Fiscal Implications of the Size and Composition of the Central Bank's Balance Sheet

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Executive Summary

This memo studies the fiscal implications of different long-run monetary policy frameworks in terms of the size and composition of the Federal Reserve System's balance sheet. The main takeaways are that:

- From the consolidated budget perspective, purchases of Treasury securities by the central bank change the maturity of government liabilities held by the public, as these securities are replaced by very short term (generally overnight) debt such as reserves. Purchases of agency MBS, agency debt, or other privately issued assets, implies expanding the assets and liabilities of the consolidated government.
- In partial equilibrium—that is, ignoring the effects of changes in the size and composition of the central bank's balance sheet on asset prices, economic activity, and inflation—the implications for the consolidated government's funding costs of Federal Reserve purchases of Treasury securities depend on the duration of the assets acquired. To the extent that the sum of the term and liquidity premiums is positive and increasing with duration, the longer the duration of the Treasury debt being purchased, the greater the decrease in average funding costs. However, such purchases also expose the consolidated government to interest-rate risk in the form of higher future interest expenses in the event of unexpected increases in short-term interest rates.
- If the Federal Reserve acquires non-Treasury obligations, the effect of these purchases on the consolidated government net revenues is positive on average to the extent that the yields on these securities carry a premium relative to the interest rate on reserves. Purchases of non-Treasury securities also imply that the consolidated government faces additional risks. For instance, agency MBS holdings result in prepayment risk, as changes in interest rates shift security cash flows forward or backward in time. Central bank purchases of other types of assets (currently permissible under the Federal Reserve Act or not) would result in the government bearing additional risks (e.g., credit, liquidity, and foreign exchange risks).[2]

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[2] Besides U.S. Treasury securities, the Federal Reserve Act allows for central bank investment in federal agency securities, short-term municipal debt, bankers acceptances, and foreign sovereign debt. Investment in other financial assets, such as corporate debt or equities, would require an amendment to the Federal Reserve Act.

- From a general equilibrium perspective, a larger central bank balance sheet may affect asset prices, including term premiums, although such effects depend on the debt management decisions of the fiscal authorities. This has implications for public financing costs, as well as for government revenues and expenditures. As discussed below, these effects can be quantitatively very significant, and overwhelm the contribution of central bank remittances in terms of the overall impact on government debt. The effect on funding costs generates an incentive for the fiscal authority to alter its debt issuance policy, which could mute the effects of the central bank's balance sheet policy and hence raises important issues of coordination between the monetary and fiscal authorities.
- The central bank's net income and remittances to the fiscal authority lay bare the fiscal implications of shortening the duration of government debt via Treasury purchases. A larger/longer-duration central bank balance sheet should lead to levels of income and remittances that are higher on average (as long as the term and liquidity premiums are positive), but possibly more volatile. Purchases of agency MBS result in higher average remittances and greater remittance volatility over time, as these securities carry higher coupons than comparable maturity Treasuries—owing to the presence of embedded borrower prepayment options that make the timing of cash flows uncertain. The volatility of the remittances depends on whether the central bank holds assets to maturity.
- Income losses *per se* are not an impediment to executing monetary policy for the Federal Reserve, as long as these losses are not so large as to impair central bank's solvency—that is, as long as they are not large enough that the central bank is forced to ask for recapitalization from the fiscal authority in order to pursue its mandate. The size of a central bank's capital is not the relevant measure of solvency, as it does not take into account the future income from seigniorage. As long as the sum of: (1) the value of central bank's assets minus the value of interest bearing liabilities and (2) the expected present discounted value (EPDV) from seigniorage is positive, then a central bank is solvent.
- Before facing the highly unlikely scenario of needing recapitalization, large income losses would likely raise important political economy issues. International experience suggests that large losses can harm a central bank's credibility, although much of this experience comes from emerging markets with arguably weaker institutions than the U.S.[3] Experience from advanced economies (e.g., Swiss National Bank) shows that the prospect of severe losses can potentially diminish the central bank's policy options. Two possible ways of addressing these political economy issues (neither of which is currently feasible for the Federal Reserve) are: (1) an ex-ante agreement between the central bank and the fiscal authority by which any gains/losses resulting from asset purchases are borne by the latter (the UK provides an example of such agreement); or (2) alternatively using central bank capital surplus as a buffer to smooth remittances over time.

[3] As discussed in section 3, many of the central bank balance sheet problems discussed in the literature arose because the government had forced the central bank to bail out financial institutions following banking crises. Even among emerging markets, there are important counterexamples where central bank balance sheet problems did not lead to poor monetary policy performance (e.g., Chile).

- Simulations using FRB/US suggest that:
    - The need for recapitalization is extremely unlikely, even in the case that reserve balances remain at current levels.
    - Average remittances over the next twenty years may not necessarily increase with the long-run size of the balance sheet. Maintaining a relatively large balance sheet while the term premium is negative implies purchasing assets that are associated with expected future negative net income. Furthermore, general equilibrium effects work toward lowering average remittances. Specifically, a larger balance sheet implies a lower term premium, which stimulates the economy, leading *ceteris paribus* to a higher IOER and interest expenses.
    - Importantly, however, because the aforementioned general equilibrium effects also influence government revenues, expenditures, and funding costs, the overall fiscal impact—as measured by the ratio of federal debt to GDP—of a large balance sheet is positive.[4]
    - The volatility of remittances and the likelihood and size of a deferred asset are roughly flat for long-run reserve balances up to $1 trillion but increase substantially if reserve balances remain at their current elevated levels. These results suggest that a prolonged period at the zero lower bound may be problematic for the central bank from the fiscal perspective insofar as it may be associated with both a large balance sheet and low (possibly negative) term premiums.

The memo is organized in four sections. Section 1 discusses the fiscal implications from the perspective of the consolidated government budget constraint. Section 2 takes into account the fact that the Federal Reserve is an agency independent from the fiscal authority, with its own balance sheet and income statement, that generates remittances to the Treasury. Section 3 discusses the political economy issues associated with a large balance sheet. Section 4 presents the results of simulations using the FRB/US model.

1. Fiscal Implications from a Consolidated Government Budget Constraint's Perspective

This section analyzes the fiscal implications of the central bank's balance sheet policy from the perspective of the consolidated government budget constraint–that is, adding the Federal Reserve's assets and liabilities to the federal government's assets and liabilities.[5] This means that we ignore the effects of balance sheet policy on remittances from the Federal Reserve to the Treasury and issues of central bank solvency, which are both discussed in section 2.

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[4] As explained in more detail below, a larger balance sheet provides additional accommodation, and in our simulations, although monetary policy responds by increasing the short-term policy rate, the inertial nature of the policy rule implies that this increase is not immediately fully offsetting. This results in higher output for some time and, in turn, higher cumulative tax receipts.

[5] This section summarizes the main results from the background memo by Bi and Rosa ("Fiscal Implications of the Central Bank's Balance Sheet from a Consolidated Government Budget Constraint Perspective").

It is important to stress that monetary policy always has fiscal implications–regardless of the size and composition of the balance sheet–primarily as it affects the rate at which the government finances its debt.[6] Changes in the size and composition of the central bank's balance sheet have additional fiscal consequences, which are the focus of this section. For the sake of clarity, this section proceeds sequentially in describing these fiscal implications. First, we describe the implications in a partial equilibrium setting—that is, ignoring the effects of changes in the size and composition of the Federal Reserve's balance sheet on asset prices, economic activity, and inflation. Next, we consider the general equilibrium effects, as they have important implications on funding costs, government revenues, and expenditures. Finally, we discuss how the fiscal implications of the central bank's balance sheet policy crucially depend on whether the fiscal authority reacts to the central bank's actions, and more specifically to a change in relative prices of government debt financing.[7]

Fiscal Implications Assuming No Reaction on the part of the Fiscal Authority

We begin our discussion by considering the effects of changes in the size and composition of the central bank's balance sheet on the funding costs of government debt in partial equilibrium – that is, without considering the effects on asset prices. Consider a balance sheet that is funded mainly by currency, as was the case before the Great Recession, and where the only choice for the central bank concerns its asset composition. From a consolidated budget perspective, central bank acquisition of Treasury debt implies simply replacing these liabilities with currency, which bears zero interest, leading to a decrease in funding costs for the government as a whole. To the extent that the sum of the term and liquidity premiums is positive and increasing with duration, the longer the duration of the Treasury debt being acquired by the central bank, the greater the decrease in average funding costs. Purchases of agency MBS or other privately issued assets imply acquiring those assets on behalf of the consolidated government, thereby expanding its assets and liabilities.

Let us now consider the fiscal implications of permanent balance sheet expansions that are larger than what is implied by currency in circulation. Again, let us first consider the case in which purchases consist of Treasury securities and where these purchases are funded by issuing reserves or reverse repurchase agreements. From a consolidated budget perspective, Federal Reserve purchases of these securities are analogous to the Treasury replacing them with overnight debt, thereby shortening the duration of overall government liabilities. The implications for the consolidated government's funding costs depend on the duration of the securities being purchased by the Federal Reserve. To the extent that the term premium is positive, as has been the case historically, and that reserves are more liquid than the securities being purchased, a permanently larger central bank balance sheet should lower government financing costs on average over the long-run, as the government as a whole pays lower term and

[6] Indeed, one of the key pillars of monetary dominance—that is, the central bank's ability to control inflation—is the fact that monetary policy sets interest rates and fiscal policy eventually adjusts primary surpluses to satisfy the intertemporal government budget constraint (see, for instance, Leeper, 1991, and Sims' presentation at Jackson Hole for a recent discussion of this topic; Sims, 2016).

[7] We define coordination a situation where both monetary and fiscal policies are jointly determined. Moreover, we define the fiscal authority's reaction as any explicit government action, and thus we abstract from the effects induced by automatic fiscal stabilizers.

liquidity premiums.[8] However, unlike in the case where the assets are funded with currency, an expansion of the balance sheet implies that the consolidated government bears more interest rate risk, as it has to refinance its debt at an uncertain future interest rate and this implies a higher volatility of funding costs.[9] If the Federal Reserve also acquires non-Treasury obligations, then it expands both assets and liabilities of the consolidated government. On average, the effect of these purchases on the consolidated government net revenues is positive to the extent that the yield on these securities carries a premium relative to the interest rate on reserves. Purchases of non-Treasury securities also imply that the consolidated government faces additional risks. For instance, in the case of agency MBS purchases, the government faces prepayment risk as changes in interest rates shift security cash flows forward or backward in time. And, in the case of municipal security purchases, the government bears credit risk.[10]

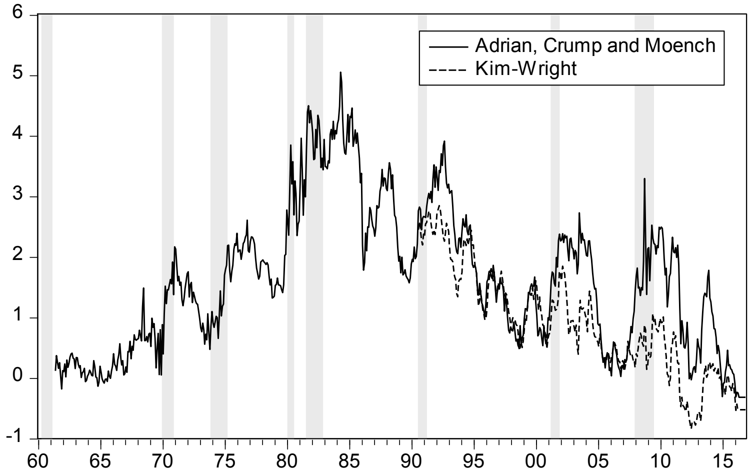
Next, we consider the funding cost implications of a countercyclical balance sheet policy, where the Federal Reserve's balance sheet increases during recessions and shrinks when economic conditions improve. To the extent that purchases consist of Treasury securities, this corresponds to a policy where the maturity of the government debt in the hands of the public varies with the business cycle. That is, the maturity of publicly held debt falls during downturns (when unemployment rises) and rises during expansions (when unemployment falls). If the term premium is countercyclical, the shortening of duration during recessions may have, on net, positive fiscal effects in terms of lowering government funding costs. Figure 1 shows two estimates of the 10-year term premium. These estimates tend to increase during recessions (shaded in grey), although they provide starkly different assessments during the most recent recession. The effect of countercyclical purchases of non-Treasury securities depends on the business cycle pattern of the risk premium on these securities.

[8] Greenwood et al. (2014) provide a recent analysis of the optimal maturity structure of the consolidated government debt as well as a literature review.

[9] Greenwood et al. (2015) analyze this trade-off in a model of optimal government debt maturity, whereas Greenwood et al. (2016) estimate the long-run fiscal risk from the government's consolidated interest expense of different configurations (in terms of size and weighted average maturity) of the Fed's balance sheet. Greenwood et al. (2014) take as given the realization of U.S. interest rates that have prevailed since 1952, and show that a counterfactual policy of shortening the maturity of government debt would have resulted in economically significant interest cost savings, and only a small increase in budgetary volatility. However, in the current environment characterized by term premiums being zero or even slightly negative, extending, rather than shortening, the maturity of government debt looks more favorable for cost minimization.

[10] Prepayment risk makes the consolidated government revenues more volatile.

Figure 1: Time series of the 10-year term premiums



Note: NBER defined recession dates shaded gray. Source: Adrian, Crump and Moench (2013), and Kim and Wright (2005). Because of data availability, term premium models are usually estimated up to 10-year maturity.

We next consider the aggregate (general equilibrium) implications of the Federal Reserve's balance sheet policies. As is discussed in Section 4 below, using the FRB/US model (see also Engen et al., 2015, for additional evidence), a central bank's balance sheet choices have important effects on the yield curve (and asset prices more generally) that influence output and inflation. These general equilibrium effects have broad fiscal implications as they impact the cost of financing fiscal deficits, tax revenues, and government expenditures (e.g., Rosengren, 2013). Indeed, we find in our simulations below that a larger long-run balance sheet boosts nominal tax revenues over the next 20 years, ultimately improving the overall fiscal position of the government in terms of budget balance and outstanding debt. While these effects are potentially very important, the literature exploring fiscal effects of balance sheet policy in general equilibrium remains limited. A key direction for future research will be to quantitatively assess the fiscal implications of unconventional monetary policies and the associated degree of (model and estimation) uncertainty surrounding these estimates.

Coordination (or Lack Thereof) between Monetary and Fiscal Authorities

So far we have considered the effects of the size of the central bank's balance sheet assuming the fiscal authority does not respond to the central bank's actions. In principle, the Federal Reserve and the Treasury may have different objectives, with the former aiming to achieve the dual mandate of maximum employment and stable prices, and the latter focusing more on minimizing debt servicing costs and fiscal risk. These differing goals may be inconsistent in some circumstances. As term premiums decline as a result of Federal Reserve's asset purchases, the Treasury may find that it is in taxpayers' interest to extend the duration of the debt outstanding by increasing the issuance of longer-term debt. Such an action could result in upward pressure on term premiums, thus potentially offsetting the easing of financial conditions the Federal Reserve is trying to achieve. According to Greenwood et al. (2014), one prominent example occurred during the Great Recession, when the Federal Reserve embarked on purchases of long-term Treasury bonds in order to support aggregate demand, while the Treasury issued more long-term debt in order to lower financing costs. Greenwood et al. (2014)

estimate that the Treasury's active maturity extension program offset 35 percent of the maturity shortening impact of LSAP.

Experiences of other central banks also suggest that the intended economic and financial effects of balance sheet policy might be muted if the central bank and fiscal authority pursue their own objectives without cooperation. Japan is an example of a country that lacks formal avenues for policy coordination, while Canada and the U.K. allow policy coordination to varying degrees. At one end of the spectrum, the U.K.'s Debt Management Office is mandated to "ensure that debt management is consistent with aims of monetary policy"; and during the recent crisis extraordinary efforts were made to ensure this consistency. By contrast, Japan has no institutional arrangement for coordination between debt management and monetary policy. Some authors have noted that the lack of coordination in the late 1990s and early 2000s might have jeopardized Japan's economic recovery and, more importantly, left monetary policy makers with a credibility issue as the public was unconvinced they could commit to future expansions (e.g., Ito and Mishkin, 2006; Kuttner and Posen, 2001, and the references therein). Overall, the historical and international experiences tend to suggest that coordination between fiscal and monetary authorities may be welfare improving.[11]

2. Implications of the Size and Composition of the Balance Sheet for Remittances and Central Bank Solvency

In this section the Federal Reserve is treated as an independent agency with its own balance sheet and income statement that generate an observable flow of remittances to the U.S. Treasury. Specifically, by law, the Federal Reserve must distribute its earnings to the Treasury, net of operating expenses and dividends and allowing for a retained surplus of no more than $10 billion.[12] In the event that earnings are insufficient to cover these costs, then no remittances are made and a "deferred asset" is booked as a negative liability on the balance sheet. Carpenter et al. (2015) provides a detailed overview of the Federal Reserve's balance sheet and income statement mechanics.[13]

The average size and variability of Federal Reserve remittances to the Treasury depend on a number of factors controlled by the central bank: the size and the composition of its balance sheet, and the decision to sell assets. We discuss each factor in turn:

[11] Since the relevant literature is fairly limited, it is difficult to quantify the net benefits of coordination, either on average or during a financial crisis. We note that coordination may pose a risk to monetary policy independence. Moreover, as discussed by Cecchetti (cited in Wessel, 2015), "putting in place a governance structure that is designed to avoid conflict when the system is under stress would leave open the opportunity for abuse in normal times." Additional information about the international experiences and a discussion of the historical experience about the coordination between the monetary and fiscal authority are provided in the background memo by Bi and Rosa (and is available upon request).

[12] Section 7 of the Federal Reserve Act defines the "division of earnings". These earnings principally reflect the difference between interest earned on assets and that paid on liabilities. Assets consist almost entirely of marketable securities that pay coupon interest – principally U.S. Treasury notes and bonds and Federal Agency mortgage-backed securities. Liabilities are currency in circulation, bank reserves, and reverse repurchase agreements. Currency pays no interest, while reserves and reverse repurchase agreements incur interest expenses (with the rates on RRPs typically paying less than the IOER rate).

[13] The background memo by Del Negro and Frame ("The Implications of the Size and Composition of the Balance Sheet for Remittances and Central Bank Solvency") provides additional details on this section and the next, including a brief overview of the Federal Reserve's balance sheet and income statement mechanics.

1.) The size and composition of the balance sheet. The effect of increasing the size of the Federal Reserve's balance sheet on the size and volatility of its income and remittances depends on the assets being purchased. We distinguish three cases for the assets held by the Federal Reserve: Treasury securities, agency MBS, and other assets.
    a. Treasury securities. As long as the term and liquidity premiums are positive and increasing with duration, a longer duration of the Treasury securities being purchased implies a higher net interest margin and, hence, higher average net income and remittances over time. However, to the extent that the marginal assets are funded by issuing short-term interest-bearing liabilities (i.e., reserves and reverse repurchase agreements), acquiring longer duration assets implies a greater maturity mismatch between assets and liabilities, and hence more risk associated with uncertain future interest rates for liabilities. As a consequence, the volatility of remittances will generally increase, on the margin, with the duration of the assets being purchased.
    b. Agency MBS. These securities carry higher coupons than comparable maturity Treasuries—owing to the presence of embedded borrower prepayment options that make the timing of cash flows uncertain. Hence, larger holdings of agency MBS result in higher average remittances and greater remittance volatility over time.
    c. Other assets. The impact on the average size of remittances of purchasing other financial assets will depend on the interest rate spread of the assets, which includes compensation for their risks (e.g., credit, liquidity, *et cetera*). Those risks may also translate in a higher volatility of remittances. Besides U.S. Treasury securities, the Federal Reserve Act allows for central bank investment in federal agency securities, short-term municipal debt, bankers acceptances, and foreign sovereign debt. Investment in other financial assets, such as corporate debt or equities, would require an amendment to the Federal Reserve Act.
2.) Asset sales. Selling assets generally results in gains or losses that are immediately recognized in income and hence generally increase the variability of remittances.[14]

Existing research, as well as the most recent SOMA Annual Report, have generally painted a benign picture of Federal Reserve's net income in future years under baseline projections for the evolution of the balance sheet (e.g., Hall and Reis, 2013; Greenlaw et al. 2013; Carpenter et al., 2015; Christensen et al., 2015). These studies suggest that the likelihood of recording a sizable and long-lasting deferred asset is quite small. Section 4 presents our own simulations of Federal Reserve income using the FRB/US model under various assumptions for the future size and composition of the balance sheet.

Income losses, and temporarily negative levels of capital, are *per se* not an impediment to normal central bank functioning. In the case of net losses, the Federal Reserve would simply record a "deferred asset." However, in principle, the deferred asset could become so large that it cannot be covered by future income. In this case, the central bank would be effectively insolvent. Of course, a central bank in a

[14] However, in principle, asset sales could be structured in such a way as to smooth remittances, recognizing capital gains in periods when income would otherwise be low and vice versa.

fiat money regime can always address insolvency by creating more liabilities and/or "printing money" (that is, generating more seigniorage), but at the cost of potentially compromising its inflation objective.[15]

The literature defines central bank's solvency in terms of its intertemporal budget constraint: a central bank is solvent if the sum of "tangible wealth"–defined as the difference between the current market value of assets minus interest-bearing liabilities–plus the expected present discounted value (EPDV) of future seigniorage ("intangible wealth") is positive.[16] The sum of the two – tangible and intangible wealth – equals the EPDV of remittances. If the latter is positive, a central bank, in principle, should not require recapitalization from the fiscal authority in order to pursue its mandate, as it can always compensate current losses by "borrowing" against future remittances.

The intertemporal budget constraint perspective offers a number of important implications. First, a central bank without interest-bearing liabilities can never be insolvent as long as interest income exceeds operating expenses. Second, factors that affect the variability of remittances, such as the choice to hold assets to maturity or use market value accounting, may be less relevant for solvency.[17] Finally, the correlation between the value of tangible and intangible wealth is key to understanding whether solvency is at stake for a given adverse scenario. For instance, if scenarios where the value of assets falls are also scenarios where the EPDV of future seigniorage increases, then intangible wealth provides a hedge for the central bank's tangible wealth. Inflationary scenarios are generally examples where such a hedge is in effect, as seigniorage generally increases with inflation.

Del Negro and Sims (2015) and Reis (2016) emphasize the quantitative importance of the EPDV of seigniorage for assessing solvency, and find that it is potentially quite large for the Federal Reserve–possibly well above the current value of interest-bearing liabilities–although uncertainty about future currency demand makes these present value calculations tentative.

3. Political Economy Considerations

In addition to the remote possibility of a need for recapitalization, the size and composition of the balance sheet and the potential for zero remittances can be a source of political pressure on the Federal Reserve. This, in turn, could jeopardize the central bank's independence and/or its ability to pursue its long term objectives.

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[15] "Printing money" should be understood in a broad sense, including keeping the IOER lower than needed to control inflation. Stella (2005), Sims (2005), Hall and Reis (2013), Reis (2013), and Del Negro and Sims (2015) all elaborate in different ways as to why an inflation targeting central bank is subject to an intertemporal budget constraint, even in a fiat money regime.

[16] The IOER is arguably the relevant discount rate. For detailed derivations, see Bassetto and Messer (2013), Hall and Reis (2013), Del Negro and Sims (2015), or Benigno and Nisticò (2015).

[17] Recognizing losses at once, or delaying the recognition until maturity, makes little difference for the present value calculations.

First, large amounts of excess reserves imply substantial interest payments to the banking sector–including to foreign banking organizations (FBOs)–when the IOER is above zero, even if remittances continue to be positive. From the perspective of a consolidated budget constraint, these payments are simply the result of the need to finance federal debt (the central bank holds Treasury securities and funds them by issuing reserves). Nonetheless, large payments to the banking system, especially to FBOs, may result in political pressures against maintaining or raising the IOER. Of course, a central bank decision to raise interest rates always makes funding public debt more expensive, regardless of the size of its balance sheet and of the holders of public liabilities.[18] A related, but distinct, point is that financing a large proportion of public debt using reserves is arguably not the least expensive way to obtain overnight financing. For instance, the rate at which banks can borrow in the federal funds market is generally lower than IOER.

Second, the temporary cessation of remittances and the creation of a deferred asset can also result in political pressures on the Federal Reserve. As discussed above, a large balance sheet may reduce the consolidated government funding costs on average. However, it can be disadvantageous in terms of public finances under some circumstances (e.g., when interest rates increase unexpectedly), potentially generating political opposition to central bank policies.[19] Negative income lays bare such circumstances–in the sense that the central bank's remittances are observable to the public–and can therefore serve to coordinate such opposition.

The experience of other central banks appears to support this view. Stella (1997, 2005) notes that several central banks have suffered chronic losses that eventually interfered with the effective conduct of monetary policy.[20] Relatedly, Cukierman (2008, 2011) argues that when central bank capital becomes negative and drops below some threshold, there is a danger that the political establishment might prevent the central bank from following useful policies that could nonetheless lead to additional losses. This literature suggests that a large balance sheet, and the associated increased risk of incurring losses, can endanger central bank independence. At the same time, many of the countries considered in the abovementioned studies are developing ones with arguably weaker institutions than the United States, so it is not clear to what extent their experiences apply to the Federal Reserve.[21] Moreover, even among emerging markets central bank balance sheet problems have not always led to poor monetary policy performance.[22]

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[18] As discussed in Section 1 and in Del Negro et al. (2013).

[19] The accompanying memo by Bi and Rosa points out that the shortening of the maturity of public debt increases the sensitivity of funding to interest rate risk.

[20] Dalton and Dziobek (2005), Kluh and Stella (2008), Leone (1994), Stella (1997, 2005, and 2009) provide brief case studies. Kluh and Stella (2008) argue that central bank losses can result in a negative public perception of the institution and its leadership.

[21] Many of the central bank balance sheet problems discussed in the literature arose because the government had forced the central bank to bail out financial institution following banking crises.

[22] For instance, Chile was able to pursue successful monetary policy for several years even under negative capital, partly because the fiscal authority was supportive of the central bank's mandate. The Czech and Israeli central banks, for example, have operated with negative net capital for extended periods without damaging their policies, as discussed by Eichengreen (2015).

The experience of advanced economies such as Japan and Switzerland is arguably more relevant, and it also suggests that political economy considerations may constrain the central bank's policy options. In particular, Stella (2005, pg. 338) argues that "in early 2002 … the market raised questions as to the likely duration of the Bank of Japan's willingness to use its rinban operations to influence the long end of the government bond yield curve, as an eventual rise in interest rates would subject it to losses that could exhaust its capital and reserves."[23] The recent abandonment of the minimum exchange rate policy by the Swiss National Bank (SNB) is also clear evidence that balance sheet concerns can take center stage in policy discussions.[24]

A central bank may take a number of actions to address the political economy risks associated with income losses and avoid the need to ask for recapitalization by the fiscal authority. First, the central bank could provision for future losses by increasing its surplus capital in order to use it as a buffer against adverse shocks. Cukierman (2008, 2011), Goodfriend (2014a,b), and Stella (2005) advocate such an approach. However, as noted earlier, increasing the size of surplus capital is not a feasible option for the Federal Reserve under current law which limits this surplus to $10 billion.[25] [26]

Second, the central bank could make an *ex ante* agreement with the fiscal authority to absorb central bank losses, as is the case in the UK (see McLaren and Smith, 2013). While such an agreement may seem desirable, it may also come with limits on the central bank's ability to pursue independent monetary policy (e.g., in the UK, balance sheet actions need to be approved by the Treasury). Finally, the central bank could reduce its interest-bearing liabilities (and increase the EPDV of seigniorage) by not paying interest on required reserves and increasing the amount of such reserves. But such an action amounts to a forced transfer of resources from the banking system to the Federal Reserve, and the central bank would likely face significant political opposition to such a maneuver.

4. **Results from Model Simulations**

In this section, we quantify the fiscal implications of the size and composition of the Federal Reserve's long-run balance sheet by reporting the main results of simulations conducted using the Board's SOMA model.[27] Specifically, we consider three scenarios for the size of long-run reserves: $100 billion, which

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[23] Similar concerns about possible future losses have been raised in regard to the latest BoJ balance sheet expansion (see Fujiki and Tomura, 2015).

[24] In the SNB own words: "Had the SNB delayed the discontinuation of the minimum exchange rate, this would only have been at the expense of an uncontrollable expansion of the SNB balance sheet by hundreds of billions of Swiss francs, and potentially by several times Swiss GDP. Such an expansion would have severely impaired the SNB's future ability to conduct monetary policy and jeopardized the fulfilment of its mandate in the long term. Moreover, given the fact that the minimum exchange rate was no longer sustainable, further intervention would have been pointless, and the enormous losses arising from it could not have been justified" (Swiss National Bank, 2015).

[25] In addition, a clear limitation of this approach is that the fiscal authority may be tempted to appropriate some of this capital, as happened in 1993, 2005, and more recently with the "Highway and Transportation Funding Act of 2015".

[26] Stella (2005) observes that countries with large foreign exchange exposure on their balance sheet tend to have mechanisms to smooth the impact of exchange rate changes movements on their accounts. This suggests that the small size of central bank capital that is characteristic of many advanced economies could be a legacy of a period in which these institutions did not actively use their balance sheet for monetary policy purposes.

[27] The background memo by Cavallo and Malin ("Implications of the Size and Composition of the Balance Sheet for Remittances: Results from Model Simulations") provides additional details and results.

represents a return to a pre-crisis "scarce-reserves" balance sheet; $2.5 trillion, which roughly corresponds to the current level of reserves; and a level in between, namely $1 trillion, which is also broadly in line with estimates of banks' total structural demand for reserves.[28] On the asset side, we assume as our baseline a Treasuries-only portfolio with securities purchased in proportion to Treasury issuance. But we also consider two alternative cases in which: [i] one-third of the portfolio is Treasury bills; and [ii] 25 percent of the portfolio consists of agency MBS. We consider the former in the small ($100 billion) reserves scenario, and the latter in the large ($2.5 trillion) scenario. Hence, we examine five balance sheet configurations.

Model Set-up

The SOMA model requires two main inputs: assumptions about the configuration of the balance sheet and projected paths for financial and macroeconomic variables that affect the evolution of the balance sheet and the income it generates. In all simulations we also assume that the fiscal authority does not respond to the size of the Federal Reserve's balance sheet, neither in terms of its willingness to engage in deficit spending nor in terms of its debt management strategy. Appendix 1 describes these inputs in detail. Here we highlight a few features that will be especially important for understanding our results.

The paths for financial and macroeconomic variables are generated from *stochastic* simulations of the FRB/US model. For each of our five scenarios, these simulations are based around *deterministic* paths that are consistent with the June 2016 public FRB/US release, in which the federal funds rate steadily rises from the zero lower bound as the economic recovery continues. For robustness, we also consider below a prolonged-low-interest-rate scenario, in which a recession drives the federal funds rate back to the zero lower bound from the first quarter of 2017 through the end of 2018.[29] Importantly, the deterministic paths in our simulations differ across scenarios because the configuration of the long-run balance sheet influences the term premium, which in turn affects the rest of the economy.[30]

Figure 2 shows the size of the balance sheet and the term premium under the deterministic path for each of our five scenarios. As expected, larger balance sheets push the term premium down. The composition of the balance sheet also affects the term premium–MBS holdings exert more downward pressure than Treasury holdings, while a shorter maturity structure exerts less.[31] Note that balance

[28] See the memo, "Considerations for the Role of Reserves in Operating Regime Designs," prepared by the Interest Rate on Reserves (IROR) working group.

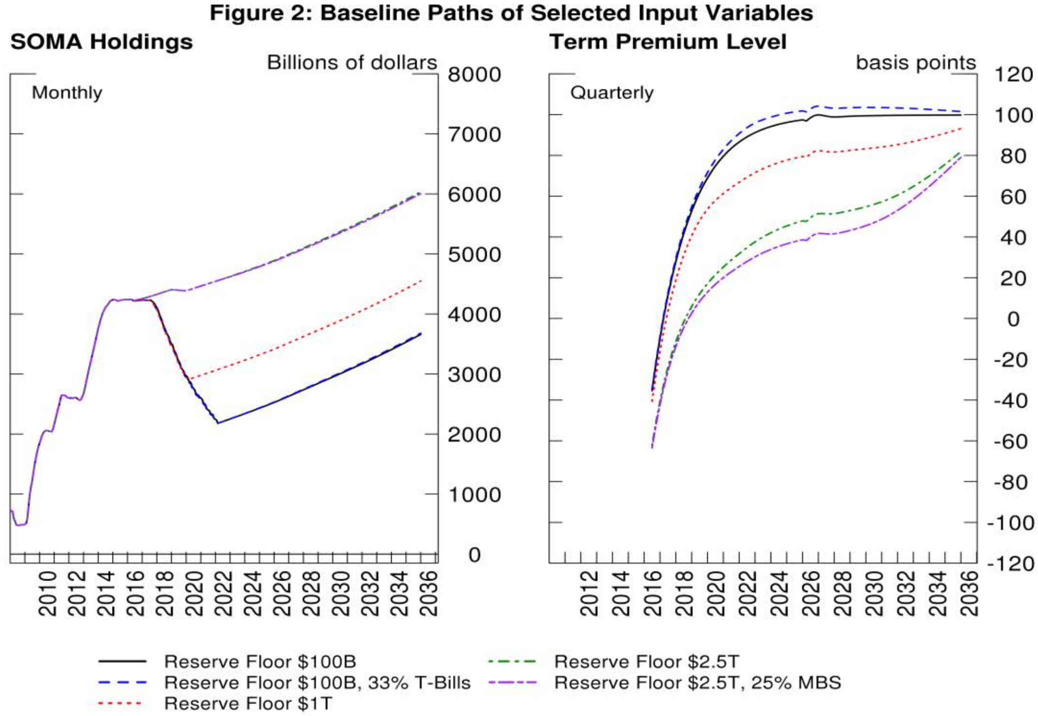
[29] Against the backdrop of this scenario, we also examine the fiscal implications of purchasing additional assets during the recession.

[30] In FRB/US, the term premium is the difference between the 10-year Treasury rate and a weighted average of the federal funds rates expected to prevail over the corresponding period.

[31] The effect of the balance sheet on the term premium is constructed using the estimated model of Li and Wei (2013). One caveat of using the Li-Wei model, though, is that the resulting term premium effect is likely to be a lower bound. In particular, the term premium implied by the Li-Wei estimates is approximated by calculating the discounted sum of the deviation of the ten-year equivalents path of the SOMA portfolio under each of our scenarios from that under a counterfactual scenario in which securities holdings are roughly equal to and grow with currency and capital, plus other liabilities. This calculation would be a correct estimate of the term premium effect if the portfolio reverted to its counterfactual path within our projection period, which ends in 2035. However, because this is not the case under our scenarios, the term premium effect we use is a

sheet configurations which lead to more accommodative financial conditions, thereby providing stimulus for inflation and the real economy, also imply higher paths for the IOER and the federal funds rate (not shown) because in FRB/US the latter is determined by an inertial Taylor (1999) rule. These interest rate paths play a prominent role in determining the fiscal implications of the Federal Reserve's balance sheet.[32]

Figure 2: Baseline Paths of Selected Input Variables



Simulation Results

This simulation exercise illustrates the implications of the long-run configuration of the balance sheet on the level and volatility of the Federal Reserve's remittances to the Treasury, as well as its broader fiscal implications on government revenues and expenditures–as summarized by the overall effect on federal government debt.[33] To preview our results, we find that the effects on government revenues and

lower bound in terms of its absolute value, hence is ultimately less negative than the estimate for the term premium effect that would arise if the Li-Wei model looked past the projection horizon.

[32] By using the Li-Wei model, our approach implies that the size of the Federal Reserve's balance sheet can affect the term premium for a prolonged period. The companion memo "Long-Run Framework: Macroeconomic Considerations of Balance Sheet Policies" by Braun et al. debates whether the size of the balance sheet can have such long-lasting effects on interest rates. We do not intend to weigh in on this debate. In fact, in background memo by Cavallo and Malin, for robustness, we provide some additional results in which the balance sheet does not affect the term premium.

[33] In addition, the background memo by Cavallo and Malin reports the effect of the long-run balance sheet on federal government revenues, outlays, and budget surpluses.

expenditures are quantitatively very significant and, in terms of the overall impact on government debt, overwhelm the contribution of central bank remittances.

Table 1 reports summary statistics for each balance sheet scenario, including the average level and variability of remittances, the likelihood of recording a deferred asset and its peak size, the market value of Federal Reserve assets less interest-bearing liabilities (which is closely related to the possibility of insolvency), and the ratio of government debt to GDP at the end of our simulation horizon. We discuss each in turn.

Before delving into the discussion of our results, a note of caution is in order. We only consider a limited number of scenarios and, moreover, our results depend on our assumptions about how macroeconomic conditions responds to shocks, the formulation of the rule for the policy rate, the ultimate size of long-run reserve balances, and the rate of growth of currency in circulation.

Earnings Remittances: In Table 1, when reporting the average and standard deviation (across simulations) of annual remittances,[34] we distinguish between what we call the “transition phase” (2016-2030), during which there are important effects stemming from the projected rise in interest rates from current low levels to their long-run level, and the “longer run” (2031-2035).[35] We do this because, as the federal funds rate and the term premium revert to steady-state levels, the relationship between the long-run configuration of the balance sheet and the level and volatility of remittances varies over time.

During the transition phase (2016-2030), we observe that remittances are smaller and more variable for the larger long-run balance sheet ($2.5 trillion, shown in columns 4 and 5 of Table 1) than for the smaller ($1 trillion and $100 million) balance sheets. But, in the longer run (2031-2035), remittances are roughly comparable across all sizes of the balance sheet for Treasuries-only portfolios. Notably, the variability of remittances is highest for the $2.5 trillion portfolio. *Cumulative* nominal remittances over the entire simulation horizon are about $100 billion less under the large ($2.5 trillion) balance sheet scenario than they are under the small ($100 billion) balance sheet scenario.[36]

[34] We calculate the statistics across simulations within each year and then take the mean across years.

[35] Although the projected increase in interest rates occurs in the next few years, its impact on remittances persists further because asset purchases remain on the balance sheet for a long time. The “longer-run” results are meant to capture steady-state differences across scenarios once the effects of the rising interest rate have mostly dissipated by 2030.

[36] As reported in the background memo by Cavallo and Malin, the difference across scenarios in the present discounted value of remittances is even greater because years further in the future–when larger balance sheets produce relatively more remittances–are discounted more heavily.

Table 1: Fiscal Implications of the Long-Run Size/Composition of the Balance Sheet
(Billions of $, unless otherwise noted)

	Long-Run Reserves Floor (Billions of $) *				
	$100		$1,000	$2,500	
	33% T-Bills	Proportional to Issuance		All Treasuries	25% MBS
	(1)	(2)	(3)	(4)	(5)
Avg. Remittances					
2016-2030	63.5	64.0	63.9	56.2	58.4
2031-2035	108.7	107.5	111.4	110.0	121.5
Std. Dev. Remittances					
2016-2030	14.4	15.4	16.5	29.6	30.4
2031-2035	34.8	33.2	32.7	43.1	44.8
Deferred Asset					
Probability of Incurring **	8.3	11.1	10.4	60.0	59.9
95th percentile of Size	2.9	7.8	5.9	76.2	80.0
5th percentile of Mkt Val Assets less Interest-Bearing Liabilities ***	859.7	752.4	868.4	693.3	691.6
Fed Gov't Debt, End-2035 (Avg.)					
Nominal outstanding	36,122	35,796	35,615	34,826	34,602
Ratio to GDP **	85.5	85.5	83.7	81.1	80.4

* As for the composition across asset classes of the SOMA portfolio, it consists of all Treasury securities in all scenarios, except for that corresponding to column (5);
As for the maturity distribution of the SOMA Treasury portfolio, it is proportional to Treasury issuance in all scenarios, except for that corresponding to column (1).
** Expressed in percentage points
*** Minimum across periods

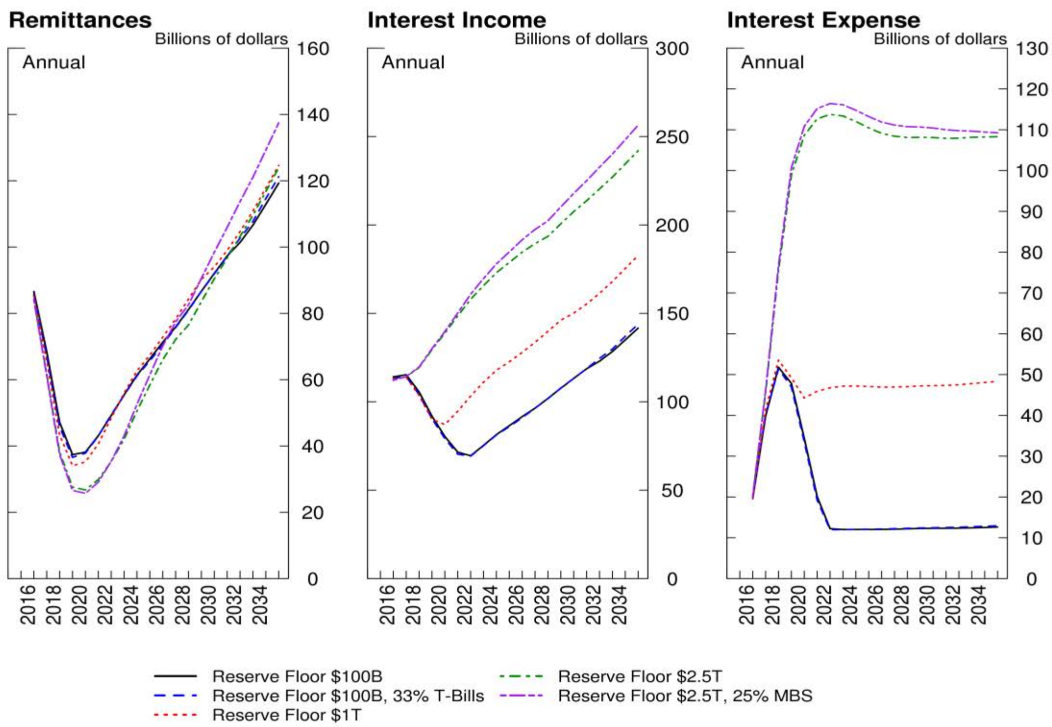
In terms of the *composition* of the balance sheet, comparing the first and second columns, we find that a shorter-maturity portfolio (i.e., one third in Treasury bills) has small quantitative effects. Qualitatively, remittances are smaller and less variable during the transition period, but larger and more variable in the longer-run. Comparing the fourth and fifth columns, we find that shifting the long-run composition of securities towards MBS increases both average remittances and their variability.[37]

It is also useful to look at the evolution of remittances over time. For the five scenarios, Figure 3 shows *average* (across simulations) annual remittances, interest income, and interest expense, respectively, from 2016 to 2035. In all scenarios, remittances decrease for the next four or five years and increase thereafter. The initial decrease is largely driven by the increase in interest expense, which rises sharply along with the projected path of the IOER at a time when the size of the balance sheet remains elevated, whereas interest income is less responsive because it mostly reflects the coupons of assets that were purchased in the past (so the average yield on asset holdings changes little). The subsequent increase in

[37] The background memo by Cavallo and Malin also reports the average and standard deviation of remittances *per unit of balance sheet dollars.* These measures give an indication about the rate of return on central bank assets and the variability of that return. The rate of return decreases in the size of the balance sheet (in both the transition and the long run), which is partly driven by the feature that the larger the balance sheet, the smaller is the fraction of assets backed by currency. The rate of return increases with the riskiness of the assets (i.e., greater for MBS holdings), while its variability varies little across scenarios.

remittances reflects the feature that, once the long-run level of reserve balances is reached,[38] the Federal Reserve begins to purchase higher yielding assets mostly to keep up with currency demand. In the long-run, purchased assets allow the Federal Reserve to earn, on average, positive net income because the yield curve is typically upward sloping and the Fed issues short-term liabilities to obtain longer-term securities.

Figure 3: Average Annual Remittances, Income, and Expense



Looking *across* scenarios, both income and expenses increase with the balance sheet size, as expected. Remittances, however, do not, especially in the transition period. This result is driven by two factors. First, maintaining a large balance sheet implies buying securities while the term premium is still very low. Second, varying the size of the balance sheet has general equilibrium effects; specifically, a larger balance sheet implies a lower term premium, which makes asset purchases more expensive and stimulates the economy, leading *ceteris paribus* to a higher IOER and interest expenses.[39,40] After all

[38] This occurs at a different time for each scenario: in 2016 for the $2.5 trillion scenarios, 2019 for the $1 trillion scenario, and 2022 for the $100 billion scenarios.

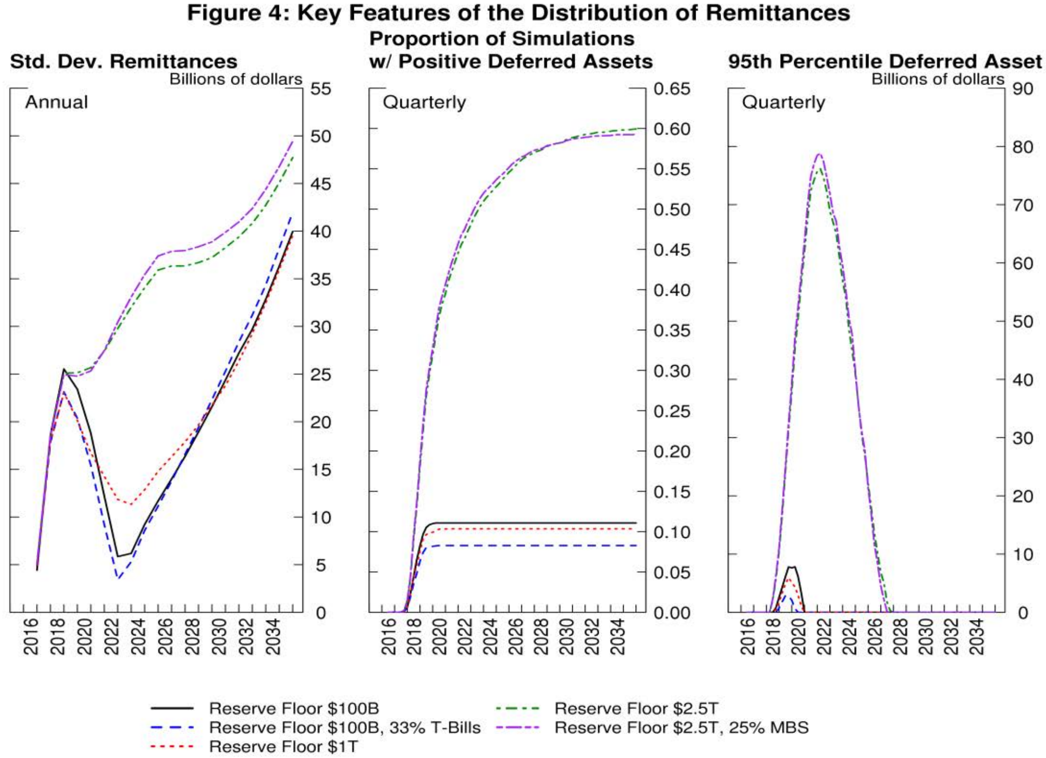
[39] To get a sense of the importance of the general equilibrium effects, the background memo by Cavallo and Malin reports results of simulations that abstract from them, by shutting off the effect of the balance sheet configuration on the term premium.

[40] The general equilibrium effects also lead to faster nominal GDP and currency growth, which work towards increasing remittances through two main channels. First, a faster pace of currency growth implies that a larger portion of the balance sheet is funded by non-interest bearing liabilities. Second, for a given level of reserves, faster currency growth implies that the Federal Reserve needs to step up its pace of purchases of Treasury securities, which ultimately generates additional interest

transition effects have dissipated, we expect remittances to be increasing in balance-sheet size as these general equilibrium effects only partly offset the greater net interest income implied, on average, by a larger balance sheet and a positive term premium.

With regard to the composition of the Federal Reserve's portfolio, the inclusion of agency MBS in the portfolio increases remittances, on average, as these securities carry higher coupons than comparable maturity Treasuries, owing to the presence of embedded borrower prepayment options. The higher interest income is only partly offset by a higher path for the IOER and thus interest expenses.

Figure 4: Key Features of the Distribution of Remittances



Turning to the variability of remittances, the left panel of Figure 4 shows the standard deviation (across simulations) of annual remittances for each balance sheet configuration. The volatility of remittances is roughly similar for the $100 billion and $1.0 trillion reserve balances scenarios, but increases substantially if reserve balances remain at their current elevated levels. Even though both the variance of interest income and interest expense (which are not shown) always increase with balance sheet size, the variability of remittances does not, at least for small-to-intermediate sizes. This pattern arises because of the property by which the variance of the difference between two random variables depends positively on the sum of the two random variables' respective variances but negatively on their covariance. This covariance term is essentially zero for the small balance sheet scenario (all assets are essentially backed by currency) and increases rapidly for the $1 trillion scenario. This increase offsets the

income. However, these channels are quantitatively less important than the general equilibrium effects that lead to higher interest expense and thus reduce remittances.

increase in the sum of variances of income and expense, thereby keeping the volatility of remittances roughly unchanged.[41] As the balance sheet grows further, the sum of variances becomes more important than the covariance term.

Deferred Assets: Table 1 also reports summary statistics on deferred assets for each scenario, including the likelihood of recording a deferred asset (i.e., the fraction of simulations that produce negative net earnings in at least one quarter) and the maximum (across periods) of the 95th percentile of its size (across simulations). Both are demonstrably higher in the $2.5 trillion scenario than the smaller-balance-sheet cases. Holding more MBS has little effect.

The middle panel of Figure 4 plots the *cumulative* share of simulations for each scenario that have experienced a positive deferred asset–that is, in a given quarter, it plots the share of simulations that have had a deferred asset in any quarter prior to and including that quarter. The *change* in the cumulative share reflects simulations that are experiencing a positive deferred asset for the first time. Negative net earnings are most common in 2018 and 2019, when short-term interest rates are projected to be rising, but the large ($2.5 trillion) scenarios also have many simulations in which a deferred asset is first recorded between 2020 and 2022. This result arises because purchasing additional securities while the term premium is negative implies that those securities are expected to generate negative net income over time. The larger are the purchases of such securities, the greater are the odds of booking a deferred asset. Specifically, moving from the $1 trillion to the $2.5 trillion scenario increases these odds from roughly 10 percent to almost 60 percent.

The right panel of Figure 4 plots the size of the deferred asset as measured by the 95th percentile of the distribution–which can be loosely interpreted as a "value at risk" measure for the Federal Reserve.[42] Looking across scenarios, we see a close relationship between the likelihood of recording a deferred asset and the size of the deferred asset. The deferred asset is unlikely to be above $10 billion in the small or medium reserve balances scenarios but can be as large as roughly $75 billion for the large scenario.

(In)Solvency:

As explained above, the Federal Reserve is insolvent if the EPDV of remittances to the Treasury is ever negative–in this case, the Fed is expected to need recapitalization from the Treasury at some point in the future or to resort to "printing money." As noted earlier in the memo, the EPDV of remittances equals the sum of what Del Negro and Sims (2015) call the Federal Reserve's "intangible" and "tangible"

[41] In Section 2, we stated that the volatility of remittances would increase with the size of the balance sheet in the long run, but in our simulations, we find that this relationship is not monotonic in what we have called the "longer run" (2031-2035). The reconciliation is that "transition effects" have not yet *fully* dissipated by 2035. A more thorough discussion is provided in the background memo by Cavallo and Malin.

[42] "Value at Risk" (VaR) is a measure of the risk of a given portfolio over a set horizon. For example, a one-day 5 percent VaR of $1 million means there is a 0.05 probability that the portfolio will fall in value by more than $1 million over a one-day period. In our case, the right panel of Figure 4 plots threshold values such that the probability of cumulative negative net earnings on the Federal Reserve's balance sheet exceeding these values is 0.05. One study that uses a probabilistic approach to analyze the interest-rate risk of the SOMA portfolio is that by Christensen, Lopez, and Rudebusch (2015).

wealth; precisely, intangible wealth is the EPDV of future seigniorage, and tangible wealth is the market value of the Fed's assets less the value of its interest-bearing liabilities.

Table 1 reports the *minimum* of the Fed's tangible wealth (as measured by the 5th percentile of the distribution). The lowest values of tangible wealth are realized in the large balance-sheet scenarios, due to large realizations of deferred assets and unrealized capital losses. But, even in this case, tangible wealth is always substantially above zero. Assuming that the EPDV of seigniorage is positive, we conclude that Federal Reserve insolvency is an extremely remote possibility under our balance sheet scenarios.

Broader fiscal implications:

We have so far focused on potential outcomes for earnings remittances (and related measures), but remittances provide an incomplete characterization of the overall fiscal implications stemming from different configurations of the balance sheet. More specifically, different sizes and compositions of the Federal Reserve's portfolio prompt more or less accommodative financial conditions, depending on the overall duration of the portfolio. In turn, different financial conditions might well affect the pace of economic expansion and thus the level of nominal tax receipts, ultimately affecting the overall fiscal position of the federal government in terms of budget balances and outstanding debt.

We use the FRB/US model to evaluate these broader fiscal effects, and Table 1 showed, as summary statistics, outstanding federal government debt at the end of 2035, expressed both in nominal dollars and relative to GDP. We see that moving from the small balance-sheet ($100 billion) scenarios to the large balance-sheet ($2.5 trillion) scenarios reduces average outstanding debt by over $1 trillion, a decrease that is about equivalent to a 5 percentage point reduction in the debt-to-GDP ratio. This is the result of the large balance sheet scenario producing substantially more tax revenues, about $2.4 trillion, over the simulation horizon. Thus, although cumulative remittances are about $100 billion lower under the large scenario, this difference is swamped by the overall impact on the government budget position.[43]

Prolonged low-interest-rates scenario:

We conclude this section with a discussion of the fiscal implications of a prolonged period of low interest rates, which results from a sluggish economy and persistent deflationary pressures. In such circumstances, the Federal Reserve may choose not to shrink the balance sheet, which implies that new long-term securities must be purchased to replace those that mature, or it may even expand its balance sheet. However, if the term premium is negative–as it is currently (see Figure 2 above)–the "carry trade" in which the Federal Reserve engages (buying long-term securities financed by short-term borrowing) has negative expected returns. Future remittances are thus expected to be low, and they could possibly

[43] A larger balance sheet provides financial accommodation in our model, and although monetary policy responds by increasing the policy rate, the increase is delayed because of the *inertial* nature of the assumed policy rule. This results in higher output for some time and, in turn, higher cumulative tax receipts in our simulations.

be negative if the balance sheet is so large that these negative returns are larger than seigniorage (i.e., the growth in currency).[44]

We consider a recessionary scenario in which the federal funds rate returns to the effective zero lower bound from the beginning of 2017 through the end of 2018. Against the backdrop of this recessionary scenario, we evaluate the implications of two balance sheet configurations that could provide further accommodation of financial conditions: the first is the "$2.5 trillion long-run reserves, Treasuries-only" case considered above; the second involves a temporary resumption of LSAPs during the recession, whose termination is conditional on the achievement of certain macroeconomic outcomes. In particular, this outcome-based LSAP program consists of purchases at monthly paces of $100 billion and $40 billion for Treasury securities and agency MBS, respectively, and continues until the unemployment rate falls back to 6½ percent. At that time, the overall size of the balance sheet reaches $6.7 trillion, with reserves balances reaching $4.7 trillion. Over time, reserve balances shrink to $2.5 trillion.

Figure 5: Average Annual Remittances, Income, and Expense in Recessionary Scenario

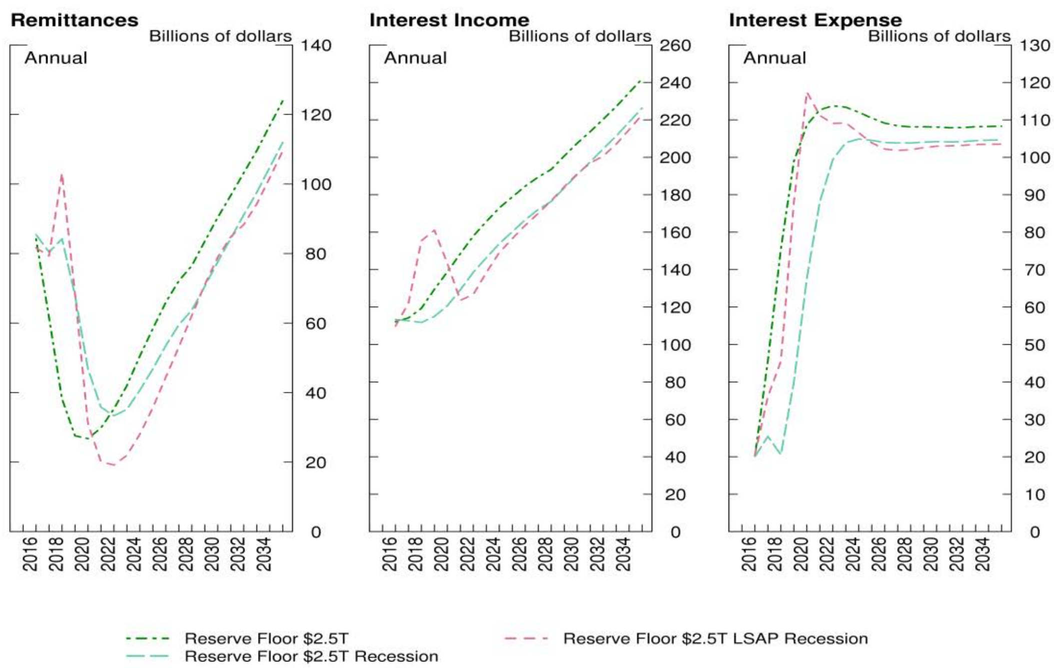


Figure 5 plots the average (across simulations) remittances, interest income, and interest expense for these configurations, and for comparison, it also plots the corresponding non-recessionary results for the first configuration. Under the first configuration, we find that the recession *per se* actually boosts remittances for the first few years. This is because the recession lowers the IOER, which decreases interest expense–and thus increases remittances–associated with assets that were *already* on the balance sheet. Furthermore, because the term premium in FRB/US is countercyclical (i.e., it depends

[44] Seigniorage itself may in principle become negative in a prolonged deflationary situation, as the public needs less currency to maintain any given amount of real balances.

negatively on expected future output gaps), the expected net income associated with *new* asset purchases is, on average, higher in the recessionary scenario.

Comparing across the two alternative configurations in the recessionary case, we find that expanding the balance sheet in response to the depressed state of the economy (that is, the LSAP scenario) boosts remittances in the near term (because the yield curve slopes upward). However, we also find that remittances are expected to be lower in the medium term (because the term premium on new asset purchases is negative). Relatedly, both the likelihood and observed magnitude of the deferred asset (not shown) increase substantially in the LSAP scenario compared with the $2.5 trillion scenario, in line with results discussed above regarding balance sheet size. That said, expanding the balance sheet also has substantial positive broader fiscal effects, which must be taken into account when assessing the desirability of such a policy.[45]

5. Conclusions

To conclude, we highlight possible avenues for future research. First, the literature on the fiscal implications of balance sheet policy in general equilibrium is very limited and based entirely on results from the FRB/US model. More work is required to assess whether its lessons are robust to the use of different models and assumptions. Second, to our knowledge, very little research has been done on the coordination between the monetary and fiscal authorities as it pertains to balance sheet policies (Bhattarai et al., 2015, is an exception). Finally, there is also a dearth of work on optimal interest and balance sheet policy that takes into account the fact that the central bank has a separate budget constraint from the fiscal authority.

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[45] Detailed results are provided in the background memo by Cavallo and Malin. In comparison to a policy that maintains the current level of reserve balances, the “resume-LSAPs” scenario reduces cumulative remittances over the simulation horizon by about $100 billion, but it also lowers the debt-to-GDP ratio at the end of 2035 by almost 2½ percentage points.

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APPENDIX 1: SOMA Model Set-up

The Federal Reserve Board's SOMA model requires two main inputs. We discuss each one in turn:

- Assumptions about the configuration of the Federal Reserve's balance sheet: Our initial condition is the configuration at the end of 2016:Q1.
    - Assumptions about the asset side:
        - No asset sales at any point in time;
        - Treasury and agency debt holdings roll off the SOMA portfolio at maturity;
        - Agency MBS prepayments are determined by a model developed by Board staff;
        - Reinvestments of maturing securities and principal payments expected to cease when the federal funds rate reaches a level between 1¼ and 1½ percent;[46]
        - No additional asset purchases are made until the size of the balance sheet "normalizes," that is, when reserve balances reach their long-run level;
        - Once the balance sheet size has normalized, securities are purchased to keep up with capital and currency growth.[47]
    - Assumptions about the liability side:
        - Currency grows with nominal GDP; Capital paid-in grows at an annual rate of 5.5 percent.

[46] This assumption is in line with expectations drawn from the June 2016 New York Fed's Survey of Primary Dealers: https://www.newyorkfed.org/markets/primarydealer_survey_questions.html.
[47] Depending on the portfolio composition assumption, Treasury securities are also purchased to replace roll-offs of agency MBS as MBS continue to pay down.

        - Along with our assumptions on the long-run level of reserves—either $100 billion, $1 trillion, or $2.5 trillion—these components determine the long-run size of the balance sheet.
    - Level of ON RRPs at $100B through the end of 2018, then declining to zero by the end of 2019.[48]

- Projected paths for financial and macroeconomic variables that affect the evolution of the balance sheet and the income it generates.
    - Paths of financial and macroeconomic variables—most importantly, interest rates and nominal GDP—are generated by running stochastic simulations of the FRB/US model;
    - Stochastic simulations are based around deterministic paths consistent with the June 2016 public FRB/US release;
    - Shocks relative to the deterministic paths are held constant across scenarios; Deterministic paths differ across scenarios because the configuration of the long-run balance sheet affects the term premium, which, in turn, affects the rest of the economy;
    - For each scenario, we conduct 5000 simulations from 2016 through 2035.

[48] This assumption follows the policy normalization principles as outlined by the FOMC: "The Committee will use an overnight reverse repurchase agreement facility only to the extent necessary and will phase it out when it is no longer needed to help control the federal funds rate." See Policy Normalization Principles and Plans, September 27, 2014, available at http://www.federalreserve.gov/newsevents/press/monetary/20140917c.htm.