the objectives of fiscal and monetary authorities, and the way

⁶Similar projections are also contained in Carpenter et al. [5] and Greenlaw et al. [8].

different asset-management constraints affect their strategic interaction; we leave this step to future research.

2 The Setup

Our analysis is based on a very stylized model based on an economy that features flexible prices and special assumptions about preferences, but the implications we discuss generalize to much richer environments, with more complex preferences and potentially many other frictions. We relegate the full description of the microfoundations of the model to the appendix and concentrate here on the essential elements.

The economy features a continuum of private households and a government, separated into two agencies: “Treasury” and the “central bank” (CB). For each one of these two agencies, we keep the model as simple as possible by only including their functions and the budget items that are relevant for our discussion.

Treasury issues government bonds of different maturities. We assume that there are just two maturities: one-period bonds, and consols, that promise a payment into the indefinite future. We denote by B_t the nominal amount of one-period bonds that are issued in period t and need to be repaid in period $t + 1$, and by D_t the coupons due at the beginning of period t on all outstanding consols. Let R_t be the nominal interest rate between periods t and $t + 1$ and Q_t be the price of a consol in period t . To repay its debts, Treasury has the power to levy (lump-sum) taxes; let T_t be their nominal amount in period t . We abstract from government spending.

The CB’s liabilities are “money” and “excess reserves.” Money is interpreted here in the narrow sense of currency held by the private sector and required reserves. It has the unique feature of being monopolistically provided by the CB and it thus represents the source of CB profits. In contrast, excess reserves do not provide households any liquidity services beyond those that are also provided by short-term government debt; as a consequence, households will only hold them if they pay the same interest rate R_t as one-period debt. We let M_t be money that can be used in transactions in period t and X_t be the amount of excess reserves at the beginning

of period t . On the asset side, the CB may hold government debt of either maturity.⁷ We assume that the CB cannot (or does not) sell government bonds short. Otherwise, the CB could circumvent a ban on paying interest on reserves simply by selling short-term Treasury bonds short. Treasury and the CB are linked by remittances (seigniorage), whose amount in period t is S_t . When $S_t > 0$, these represent distributions of profits from the CB to Treasury; this is the ordinary direction of transfers that we observe in the data. $S_t < 0$ indicates a recapitalization of the CB by Treasury.

The actions of Treasury and the CB are subject to their budget constraint. It is customary in macroeconomic models to lump the two constraints into one, since in practice Treasury is a residual claimant of the profits of the CB (through the seigniorage payments S_t) and, from a purely economic perspective, the distinction between the two agencies is superfluous. However, as we emphasized in the introduction, there are several reasons why the balance sheet of the CB may affect its ability and/or willingness of entertaining alternative policy options and its independence. We thus consider the two as separate budget constraints.

On a period-by-period basis, the budget constraint for Treasury is given by the following:

$$B_{t-1} + D_{t-1} = \frac{B_t}{1 + R_t} + Q_t(D_t - D_{t-1}) + S_t + T_t. \quad (1)$$

At each period t , the left-hand side of equation (1) represents the Treasury's repayment commitments: B_{t-1} to the holders of short-term debt, and a coupon D_{t-1} to the holders of consols. The right-hand side represents the sources of funds: taxes from the private sector (T_t), seigniorage transfers from the central bank to Treasury (S_t), new issuance (or repurchase, if negative) of consols ($D_t - D_{t-1}$, valued at the consol price Q_t), and new issuance of short-term debt (B_t , discounted at the current short-term nominal interest rate R_t).

For the central bank, the budget constraint in period t is

$$M_t - M_{t-1} = \frac{B_t^B}{1 + R_t} - B_{t-1}^B + Q_t(D_t^B - D_{t-1}^B) - D_{t-1}^B + S_t - \frac{X_t}{1 + R_t} + X_{t-1} \quad (2)$$

⁷We assume that the central bank only holds government debt. The analysis could readily be extended to the case in which the assets include privately-issued debt; in this case, in addition to interest-rate risk discussed in this paper, the central bank is also subject to credit risk.

Here, B_t^B and D_t^B are central bank holdings of short-term and long-term Treasury debt respectively. Equation (2) shows all the possible sources of growth in the supply of money (as defined above). The central bank must increase the money supply if it decides to acquire more short-term debt than needed to roll over existing debt; similarly, it grows the money supply if it purchases new consols with value in excess of the coupon payment on existing holdings, or if it increases its remittances to Treasury. Finally, the money supply increases if the central bank uses it to repay some of its own interest-bearing liabilities (excess reserves), rather than rolling them over. A contraction in the money supply can be achieved by any combination of these factors in reverse.

The economy starts at time 0 with some initial stock of bonds, money, and excess reserves, described by $(B_{-1}, D_{-1}, B_{-1}^B, D_{-1}^B, X_{-1}, M_{-1})$.

From the terms in equation (2) it will be useful to identify the profits of the CB, which we define in two ways, depending on whether assets are carried at their historical cost or marked to market. In period t , profits at historical cost are given by

$$\Pi_t^{HC} := \frac{R_{t-1}}{1 + R_{t-1}}(B_{t-1}^B - X_{t-1}) + D_{t-1}^B + (Q_t - \bar{Q}_{t-1})(D_{t-1}^B - D_t^B)I_{D_{t-1}^B > D_t^B}, \quad (3)$$

where $I_{D_{t-1}^B > D_t^B}$ is an indicator function that is 1 if $D_{t-1}^B > D_t^B$ and 0 otherwise, and \bar{Q}_t is the average historical cost of consols held by the central bank at the end of period $t - 1$.⁸ The first term of equation (3) represents net interest receipts on short-term debt instruments: the CB earns profits from its holdings of government debt, but makes losses when it pays interest on excess reserves. The second term represents the coupon payments on consols held at the beginning of the period. Finally, the last term, which is present only if the central bank sells long-term debt during the period, represents the realized capital gain (or loss, if negative) on the sale.

The corresponding expression for profits when assets are marked to market is⁹

$$\Pi_t^{MM} := \frac{R_{t-1}}{1 + R_{t-1}}(B_{t-1}^B - X_{t-1}) + D_{t-1}^B + (Q_t - Q_{t-1})D_{t-1}^B. \quad (4)$$

⁸Starting from some initial condition \bar{Q}_{-1} , \bar{Q}_t is defined recursively as $\bar{Q}_t = \bar{Q}_{t-1}$ if $B_t^D \leq B_{t-1}^D$, and $\bar{Q}_t = (B_{t-1}^D/B_t^D)\bar{Q}_{t-1} + (1 - B_{t-1}^D/B_t^D)Q_t$ otherwise.

⁹Since we assumed all of the CB liabilities to be short term, there is no issue of marking liabilities to market.

Compared to equation (3), the first two terms are identical, but now profits (or losses) are measured taking into account both realized and unrealized capital gains.

The flow budget equations above will play an important role in our discussion of payments across different actors. Of independent interest are the present-value budget constraints, which can be computed by rolling equations (1) and (2) forward and imposing long-run balance:

$$B_{t-1} + (1 + Q_t)D_{t-1} = \sum_{s=t}^{\infty} PV_t(S_s + T_s) \quad (5)$$

and

$$B_{t-1}^B + (1 + Q_t)D_{t-1}^B - X_{t-1} + \sum_{s=t}^{\infty} PV_t(M_s - M_{s-1}) = \sum_{s=t}^{\infty} PV_t(S_s), \quad (6)$$

where the function PV_t represents the present value computed as of time t ; details of the PV function are provided in the appendix.

Equation (5) shows that the value of government debt at the beginning of period t is equal to the present value of future taxes and seigniorage transfers that will be used to repay it.

In equation (6), the left-hand side represents the net value of the central bank at the beginning of period t . This is represented by two components. The first component represents the value of holdings of government debt (which are assets for the CB), net of money and excess reserves (liabilities). The second component, represented by the infinite sum, stems from the monopoly privilege granted to the central bank to issue money, a liability that carries no interest but is still valued by the private sector for its liquidity services. This term captures the present value of monopoly profits that will accrue to the central bank from period t onwards. The net value of the CB matches the present value of seigniorage distributed to Treasury, the right-hand side of equation (6).¹⁰

We complete the description of the economy by the following three equations, that characterize the behavior of the private sector in each period t (a full description of the microfoundations of these equations appears in the appendix):

$$\frac{M_t}{P_t} = L(R_t), \quad (7)$$

¹⁰It is natural to think of these as dividend payments, treating Treasury as the true owner of the CB. Alternatively, this can be viewed as a tax on the CB.

$$1 = \beta_t E_t \left[\frac{P_t}{P_{t+1}} (1 + R_{t+1}) \right], \quad (8)$$

and

$$Q_t = \frac{1}{1 + R_t} \left\{ 1 + \beta_t E_t \left[(1 + R_{t+1}) \frac{P_t}{P_{t+1}} Q_{t+1} \right] \right\}, \quad (9)$$

where E_t represents the expected value as of time t , P_t is the price level in period t , and β_t is an exogenous shock to the real interest rate,¹¹ which is the only source of extrinsic uncertainty in the model.

Equation (7) represents money demand, and shows that real money balances (money divided by the price level) are a (decreasing) function of the opportunity cost of holding money, which is the nominal interest rate.

Equation (8) is a Fisher equation that relates nominal interest rates and inflation: in high-inflation environments, households require higher nominal rates to willingly hold government debt (or central bank excess reserves).¹²

Finally, equation (9) recursively links the price of a consol to current and future expected interest rates. In the absence of uncertainty, the equation would simplify to $Q_t = (1 + Q_{t+1}) / (1 + R_t)$: the value of a consol in period t would be equal to the discounted value of its dividend in period $t + 1$ (which is 1) and its price in period $t + 1$ (Q_{t+1}). In the presence of uncertainty, the more-complicated expression (9) takes into account of the covariance between future interest rates and inflation, and it encompasses a risk premium that may make long-term rates higher than short-term rates on average.

An additional condition, that we directly imposed, states that any excess reserves held by the public must yield the same return as short-term debt. Hence, if the short-term rate R_t is greater than zero and the CB is not allowed to pay interest on reserves, X_t will necessarily be zero.

¹¹As commonly done in the literature (e.g., Eggertsson and Woodford [7]), this is introduced as a preference shock. In practice, it is a shortcut for a shock that affects financial intermediation, and, through that channel, the desire of households to save and (in a richer model) to invest.

¹²Equation (8) links inflation between period t and $t + 1$ to the nominal interest rate between period $t + 1$ and $t + 2$. As discussed in Carlstrom and Fuerst [4], this is a consequence of assuming the “cash-in-advance” timing. Our results would be equivalent under alternative timing assumptions in which R_{t+1} is replaced by R_t .

A (competitive) equilibrium \mathcal{C} is thus a sequence of asset balances $(M_t, X_t, B_t, D_t, B_t^B, D_t^B)_{t=0}^\infty$, of taxes and seigniorage transfers $(T_t, S_t)_{t=0}^\infty$, of asset prices (R_t, Q_t) and present-value operators PV_t such that equations (1), (2), (5), (6), (7), (8), (9), and (12) hold. Whenever these equations are satisfied, households find it optimal to hold money and excess reserves in amounts M_t and X_t respectively, as well as short-term bonds and consols in amounts $B_t - B_t^B$ and $D_t - D_t^B$ (what is issued by Treasury, net of CB holdings).

3 Properties of Equilibria

Having characterized the equilibrium conditions, we are now ready to study its properties. Our first step is to establish an economic equivalence proposition. This proposition formally states that, in our simple model, the timing of taxes and seigniorage transfers from the CB to Treasury is irrelevant; only their present values matter. Since taxes are non-distorting in our economy, Ricardian equivalence holds, as in Barro [1].¹³ Furthermore, the dividend policy followed by the CB in distributing its profits to Treasury is economically irrelevant: as an example, in a period in which the CB makes large profits, it does not matter whether it immediately distributes them to Treasury or whether instead it distributes them over time, purchasing short-term Treasury debt with the retained earnings in the meantime.

Proposition 1 *Let \mathcal{C}_1 be a competitive equilibrium. It is then possible to construct many other equilibria as follows:*

1. *By changing the timing of taxes:*

- *Given some arbitrary period t_1 and some arbitrary state of nature realized in period t_1 , increase (decrease) taxes in period t_1 by ΔT ;*

¹³The proposition would be simpler to state if the economy featured complete markets; in this case, taxes and seigniorage payments could be varied in arbitrary ways both across time and states of nature as long as their present values are unaffected. Since we do not allow arbitrary contingent contracts across agents, the proposition considers only a specific class of tax and payment shifts, that can be financed with appropriate issuance of short-term debt.

- In each subsequent period s up to some other arbitrary period $t_2 > t_1$, increase (decrease) short-term borrowing by Treasury (B_s) by $\Delta T \prod_{v=t_1}^s (1 + R_v)$;
- Decrease (increase) taxes in period t_2 by $\Delta T \prod_{v=t_1}^{t_2-1} (1 + R_v)$.

2. By changing the timing of seigniorage remittances:

- Given some arbitrary period t_1 and some arbitrary state of nature realized in period t_1 , increase (decrease) seigniorage transfers in period t_1 (S_{t_1}) by ΔS ;
- In each subsequent period s up to some other arbitrary period $t_2 > t_1$, decrease (increase) short-term borrowing by Treasury (B_s) by $\Delta S \prod_{v=t_1}^s (1 + R_v)$;
- Between periods t_1 and t_2 , decrease (increase) holdings of short-term debt the CB (B_s^B) by $\Delta S \prod_{v=t_1}^s (1 + R_v)$; alternatively, increase (decrease) excess reserves (X_s) by the same amount;
- Decrease (increase) seigniorage transfers in period t_2 by $\Delta S \prod_{v=t_1}^{t_2-1} (1 + R_v)$.

Proof. Equations (5), (6), (7), (8), (9), and (12) are unaffected by these changes, since they are constructed in a way that alters only the timing, but not the present value of taxes and seigniorage revenues. Similarly, it is straightforward to verify that the debt adjustments described in the proposition are exactly those that are needed to ensure that equations (1) and (2) continue to hold. The new sequences thus satisfy all the conditions for a competitive equilibrium. QED.

The economic equivalence of proposition 1 ignores the reality that Treasury and the CB may make decisions over time, rather than committing to their entire future strategy at time 0, and at times they may have conflicting objectives. Specifically, it is likely that Treasury will be mostly be concerned with the fiscal implications of the seigniorage transfers, while an independent central bank is typically tasked with price and macroeconomic stability. The main rationale for segregating monetary policy in an independent actor is precisely to insulate it from the temptation to resort to the printing press to inflate debt away and to raise seigniorage revenues.

When conflict is present, who controls the size and timing of seigniorage transfers may be important, and this in turn is likely to depend on the balance sheet of the CB. To illustrate this

point with an extreme example, suppose that at time 0 the CB disburses to Treasury more than the value of its initial net assets, plus the entire present value of future seigniorage profits:

$$S_0 > B_{-1}^B + (1 + Q_0)D_{-1}^B - X_{-1} + \sum_{s=0}^{\infty} \text{PV}_0 (M_s - M_{s-1})$$

Using equations (2) and (6) it is easy to verify that, at least in some states of the world, this dividend policy leads the CB to start period 1 with net liabilities that exceed the present value of its future seigniorage profits:

$$X_0 - B_0^B - (1 + Q_1)D_0^B > \sum_{s=1}^{\infty} \text{PV}_1 (M_s - M_{s-1}).$$

This situation is only sustainable if Treasury recapitalizes the CB by sending some reverse transfers in period 1 or in one of the later periods. But by having to rely on transfers from Treasury the CB may see its independence reduced, and this may affect the balance of powers between the two government agencies if their objectives conflict in the future. It is thus quite possible that such a dividend policy would generate incentives to pursue a different monetary-fiscal policy than the one that would be selected if the central bank does not disburse immediately its entire present value of its future profits, and retains instead assets and profits, disbursing the proceeds over time; in particular, a temptation might emerge to resolve the imbalance by printing extra money and thereby raising seigniorage instead.

We already observed from equation (6) that the present value of seigniorage transfers from the CB to Treasury arises from two distinct sources: the value of its asset portfolio, and the monopoly profits on money issuance. In the discussion that follows, a special case will play a prominent role:

Definition 1 We define money to be *fiat* whenever monetary policy is such that $M_s \geq M_{s-1}$ in every period.

We call money fiat in this case because the value of money derives value uniquely from its liquidity services, and not from the CB assets: the CB never uses its assets to redeem any money that it issued in the past. The case of fiat money is particularly relevant because it describes well

the behavior of most contemporary CBs: they increase the money supply both to accommodate real growth, as well as to allow some inflation.

We now proceed as follows:

- We fix an arbitrary desired path for prices (and thus inflation), P_t , as well as an initial nominal interest rate R_0 ; in equilibrium, this determines all future nominal interest rates, present values, and money balances (from equations (7), (8), and (12));¹⁴
- We then study the profits of the central bank and the evolution of its net worth under different policy scenarios that are consistent with the desired path. While M_t and R_t are set by the requirements of the desired path, the CB and Treasury still have freedom in setting different paths for short and long-term debt, excess reserves, taxes, and seigniorage transfers. Through a sequence of simple propositions, we illustrate how the timing and riskiness of the CB profits depend on its choices of asset holdings and reserves.

In particular, we will be interested in two related, but distinct questions:

1. When will the CB be able to guarantee a positive stream of payments to Treasury all along the desired path?¹⁵
2. When will the CB be able to always book positive profits all along the path?

We will consider a sequence of asset-management strategies on the part of the CB, starting from the most conservative policy, where CB profits are guaranteed to be positive independent of the accounting criterion, to the least restrictive one, where the CB is potentially exposed to unbounded losses. We will do so first for the simpler case in which the desired path features nominal interest rates that are always strictly positive. We will then expand the discussion to situations in which the short-term rate may occasionally drop to zero, in which case the distinction between the powers that the CB has with or without the ability to pay interest on reserves is blurred.

¹⁴Fiat money will characterize a subset of these possible desired paths.

¹⁵Throughout the paper, “positive” [“negative”] means greater or equal [less or equal] than 0. Whenever a quantity is strictly greater [smaller] than 0, we will call it “strictly positive” [“strictly negative”].

3.1 $R_t > 0$ Always

3.1.1 Bills Only

We call the most conservative asset-management strategy *bills only*: it entails investing the entire portfolio of assets in short-term securities.¹⁶

Proposition 2 *Suppose that the CB is not allowed (or never chooses) to pay interest on reserves, and that it invests all of its assets in short-term securities. Then its profits are always positive, whether they are measured at historical prices or marked to market.*

Proof. With $R_t > 0$, excess reserves will always be 0 if the CB does not pay interest on them: the private sector will find it preferable to invest in government bonds any funds that are not needed for liquidity services. Furthermore, $D_t^B = 0$ in any period t . From equations (3) and (4) we thus obtain

$$\Pi_t^{HC} = \Pi_t^{MM} = \frac{R_t}{1 + R_t} B_t^B \geq 0. \quad (10)$$

QED.

In general, the profits from equation (10) will always be strictly positive, because the CB holds some assets on its balance sheet. However, they could be 0 if the CB chooses (or is forced to) immediately remit to Treasury a payment equal to its assets in every period. If CB independence is related to its profit stream, the bills-only policy coupled with no excess reserves gives the best case scenario, since the CB is guaranteed to never record losses, either at historical prices or marking its assets to market. When money is fiat, this policy can also guarantee a positive stream of seigniorage transfers, as we establish below:

Proposition 3 *Suppose that the CB is not allowed (or never chooses) to pay interest on reserves, and that it invests all of its assets in short-term securities. In addition, suppose that money is fiat. Then the CB can guarantee a positive stream of seigniorage transfers to Treasury.*

¹⁶The bills only doctrine was introduced in the United States in the aftermath of the Treasury accord of 1951, which freed the Federal Reserve from pegging interest rates on government debt. For a presentation of the arguments discussed at the time, see e.g. Young and Yager [19].

Proof. In the appendix.

Intuitively, since its portfolio of assets is not needed to redeem money issues when money is fiat, the CB can simply pay to Treasury its profits from equation (10) plus the value of any new money that it issued during the period.

3.1.2 Buy and Hold

In the strategy that we call *buy and hold*, the CB invests in both long and short-term debt, but it holds all of its debt to maturity.

Proposition 4 *Suppose that the CB is not allowed (or never chooses) to pay interest on reserves. Suppose further that its assets are invested in both short and long-term debt, but that the CB holds long-term debt to maturity.¹⁷ Then its profits at historical prices are always positive.*

Proof. As before, no interest payment on reserves implies $X_t = 0$ in all periods. Furthermore, since the CB holds its debt to maturity, $D_t^B \geq D_{t-1}^B$ in all periods. Equation (3) then implies

$$\Pi_t^{HC} = \frac{R_{t-1}}{1 + R_{t-1}} B_{t-1} + D_{t-1}^B \geq 0.$$

QED.

While the value of the CB portfolio can now fluctuate with movements in long-term rates, the CB is still investing in assets that command a positive interest rate, and issuing money that pays no interest rate. Under the “buy and hold” strategy, at historical cost the CB simply books as profits the interest on short-term debt and the coupon paid by long-term debt.

We do not discuss here the profits and losses that the CB faces when its assets are marked to market, nor its ability to pay positive seigniorage transfers: this is because the implications of “buy and hold” on these two subjects are the same as “unlevered active trading,” the strategy to which we turn next.

¹⁷In the case of consols, this means that the stock of consols held by the CB never declines in nominal terms; the CB uses only the coupon payments from the consols (along with maturing short-term debt) for reinvestment into new government bonds or for paying seigniorage transfers.

3.1.3 Unlevered Active Trading

Here, we do not make any assumption of the CB's portfolio, other than imposing that it does not pay interest on reserves.

Proposition 5 *Suppose that the CB is not allowed (or never chooses) to pay interest on reserves. Then the CB losses, whether at historical prices or marked to market, cannot exceed the value of the CB portfolio in the previous period (evaluated at historical prices or marked to market, respectively).*

Proof. Once again, no interest on reserves implies $X_t = 0$. From equation (3),

$$\Pi_t^{HC} = \frac{R_{t-1}}{1 + R_{t-1}} B_{t-1}^B + D_{t-1}^B + (Q_t - \bar{Q}_{t-1})(D_{t-1}^B - D_t^B) I_{D_{t-1}^B > D_t^B} \geq -\bar{Q}_{t-1} D_{t-1}^B \geq -B_{t-1}^B - \bar{Q}_{t-1} D_{t-1}^B.$$

From equation (4),

$$\Pi_t^{MM} = \frac{R_{t-1}}{1 + R_{t-1}} B_{t-1}^B + D_{t-1}^B + (Q_t - Q_{t-1}) D_{t-1}^B \geq -Q_{t-1} D_{t-1}^B \geq -B_{t-1}^B - Q_{t-1} D_{t-1}^B.$$

QED.

When the CB invests in long-term securities, movements in long-term interest rates affect the value of its portfolio. Under “buy and hold,” these changes are reflected in the CB's accounting only if it marks its assets to market, while active trading may lead the CB to realize its losses and thus book them even if it values its assets at historical cost.

In either case, the CB can do no worse than losing all of its investments, which would happen in the extreme circumstance in which all of its assets are long term and the long-term interest rate becomes so large that Q_t becomes close to 0.¹⁸ Not surprisingly, in the case of fiat money, when assets are not needed to redeem previously issued money, such a loss would not threaten the CB's ability to pay positive seigniorage transfers, as the following proposition formally states:

Proposition 6 *Suppose that the CB is not allowed (or never chooses) to pay interest on reserves, and that money is fiat. Then the CB can guarantee a positive stream of seigniorage transfers to Treasury.*

¹⁸To be precise, even in this extreme circumstance the CB would still have positive assets left, from the coupon payment D_{t-1}^B .

Proof. In the appendix.

Even though under fiat money the CB can arrange its payments to Treasury so as to never need to require a reverse transfer (a “bailout”), the potential loss of value of its portfolio will still translate into a smaller present-value of seigniorage transfers to Treasury (equation (6)); this risk may be undesirable to the fiscal authorities.

3.1.4 Quantitative Easing

In our final step, we consider the case in which the CB issues interest-bearing reserves. To the extent that these reserves are invested in short-term government debt, this policy has no effect: the CB buys a debt instrument that promises to pay 1£ in the subsequent period and finances the purchase by issuing a promise to deliver the same amount.¹⁹ But when the CB uses excess reserves to finance purchases of long-term debt, it is effectively taking a levered bet on long-term interest rates. Because of its leverage, the CB can no longer guarantee that the value of its portfolio will remain positive, independent of movements in long-term rates. If the CB position is sufficiently large, the losses from this bet will thus need to be covered with profits from the monopoly over the issuance of money, or, in extreme circumstances in which not even those are sufficient, with transfers from Treasury. This intuition is formalized in the following proposition.

Proposition 7 *Suppose that the CB is allowed to pay interest on reserves, and that the path of future long-term interest rates is uncertain. Then the CB is free to choose policies that entail the risk of arbitrarily large losses. Some of these trading strategies will require transfers from Treasury to the CB to keep inflation at the preset desired path.*

Proof. In the appendix.

In our highly stylized model, where there is no cost of raising taxes, fiscal losses (whether incurred by the CB or by Treasury) carry no welfare consequences. This is no longer the case

¹⁹In practice, excess reserves held by banks at the CB are overnight loans, while government debt is of longer maturity. At the height of a financial crisis, this difference may be important. For the fiscal implications considered here, a CB policy of purchasing short-term debt (e.g., of a 3-month maturity) by issuing overnight reserves will still carry very low interest rate risk.

in environments where taxes are distortionary. Long-term debt will be particularly helpful if strains on the government budget are associated with higher long-term interest rates, a likely event in practice. Lustig, Sleet, and Yeltekin [13] study the case of distortionary taxes in detail and formally prove that the maturity structure that minimizes expected distortions arising from taxes and inflation involves issuing only long-term debt. In this case, expected tax distortions increase if the CB engages in maturity transformation by replacing long-term debt issued by Treasury with short-term obligations of its own.

The fact that the CB *can* take risks large enough that would require a recapitalization does not need that it *will* do so. As an example, Carpenter et al. [5] and Greenlaw et al. [8] compute some projections of the balance sheet of the Federal Reserve; under adverse scenarios, they establish that these could lead to losses according to the accounting developed here,²⁰ but these losses would be very minor compared to the present value of seigniorage revenues going forward.

In proposition 7, as well as in all previous propositions, we kept the stochastic process for inflation, nominal interest rates, and money fixed. Because of this assumption, the CB profits and losses only had fiscal implications, affecting the size (and, in extreme cases, the sign) of seigniorage transfers to Treasury, and from there would spill over to taxes. But inflation, (nominal) interest rates, and the money supply are under CB control. This suggests that a CB facing losses always faces a second alternative: resorting to the printing press. To better understand this alternative, suppose that a CB starts period t in a situation such that, at the desired path of inflation, nominal interest rates, and money balances, the left-hand side of equation (6) is negative, which would require (sooner or later) a transfer from Treasury. The CB liabilities are made of 2 items, both of which can be discharged with no need of transfers from Treasury, provided the CB is willing to let money grow sufficiently fast and suffer the inflationary consequences:

- Promises to decrease the money supply (when $M_s < M_{s-1}$) can be avoided simply by never repurchasing previously issued money, but rather choosing an increasing path for the

²⁰What is called losses in this paper is called a “deferred asset” in Carpenter et al. [5] and Greenlaw et al. [8]. This is consistent with a view that seigniorage payments are not profits distributed to Treasury, but rather a tax paid by the Federal Reserve. According to this interpretation, current losses could be used to reduce future seigniorage payments, and thus future tax liabilities, thereby resulting in a “deferred asset.”

money supply.

- Excess reserves X_t are simply a promise to deliver money, so they can be discharged by increasing the money supply by X_t in period t (in equation (6), this will generate a corresponding increase in the profits from the monopoly issuance of money).

3.2 The Zero Lower Bound

Propositions 2-7 rely on the fact that excess reserves are necessarily zero unless the CB pays interest on them. However, whenever the nominal interest rate R_t is at 0, this is no longer the case: the distinction between paying or not paying interest on excess reserves is lost. This has effectively been the case in the last few years.

The following proposition shows that excess reserves cannot cause losses on the CB balance sheet, whenever they are invested according to the “bills only” doctrine. This result is intuitive: any excess reserves are matched by assets of the same maturity, and hence no loss can arise from their issuance. The only qualification that is required for the case in which R_t may hit zero is that the CB should never distribute transfers to Treasury in such an amount that it would lead its portfolio of assets to have negative value.²¹

Proposition 8 *Suppose that the CB invests all of its assets in short-term securities, and that its dividend policy is such that $B_t - X_t \geq 0$ always. Then its profits are always positive, whether they are measured at historical prices or marked to market. When money is fiat and the CB starts from an initial portfolio of positive value, this policy can be achieved while paying positive transfers in every period, $S_t \geq 0$.*

Proof. After imposing $D_t^B = 0$, equations (3) and (4) imply

$$\Pi_t^{HC} = \Pi_t^{MM} = \frac{R_t}{1 + R_t}(B_t^B - X_t),$$

which is positive whenever $B_t^B - X_t$ is positive. If the CB starts from an initial condition $B_{-1} - X_{-1} \geq 0$ and the money supply is an increasing sequence (money is fiat), equation (2)

²¹In the case of $R_t > 0$, this was guaranteed, since we necessarily had $X_t = 0$.

implies that the CB can set $S_t = M_t - M_{t-1} + B_{t-1}^B - X_{t-1} \geq 0$ and still retain a portfolio of zero value ($B_t^B = X_t$) from period 0 onwards. QED.

While the bills-only doctrine ensures the CB against losses on its balance sheet, it also makes monetary policy particularly ineffective when short-term nominal interest rates are 0, since it is unlikely that swapping Treasury short-term liabilities for CB short-term liabilities would have any effect.

When the CB buys long-term debt, it is straightforward to verify that propositions 4-6 continue to be true if the CB limits its creations of excess reserves to the amount of short-term bills in its portfolio. Further quantitative easing beyond this value involves taking leveraged interest-rate risk, and may cause losses that would need to be repaid with profits from money issuance and/or transfers from Treasury, even if the risk is originally taken at a time in which short-term rates are zero.

4 Conclusion

We have analyzed simple conditions under which central bank policy ensures positive profits and/or positive transfers to Treasury. We did so by use of a highly stylized model, where the results are particularly transparent and easy to derive. Nonetheless, the implications apply equally well to much richer environments featuring nominal frictions, an explicit banking sector, and transaction or regulatory costs that may segment markets for government debt of different maturities. In these environments, more interesting roles for monetary policy and quantitative easing emerge, which are not present in our simple setup;²² a trade-off would then emerge between the pursuit of these roles and the minimization of fiscal risks.

To the extent that financial market imperfections warrant a role for adjusting the maturity structure of the liabilities of the central bank and Treasury, an expansion of the balance sheet of the central banks financed with excess reserves held by commercial banks is only one of many potential arrangements. As an example, on September 17, 2008, with the Fed funds

²²Optimal monetary policy in our stylized economy would call for the “Friedman rule,” where the CB pursues a deflationary policy by repurchasing money over time and keeping nominal interest rates at zero.

target rate still at 2% and while the Federal Reserve did not yet have power to pay interest on reserves (and thus to raise funds from commercial banks at that rate), the U.S. Department of Treasury announced a Supplementary Financing Program,²³ whereby T-Bills would be sold and the cash proceeds would be deposited at the Federal Reserve, which could in turn use the cash to buy privately-issued and mortgage-backed securities, without increasing the overall level of the monetary base. The Treasury deposits with the Federal Reserve did not earn interest; this represented an alternative funding mechanism for quantitative easing that shifted interest rate risk from monetary to fiscal authorities. Similarly, to the extent that a policy of lowering long-term interest rates by shifting the maturity structure held of government debt held by the public is desirable, this goal could be attained either by the policy of quantitative easing pursued by the Federal Reserve and the Bank of England, or by the Treasury's choice of concentrating its issued of debt at the short end of the maturity structure. While the two options have similar implications for the portfolio of securities available to the private sector, they allocate fiscal risk differently between the central bank and the government. A goal of this paper is to stimulate further analysis on how the allocation of this risk is likely to affect macroeconomic outcomes, and ultimately on the optimal allocation of this risk.

A Model Microfoundations.

We consider a model economy populated by a continuum of identical households that consume a single good in each period, produced by working. The consumer's preferences are given by

$$u(c_0) - \phi y_0 + E_0 \sum_{t=1}^{\infty} \left(\prod_{s=0}^{t-1} \beta_s \right) [u(c_t) - \phi y_t],$$

where c_t is consumption in period t and y_t is labor supplied in period t . While we allow for periods in which the discount factor β_s is greater than 1, so that the zero-bound on nominal interest rates may be binding for a central bank that attempts to target stable prices, we assume that there is a period T and a value $\bar{\beta} < 1$ such that $\beta_s \leq \bar{\beta}$ with probability 1 when $s > T$. This assumption could be relaxed, but is convenient to ensure that, in an equilibrium, present-value

²³See <http://www.treasury.gov/press-center/press-releases/Pages/hp1144.aspx>

budget constraints will have to be well defined. There is a technology with constant returns to scale that produces one unit of the 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 with money acquired beforehand; this imposes the following cash-in-advance constraint:²⁴

$$m_t \geq P_t c_t,$$

where m_t are money balances held by the individual household (we thus use lowercase letters for variables that are chosen individually by each household, and uppercase letters for aggregate equilibrium values).

In each period, the household budget constraint is given by

$$\frac{b_t + x_t}{1 + R_t} + Q_t d_t + m_t + T_t \leq m_{t-1} + P_{t-1}(y_{t-1} - c_{t-1}) + b_{t-1} + x_{t-1} + (1 + Q_t)d_{t-1}, \quad (11)$$

where b_t and d_t are household holdings of short and long-term bonds, and x_t are holdings of excess reserves. We also impose a lower bound on household indebtedness in each period (i.e., the lower bound affects $b_{t-1} + x_{t-1} + (1 + Q_t)d_{t-1}$); the lower bound is chosen so as to never be binding in equilibrium, but is there simply to prevent household from rolling over their debt into the indefinite future without ever repaying it, imposing a transversality condition.

Manipulation of the first-order (necessary) conditions of the household problem yields equations (7), (8), and (9), as well as the following expression for the present-value function:

$$PV_t(w_{t+k}) = \frac{1}{z_t} E_t(z_{t+k} w_{t+k}), \quad (12)$$

where w_{t+k} is an arbitrary payoff realized at time $t + k$, and

$$\begin{aligned} z_0 &= u'(C_0)/P_0, \\ z_t &= \left(\prod_{s=0}^{t-1} \beta_s \right) u'(C_t)/P_t \end{aligned} \quad (13)$$

²⁴See Lucas and Stokey [12] for an early formulation of this model, and Lagos and Wright [10] for a deeper justification of this constraint.

These conditions are also sufficient for a competitive equilibrium when the budget constraints (in flow and present-value form) and the transversality condition are satisfied; the transversality condition is in turn implied by the present-value budget constraints (5) and (6).

B Proofs

B.1 Proof of Propositions 3 and 6

Substitute $X_t = X_{t-1} = 0$ in equation (2). In period t , any choice of $0 \leq S_t \leq M_t - M_{t-1} + B_{t-1}^B + (1 + Q_t)D_{t-1}^B$ ensures that $Q_t D_t^B + B_t^B \geq 0$, leaving enough resources to ensure that the CB starts period $t + 1$ with a portfolio of positive value, in addition to the present value of future revenues from money issuance. QED.

B.2 Proof of Proposition 7

Consider an arbitrary period t for which the future price of long-term bonds Q_{t+1} is uncertain. The CB balance available for investment in period t are given by V_t , defined as

$$V_t := B_{t-1}^B + (1 + Q_t)D_{t-1}^B - S_t - X_{t-1} - (M_t - M_{t-1}),$$

where M_{t-1} , M_t , R_t , and Q_t are dictated by the desired equilibrium path. This balance can be allocated in any way that satisfies the budget constraint (2):

$$\frac{B_t^B - X_t}{1 + R_t} + Q_t D_t^B = V_t \quad (14)$$

The value of this portfolio in period $t + 1$ (after some algebra, and using equation (9)) will be

$$B_t^B - X_t + (1 + Q_{t+1})D_t^B = (1 + R_t)V_t + \left[Q_{t+1} - \beta_t E_t \left((1 + R_{t+1}) \frac{P_t}{P_{t+1}} Q_{t+1} \right) \right] D_t^B. \quad (15)$$

If Q_{t+1} is known as of time t , equation (8) implies that the term within brackets is 0, and it does not matter whether the CB invests in long or short-term bonds: with no uncertainty about the price Q_{t+1} , short and long-term bonds must yield exactly the same rate of return between periods t and $t + 1$. However, when Q_{t+1} is uncertain, the term in brackets will be strictly negative (and

strictly positive) with probability greater than 0.²⁵ Provided that the CB chooses to a sufficiently long position in D_t^B , the value of its portfolio could thus turn strictly negative, and unboundedly so. Using equation (15) in the present-value budget constraint of the CB (equation 6) as of period $t + 1$, we obtain

$$(1+R_t)V_t + \left[Q_{t+1} - \beta_t E_t \left((1 + R_{t+1}) \frac{P_t}{P_{t+1}} Q_{t+1} \right) \right] D_t^B = \sum_{s=t+1}^{\infty} \text{PV}_{t+1}(S_s) - \sum_{s=t+1}^{\infty} \text{PV}_{t+1}(M_s - M_{s-1}). \quad (16)$$

For intermediate values of D_t^B , even if the value of the portfolio at $t + 1$ (the left-hand side of equation (16)) is strictly negative, the present value of profits from money issuance may ensure that $\sum_{s=t+1}^{\infty} \text{PV}_{t+1}(S_s) > 0$. But for D_t^B large enough, there are states of the world in period $t + 1$ in which $\sum_{s=t+1}^{\infty} \text{PV}_{t+1}(S_s) < 0$: in these states, the fiscal risk taken by the CB is so large that a transfer from Treasury to the CB is eventually needed to achieve the desired path for inflation and money.

When marked to market, CB profits are given by

$$\Pi_t^{MM} = B_t^B - X_t + (1 + Q_{t+1})D_t^B - \frac{B_t^B - X_t}{1 + R_t} - Q_t D_t^B = R_t V_t + \left[Q_{t+1} - \beta_t E_t \left((1 + R_{t+1}) \frac{P_t}{P_{t+1}} Q_{t+1} \right) \right] D_t^B;$$

once again, arbitrarily high losses are possible provided D_t^B is sufficiently large. Profits at historical prices will coincide with profits marked to market if the CB starts period t with no long-term debt and sells all of its long-term debt in period $t + 1$, so unboundedly large losses are possible even in this case.²⁶

C Description of Data

The graphs pertaining to the assets and liabilities for the Federal Reserve and the liabilities of the European Central Bank and the Bank of England were compiled using data directly from

²⁵That this term cannot always take the same sign follows from a simple no-arbitrage argument, which is omitted here for brevity.

²⁶With some additional algebra that we can skip here, it is possible to prove that unboundedly large losses at historical cost are possible even if the CB follows a “buy and hold” strategy. These losses occur in subsequent periods, in which the short-term interest rate paid on excess reserves may exceed the rate of return on the CB’s holdings of long-term debt.

their web sites. For the Federal Reserve, data comes from the Federal Reserve’s balance sheet.²⁷ For the European Central Bank, data comes from the ECB Eurosystem Statistical Warehouse.²⁸ Finally, for the Bank of England, data comes from the Statistical Interactive Database.²⁹

To construct the Federal Reserve graph of assets, we constructed three categories - Loans to Government, Loans to Private Institutions, and Other. In the “Loans to Government” category, we include all securities held outright (Treasury bills, Treasury notes, Treasury bonds, agency debt, mortgage-backed securities, unamortized premiums and unamortized discounts).³⁰ In the “Loans to Private Institutions category,” we include Maiden Lane I, Maiden Lane II, Maiden Lane III, TALF, CPFF, and TAF. Finally, in the “Other” category, we include gold stock, special drawing rights, Treasury currency outstanding, float, central bank liquidity swaps, and foreign currency denominated assets, and other assets.

The basic construction of the three liabilities graphs all follow a similar breakdown - currency that does not pay interest, liabilities that could pay interest, and other (mostly capital).

To construct the Federal Reserve graph of liabilities, we constructed three categories - Currency, Reverse Repos and Deposits, and Capital. In the Currency category, we include currency in circulation. In the Reverse Repos and Deposits category, we include reverse repurchase agreements, Treasury Cash Holdings, Deposits, and Reserves. Finally, in the Capital category, we include other liabilities and capital.

To construct the European Central Bank graph of liabilities, we constructed three categories - Currency, Deposits and Other, and Capital and Reserves. In the Currency category, we include banknotes in circulation. In the Deposits and Other category, we include current accounts, the deposit facility, fixed-term deposits, fine tuning reverse operations, deposits related to margin calls, other liabilities denominated in world, debt certificates issued, other euro-denominated liabilities, and Special Drawing Rights allocated by the IMF. In the Capital and Reserves category,

²⁷http://www.federalreserve.gov/monetarypolicy/bst_fedsbalancesheet.htm

²⁸<http://sdw.ecb.europa.eu/browse.do?node=bbn129>

²⁹<http://www.bankofengland.co.uk/boeapps/iadb/BankStats.asp?Travel=NIxSTxTBx>

³⁰Agency debt and mortgage-backed securities are technically not issued by the government, but we treat them as part of the loans to the government, since their repayment was guaranteed by the government during the financial crisis, and it is widely believed that they will continue to be guaranteed in the future.

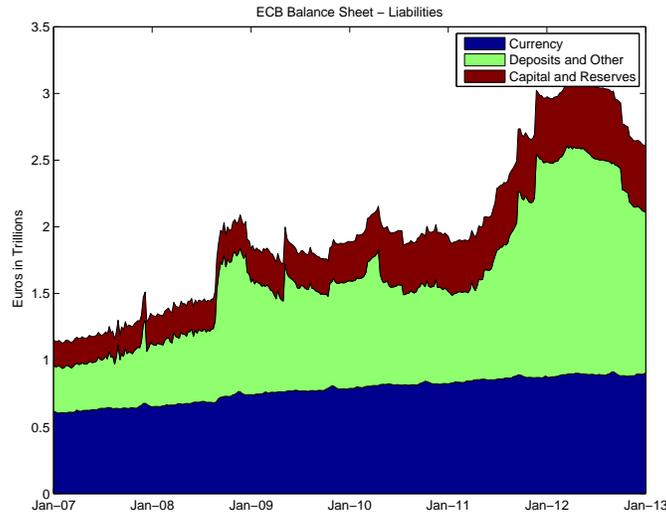


Figure 4: ECB Liabilities since 2007

we include all other liabilities, revaluation accounts, and capital and reserves.

To construct the Bank of England graph of liabilities, we constructed three categories - Sterling Notes, Reserve Balances, and Other. In the Sterling Notes category, we include sterling notes in circulation. In the Reserve Balances category, we include sterling reserve balance liabilities. Finally, in the Other category, we include standing facility deposits, short-term open market operations, foreign currency public securities issued, cash deposit ratios from MFIs, and all other liabilities.

To construct the Federal Reserve maturity structure, we only include Liquidity and Credit Facilities, Securities held Outright, TALF, Repurchase agreements, and central bank liquidity swaps.

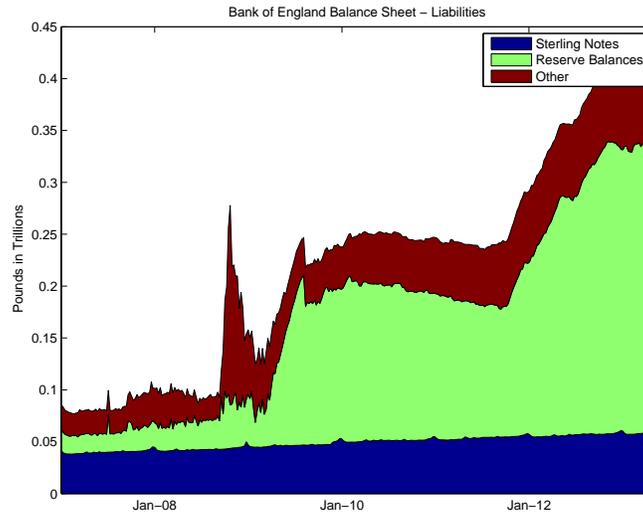


Figure 5: Bank of England Liabilities since 2007

References

- [1] Robert J. Barro. Are Government Bonds Net Wealth? *Journal of Political Economy*, 82:1095–1117, 1974.
- [2] Marco Bassetto. A Game-Theoretic View of the Fiscal Theory of the Price Level. *Econometrica*, 70(6):2167–2195, 2002.
- [3] Marco Bassetto. Fiscal Theory of the Price Level. In Steven N. Durlauf and Lawrence E. Blume, editors, *The New Palgrave Dictionary of Economics*. Palgrave Macmillan, 2008.
- [4] Charles T. Carlstrom and Timothy S. Fuerst. Timing and Real Indeterminacy in Monetary Models. *Journal of Monetary Economics*, 47(2):285–298, 2001.
- [5] Seth B. Carpenter, Jane E. Ihrig, Elizabeth C. Klee, Daniel W. Quinn, and Alexander H. Boote. The Federal Reserve’s Balance Sheet and Earnings: A primer and projections. Finance and Economics Discussion Series 1, Federal Reserve Board, 2013.
- [6] John H. Cochrane. Money as Stock. *Journal of Monetary Economics*, 52(3):501–528, 2005.

- [7] Gauti B. Eggertsson and Michael Woodford. The Zero Bound on Interest Rates and Optimal Monetary Policy. *Brookings Papers on Economic Activity*, 2003(1):139–211, 2003.
- [8] David Greenlaw, James D. Hamilton, Peter Hooper, and Frederic S. Mishkin. Crunch Time: Fiscal Crises and the Role of Monetary Policy. http://dss.ucsd.edu/~jhamilto/USMPF13_final.pdf, 2013. Mimeo, University of California – San Diego.
- [9] Robert E. Hall and Ricardo Reis. Maintaining Central-Bank Solvency under New-Style Central Banking. <http://www.columbia.edu/~rr2572/papers/13-HallReis.pdf>, 2013. Mimeo, Hoover Institution, Stanford University, and Columbia University.
- [10] Ricardo Lagos and Randall Wright. A Unified Framework for Monetary Theory and Policy Analysis. *Journal of Political Economy*, 113(3):463–484, 2005.
- [11] Eric Leeper. Equilibria under ‘Active’ and ‘Passive’ Monetary Policies. *Journal of Monetary Economics*, 27(1):129–147, 1991.
- [12] Robert E. Lucas, Jr. and Nancy L. Stokey. Money and Interest in a Cash-in-Advance Economy. *Econometrica*, 55(3):491–513, 1987.
- [13] Hanno Lustig, Christopher Sleet, and Şevin Yeltekin. Fiscal Hedging with Nominal Assets. *Journal of Monetary Economics*, 55(4):710–727, 2008.
- [14] Thomas J. Sargent and Neil Wallace. Some Unpleasant Monetarist Arithmetic. *Federal Reserve Bank of Minneapolis Quarterly Review*, 5(1):1–17, 1981.
- [15] Christopher A. Sims. A Simple Model for Study of the Determination of the Price Level and the Interaction of Monetary and Fiscal Policy. *Economic Theory*, 4(3):381–399, 1994.
- [16] Christopher A. Sims. Limits to Inflation Targeting. In Ben S. Bernanke. and Michael Woodford, editors, *National Bureau of Economic Research Studies in Business Cycles*, volume 32, chapter 7, pages 283–310. University of Chicago Press, 2005.
- [17] Christopher A. Sims. Paper Money. *American Economic Review*, 103(2):563–584, 2013.

- [18] Michael Woodford. Monetary Policy and Price Level Determinacy in a Cash-in-Advance Economy. *Economic Theory*, 4(3):345–380, 1994.
- [19] Ralph A. Young and Charles A. Yager. The Economics of “Bills Preferably”. *Quarterly Journal of Economics*, 74(3):341–373, 1960.

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