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Long-Run Framework: Macroeconomic Considerations of Balance Sheet Policies[1]

1. Introduction

In response to the financial crisis and the subsequent slow recovery, the Federal Open Market Committee (FOMC) undertook a series of balance sheet programs, which included large-scale asset purchases (LSAPs)—primarily of longer-term Treasury securities and agency mortgage-backed securities (MBS)—and a maturity extension program (MEP). These programs were intended to provide additional monetary policy accommodation by putting downward pressure on longer-term interest rates and improving overall financial conditions at a time when the conventional policy instrument, the federal funds rate, was constrained by the effective lower bound (ELB). More favorable financial conditions would in turn promote stronger economic activity and thus help keep disinflationary pressure in check, aiding the Committee in achieving its mandated objectives of maximum employment and price stability.

These programs greatly transformed the size and composition of the Federal Reserve's balance sheet. Assets rose from around $800 billion (about 5 percent of nominal GDP) prior to the financial crisis to over $4 trillion (about 24 percent of nominal GDP) when the most recent LSAP program concluded in the fall of 2014. On the liability side, there was a substantial increase in bank reserves held at the Federal Reserve. Moreover, the average duration of assets held by the Federal Reserve increased significantly as a result of these programs.

In this memo, we survey the theoretical and empirical literature on the macroeconomic effects of balance sheet policies to highlight the possible tradeoffs associated with various configurations of the balance sheet. We focus primarily on analyzing balance sheet policies involving Treasury securities and agency MBS, since these are the principal assets that the Federal Reserve is permitted to buy under the Federal Reserve Act. However, some of our analysis applies to purchases and sales of riskier securities, which are more applicable to the specialized lending and liquidity programs that the Federal Reserve undertook at the onset of the crisis.

Our analysis begins by discussing the channels through which central bank asset purchases and sales affect asset prices and the macroeconomy. We then survey estimates of the effects of asset purchases and sales on longer-term interest rates and financial conditions as well as estimates of the effects on real activity and inflation. We also discuss international dimensions to the transmission of balance sheet policies and complement our survey with evidence on the effects of asset purchases by foreign central banks. Our reading of the literature suggests that the LSAPs and MEP undertaken by the Federal Reserve were successful in improving financial and

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macroeconomic conditions during and in the aftermath of the financial crisis, both here and abroad.

We use this empirical analysis to assess the macroeconomic benefits of employing balance sheet policies in periods when the policy rate is constrained by the ELB and in "normal" times when the policy rate is well above the ELB. We then briefly discuss some of the possible macroeconomic costs of using balance sheet tools, including those related to the FOMC's dual mandate.

We use the cost-benefit analysis to highlight the arguments for and against the Federal Reserve employing the balance sheet actively along with the policy rate away from the ELB to achieve macroeconomic objectives. An important consideration in such a decision is the degree of substitutability between balance sheet tools and interest rate tools. If balance sheet tools and interest rate tools are highly substitutable, then balance sheet actions may be better reserved for ELB-constrained periods. But if balance sheet tools operate differently from interest rate tools along some dimensions, then it is at least theoretically possible to achieve better outcomes using the tools in tandem. Although we do not arrive at firm conclusions regarding these alternative configurations, our analysis points to some of the key tradeoffs and issues in assessing their relative merits.

2. Transmission Channels of Balance Sheet Policy

In this section, we outline some of the main channels through which balance sheet policy might affect the macroeconomy.

2.1 Signaling Channel

Changes in the Federal Reserve's balance sheet can affect expectations of the path of short-term rates to the extent that they convey information about the FOMC's reaction function for setting the policy rate or the state of the economy to the public. Similar to forward guidance for the policy rate, this channel works through the standard expectations hypothesis connecting shorter- and longer-term interest rates. Accordingly, an expansion in the Federal Reserve's holdings of longer-term securities can cause the expected path of short-term rates to shift down and inflation expectations to shift up, reducing real long-term rates. Through arbitrage and spillover effects, the decline in real long-term rates can raise equity prices and reduce the real exchange value of the dollar, leading to a broader easing in financial conditions which in turn stimulates aggregate demand through increased consumer spending, investment, and net exports.

Some analysts suggest that the balance sheet can be a commitment device to make forward guidance more credible, as demonstrated in Bhattarai, Eggertsson, and Gafarov (2015). In their model, the central bank uses reserves to purchase longer-term Treasuries and shortens the maturity of the consolidated government's debt held by the public. With a shorter maturity structure, an increase in the future policy rate would result in higher government financing costs, which in turn would lead the government to raise taxes. Therefore, in equilibrium, monetary and

fiscal authorities will coordinate to keep real rates low, leading private agents to expect that interest rates will remain low for longer, boosting the economy immediately.

2.2 Imperfect-Substitutability Channel

Central bank asset purchases and sales can affect asset prices and economic conditions through additional channels when financial assets are not perfect substitutes. In this channel, central bank asset purchases reduce the supply of the targeted securities available to private investors, creating excess demand. Substitution into other securities cannot completely satiate the excess demand because these other securities—which have different maturity, safety, and liquidity characteristics—are imperfect substitutes. As a result, central bank asset purchases drive up the prices and correspondingly reduce the yields of the targeted securities.[2] This decline in yields eases overall financial conditions, as the yields of other similar but non-targeted securities also falls, and stimulates aggregate demand in a manner similar to the signaling channel; however, more of the fall in longer-term rates should be manifested in term-premium and other risk-premium components rather than in the expectations component.

The imperfect substitutability of assets is often associated with the preferred habitat approach that gives rise to a portfolio balance effect in which central bank purchases of longer-term securities influences the term premium component of interest rates.[3] Deviations of longer-term interest rates from the strict expectations theory are well-documented empirically, and the preferred habitat approach implies that some of these deviations reflect movements in the relative supplies of outstanding stocks of debt held by the public.

Imperfect asset substitutability can arise from a variety of market imperfections that restrict arbitrage such as capital constraints on financial intermediaries, limited-risk bearing capacity, elevated transactions costs, and limited market participation.[4] Curdia and Woodford (2011), He and Krishnamurthy (2013), Gertler and Karadi (2011, 2013), and Schabert (2015), among others, emphasize alternative imperfections in financial markets that give rise to a role for central bank purchases and sales to affect asset prices via imperfect asset substitution and in turn economic activity and inflation. Many of these papers emphasize financial market imperfections that are more applicable to the specialized lending programs undertaken by central banks in the depth of a financial crisis; however, papers like Gertler and Karadi (2013) discuss how collateral

[2]If securities were perfect substitutes and the central bank purchases were large enough, there could still be a price effect though it probably would dissipate quickly as arbitragers eliminated the price discrepancy between purchased and unpurchased securities.

[3]Prominent papers from the literature in the 1950s and 1960s on this topic include Culbertson (1957), Modigliani and Sutch (1966), Tobin (1961, 1963), and Wallace (1967). See Vayanos and Vila (2009) for a more rigorous theoretical approach in the context of a term-structure model, while Andres, Lopez-Salido, and Nelson (2004), Kiley (2014), and Chen, Curdia, and Ferrero (2012) incorporate these ideas into macroeconomic models.

[4]In a series of papers, Christensen and Krogstrup (2016a, 2016b) emphasize that because reserves can be held only by banks, they are an asset that is imperfectly substitutable with other assets in the financial system. They show how an increase in reserves held at the central bank can reduce longer-term yields independent of the particular assets that the central bank purchases and provide evidence for this mechanism based on Swiss data.

constraints on financial intermediaries create a role for central bank purchases and sales of longer-term Treasury securities and MBS to affect asset prices and the macroeconomy.[5]

Caballero and Farhi (2016) focus on the imperfect substitutability between risky and safe assets broadly defined. Their analysis suggests that central bank purchases of risky private assets can expand the supply of safe assets (through expanded bank reserves) when there is a "shortage" of such assets, lower risk premiums on risky assets, and raise the equilibrium real rate. Moreover, they suggest that purchases of risky assets are more effective than forward guidance about the policy rate at the ELB.

2.3 Duration-Risk Channel

The duration-risk channel derives from the sensitivity of longer-term assets to interest-rate risk. Specifically, longer-term securities are exposed to short-rate volatility for a longer period of time than shorter-term securities, and investors demand a premium for bearing this risk. This implies a direct relationship between the bond term premium and investors' aggregate exposure to short-rate risk as measured by the average duration of their portfolio.[6] To the extent that the central bank removes aggregate duration risk from private investors through an MEP or purchases of longer-term securities, term premiums should decline. The removal of a certain quantity of duration risk, independent from the maturities of the securities used to achieve this reduction, should generate reactions across the entire yield curve. This effect should be larger for the yields of longer-term securities than for the yields of purchased securities.[7]

Though the duration-risk channel is often studied in models in which assets are imperfect substitutes, both Greenwood and Vayanos (2014) and King (2015) show the existence of the duration-risk channel does not require market segmentation or restrictions on arbitrage.[8] In the context of their models, when short-rate volatility is greater than zero, changes in the public's holdings of bonds can affect term premiums. Moreover, King (2015) and Li and Wei (2013)

[5]Gabaix, Krishnamurthy, and Vigneron (2007) and Krishnamurthy and Vissing-Jorgensen (2013) present evidence that capital constraints on sophisticated investors such as hedge funds and mutual funds were important in determining the effect of purchases of MBS on spreads of these securities and financial conditions more broadly.
[6]As shown in Greenwood and Vayanos (2014), the term premium reflects the product of the quantity of risk for the short-term interest rate and the market price of that risk. In their model, a reduction in the supply of bonds reduces the market price of risk for the short-term rate, which is also equal to the average duration of investors' portfolio and is common to all bonds through the absence of arbitrage.
[7]Vayanos and Vila (2009), for example, highlight the interaction between the imperfect asset substitutability and the duration-risk channels. Their model includes preferred-habitat investors to pin down the demand for securities with specific maturities as well as risk-averse arbitrageurs to eliminate arbitrage opportunities across maturities. When risk-aversion is very low, bond prices are arbitrage-free and supply shocks affect the term premium by altering the duration of the arbitrageurs' portfolio, hence only the duration-risk channel matters. However, when risk-aversion is high, the supply effects through the preferred-habitat investors become relatively more important in determining bond prices and term premiums.
[8]As discussed in King (2015), changes in the supply of asset quantities affect asset prices in any model in which the pricing kernel depends on the return on wealth. King (2015) calls this a no-arbitrage portfolio balance effect in models without restrictions on arbitrage.

show that the magnitude of the effects stemming from the duration-risk channel depends on the expected future supply of longer-term bonds, because this determines market expectations about the persistence of the reduction in duration risk. King (2016) also shows that the effects of the duration-risk channel depend on whether the policy rate is at the ELB. At the ELB, the duration-risk channel has less effect because the ELB constraint lowers the volatility of the short-term interest rate, which is the dominant factor driving this channel's impact.[9] The diminution of duration-risk-channel effects is greater the longer the short-rate is expected to remain at the ELB. This implies that the macroeconomic effects of central bank asset purchases or sales operating through the duration-risk channel may be larger away from the ELB.

2.4 Prepayment-risk channel

The prepayment-risk channel is specific to MBS and derives from the relationship between the probability of prepaying (or refinancing) a mortgage and the level of interest rates.[10] Specifically, in the United States, mortgage borrowers have the option to prepay mortgages without penalty. Their incentives to prepay and refinance increase when new mortgages are available at lower rates. This exposes MBS investors to uncertain investment horizons and therefore to higher risk.[11] The premium demanded for such risk is lower for those MBS in which the rate on the underlying loans is closer to the current mortgage rate, as a smaller spread between these two rates implies a lower incentive to prepay.

As central bank asset purchases push interest rates lower, MBS with lower coupons will be less affected than MBS with higher coupons, whose relative increase in prepayment risk will command a higher premium. As emphasized in Boyarchenko, Fuster, and Lucca (2015), when the central bank purchases MBS, the increase in premiums due to the prepayment-risk channel for higher-coupon MBS can have an offsetting effect from the decline in premiums occurring through other channels such as the duration-risk channel. This suggests that, all else equal, MBS purchases would be more effective in lowering MBS yields if concentrated in lower-coupon MBS for which changes in prepayment risk would be negligible. Similar logic would apply to MBS sales: If MBS sales are conducted in an increasing interest-rate environment, the lower prepayment-risk premiums should attenuate the impact of sales on MBS prices.

2.5 Open Economy Considerations of the Transmission of Balance Sheet Policies

So far, we have emphasized that central bank asset purchases can stimulate aggregate demand by putting downward pressure on longer-term interest rates and other risky spreads, and generally improving domestic financial conditions. This improvement in financial conditions and in turn

[9]While the ELB lowers the volatility of nominal short-term rates, it is theoretically possible that it increases the volatility of real short-term rates through movements in inflation. However, the effect on inflation tends to be small in empirically realistic models so that the volatility of real short-term rates is lower too. Hence the duration-risk channel's effects on real term premiums are smaller at the ELB.

[10]Even though the vast majority of U.S. mortgage debt outstanding (about $10 trillion) are 30-year fixed rate mortgages, their actual duration rarely exceeds 8 years because of prepayments.

[11]In contrast, Australia and most European countries have prepayment penalties. See Jaffe (2011) and Badarinza et al. (2016) for a discussion.

aggregate demand occurs in part through a depreciation of the domestic country's currency that stimulates net exports. An additional open-economy consideration, arising from imperfect asset substitution, is that investors appear to have a preference for domestic securities relative to foreign securities; as a result, as shown in Neely (2015), central bank asset purchases can generate movements in excess returns that create greater financial spillover effects across countries.[12] In his model, asset purchases not only lower longer-term yields, raise asset prices domestically, and boost domestic economic activity but they also lead to lower yields and to higher asset prices abroad, which in turn helps boost foreign activity.[13] Haberis and Lipinska (2015) show that the size of such spillovers onto foreign activity can be much larger if foreign policy rates are constrained by the ELB.

2.6 Other Considerations of the Transmission of Balance Sheet Policies

The transmission of balance sheet policies to the real economy through the aforementioned channels depends upon settings of other economic policies. As we discuss in subsequent sections, the setting of the policy interest rate and the ELB constraint are important determinants of the general equilibrium effects of balance sheet policy. In addition, as discussed in the fiscal considerations memo, fiscal policy can influence the effectiveness of balance sheet policy through two avenues. First, the fiscal policy and central bank balance sheet policy jointly determine the maturity structure of the consolidated government debt in the hands of the public, which in turn influence the ultimate impact of balance sheet policy on the economy. Second, a central bank with a large balance sheet potentially could require a capital infusion from the fiscal authority that might influence the central bank's policy decisions, although the analysis in the fiscal considerations memo suggests that this is a remote possibility.

3. Estimates of the Effects of Balance Sheet Policies on Asset Prices

Estimating the impact of balance sheet policies on asset prices requires isolating the effect of a change in the amount and maturity structure of securities available to the private sector on the asset's price, controlling for a variety of factors including expectations about future monetary policy and macroeconomic conditions. A number of approaches have been used to estimate the effects of central bank asset purchases, including event studies (the most common approach[14]), time series models, and cross-sectional analysis.

[12]Huberman (2001) discusses home country bias and shows that people prefer to invest in familiar assets while ignoring principles of portfolio theory.
[13]Borio and Zhu (2012) also emphasize how portfolio balance effects can occur through international financial markets. Hofman, Shim, and Shin (2015) find that U.S. monetary easing results in lower yields in emerging market economies in part because of improvements in the balance sheets of financial firms in those economies.
[14]Early examples include Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Swanson, (2011), and Rosa (2012).

Table 1 reports the estimates from several studies of the price elasticity of the 10-year nominal Treasury yield (i.e., the change in basis points per $100 billion purchases of longer-term securities). Each study in Table 1 attempts to identify the impact operating through the imperfect-substitutability, duration-risk, or signaling channels by controlling for the effects from the other channels.[15] The studies differ in their samples, the purchase programs evaluated, and their methodologies. Estimates of the price elasticity from the imperfect-substitutability channel vary from -4 basis points per $100 billion to -10 basis points. The comparatively large estimates in D'Amico and King (2013) likely reflect its focus on the first LSAP, when impaired market functioning and elevated risk aversion enhanced the impact of the imperfect-substitutability channel. Accordingly, the smaller estimates of the other papers may be more applicable to relatively "normal" financial market circumstances.

Estimates of the price elasticity from the duration-risk channel vary from about -2 basis points to about -5 basis points per $100 billion of longer-term asset purchases. The larger estimate of Li and Wei (2013) reflects the fact that they account for the contemporaneous change in MBS duration while most studies do not. In contrast, King (2016) finds a smaller effect because he takes into account ELB-related compression of interest-rate volatility that reduces the effect of the duration-risk channel. Cahill, D'Amico, Li, and Sears (2013) (henceforth, CDLS) estimate an elasticity of -4 basis points that does not appear to have changed across programs, suggesting that this channel remains important even in environments in which financial stress is low. Assuming no nonlinear interactions between the duration-risk and imperfect-substitutability channels, the effect of these two channels can be added together, implying that the term premium on the 10-year Treasury falls 8 basis points per $100 billion of purchases based on the estimates of CDLS. Their estimates appear fairly stable despite the expansion of the Federal Reserve's balance sheet.

For the signaling channel, the estimated price elasticity ranges from -2 to – 5 basis points per $100 billion of purchases, primarily reflecting the different sample periods of the studies. However, both Bauer and Rudebusch (2014) and King (2016) study periods when the federal funds rate was constrained by the ELB, so their findings may be less applicable to periods when the ELB is not binding. Their estimates may also have been influenced by changes in forward guidance for the federal funds rate.[16]

An important determinant of the effects of balance sheet policy on the macroeconomy is the persistence of these policies' impact on financial prices. In the context of the dynamic term structure model of Li and Wei (2013), central bank asset purchases can induce a persistent decline in term premiums through the duration-risk channel. Similarly, Rogers, Scotti and Wright (2014) (henceforth, RSW) find that the effects of announcements about the Federal

[15]It is particularly challenging for studies using time-series analysis to control for the possibility that forward guidance for the federal funds rate can reduce uncertainty about the future path of the policy rate and lower term premiums. See Akkaya (2014) and King (2015) for a discussion.

[16]In addition, changes in the maturity structure of the Federal Reserve's balance sheet may affect the estimates on the importance of the signaling channel, making it hard to disentangle its effects from the duration-risk channel.

Reserve's asset purchases and forward guidance for the federal funds rate on financial prices wear off fairly slowly.[17]

The studies listed in Table 1 mostly emphasize "stock" effects, whereby a central bank's asset purchases (or sales) affect asset prices by changing expectations about the size and duration of assets available to the public. In contrast, Kandrac and Schlusche (2013) consider "flow" effects in which central bank's asset purchases or sales at the time of the transactions can affect an asset price by altering market liquidity and functioning. They find that such effects dissipate quickly. Accordingly, flow effects likely are less relevant for assessing the macroeconomic benefits of asset purchases than "stock" effects. However, asset price movements arising from "flow" effects may yield benefits for the financial system or pose risks.

Another pertinent issue is whether the effects of asset purchases differ for programs whose total size and duration are "fixed" at the onset or "open ended" with the pace and duration depending on economic outcomes. Some results in Li and Wei (2013) and King (2016) suggest that "fixed" programs tend to be more effective. In their models, they compare a scenario in which there is a single large shock to the supply of securities available to the public to a scenario in which there is a sequence of smaller shocks (whose total effect on the supply of securities is comparable to the single shock) and find that the cumulative impact on yields of the sequence of smaller shocks is smaller than the impact of the single large shock. Still, a clearly-communicated open-ended program tied to a central bank's objectives might be helpful for the public to understand a central bank's commitment to achieve its goals. It would also enable expectations of the path of the balance sheet to adjust appropriately to shocks, which could enhance policy efficacy.

Regarding the evidence more specific to purchases of MBS, Hancock and Passmore (2014) find that the Federal Reserve's asset purchases lowered MBS yields and mortgage rates, consistent with portfolio balance effects arising from a variety of sources. Boyarchenko et al. (2015) show that following those purchases, yields of MBS with low coupons fell more than those with high coupons, consistent with the effects from the prepayment-risk channel discussed in Section 2.4.

A few studies are also consistent with central bank asset purchases leading to an improvement in broader financial conditions. The evidence in Rosa (2012) and RSW suggests that the Federal Reserve's asset purchases helped boost equity prices, while the evidence in Gilchrist, Lopez-Salido, and Zakrajsek (2015) suggests that the Federal Reserve's asset purchases lowered corporate yields.

Almost all of the available evidence on the effects of balance sheet policy is derived from asset purchases and hence it is difficult to determine whether the effects of sales would be asymmetric. CDLS exploit the fact that both asset purchases and sales took place during the MEP and find that asset sales and purchases have similar-sized effects through the imperfect-substitutability channel. RSW provide evidence that announcements that signaled an earlier-than-expected end to the third LSAP, such as then-Chairman Bernanke's May 2013 Congressional testimony, had

[17]Using a similar methodology as RSW, Wright (2012) finds less persistent effects. However, the sample size is notably smaller in Wright (2012) than in RSW.

similar-sized effects on Treasury yields as asset purchase announcements; however, they also find that unconventional policy easings had a bigger impact on U.S. equity prices than tightenings. In light of these results, more analysis and evidence is necessary to arrive at a firmer conclusion regarding the effects of asset sales, particularly in regard to flow effects from sales.

Overall, for the Federal Reserve's asset purchases, the evidence suggests that they noticeably lowered the yields on the targeted assets and were associated with improvement in broader financial conditions. However, there is still considerable uncertainty about the precise magnitude of these effects and how these effects could vary with the size of the balance sheet. Moreover, researchers reach differing conclusions about the relative importance of the channels, complicating any analysis of the effect of balance sheet policies when the policy rate is away from the ELB.

3.1 International Evidence

The international evidence is generally consistent with domestic central bank asset purchases reducing yields abroad and improving domestic financial conditions in part through the exchange rate. For the United States, Glick and Leduc (2015) concentrate on the effects of monetary policy shocks on the exchange value of the dollar and show that the effects of unconventional monetary policy are greater than those of conventional policy. Other studies such as RSW and Ammer et al. (2016), however, find that conventional and unconventional policies had similar effects on the dollar.

For the United Kingdom, Joyce et al. (2011), Banerjee et al. (2012), and Churm et al. (2015), provide evidence that the BOE's asset purchases had significant effects on long-term yields in part through portfolio rebalancing.[18] De Pooter et al. (2014), Fratzscher et al. (2016) and Georgiadis and Grab (2015) all provide evidence that asset purchases by the European Central Bank (ECB) helped restore confidence in euro area financial markets. Finally, Andrade et al. (2016) finds that the latest ECB program of asset purchases that included sovereign bonds (in addition to private bonds) led to a significant and persistent decline in euro area longer-term sovereign yields and to an increase in equity prices of banks that held more sovereign bonds.

RSW studied the effects of the unconventional policies of the ECB, Bank of Japan (BOJ), Federal Reserve, and BOE on asset prices, focusing on international bonds, stock prices and exchange rates.[19] They found that Federal Reserve asset purchases reduced foreign long-term rates as well as the exchange value of the dollar. For the Federal Reserve and the BOE, RSW do not find significant differences between the effects of announcements involving asset purchases in 2008-2009 and announcements about policy rates prior to the crisis. In case of the BOJ,

[18]Focusing on the imperfect substitutability channel, Banerjee et al. (2012) finds that the estimated effects of asset purchases announced by the BOE in 2011 had similar effects as the program announced in 2009. In contrast, Churm et al. (2015) find that the effects of the 2011 program were smaller than the earlier program, as the 2009 program had a stronger signaling effect. There has been no formal analysis of the new program that the BOE announced in August though 10-year yields and corporate bond spreads fell at the time of the announcement.

[19]The authors cover a number of asset purchases programs by these foreign central banks including the ECB's announcements of the Outright Monetary Transaction program and Securities Market Program, the BOJ's quantitative easing programs both during and prior to the financial crisis, and the BOE's Asset Purchase program.

announcements involving asset purchases had a bigger impact than other policy announcements.[20]

4. Estimates of the Effects of Balance Sheet Policies on the Macroeconomy

In contrast to the empirical estimates of the effects of balance sheet policy on asset prices, there are fewer studies quantifying the effects of balance sheet policy on economic activity and inflation. All of the studies reviewed below find empirical support for the notion that balance sheet policy has important macroeconomic effects. However, there is little consensus on the magnitude of such effects. The different estimates can be ascribed mainly to alternative modeling frameworks and in particular to assumptions made about the policy rate response to changes in balance sheet policy. Accordingly, this literature highlights the interaction of balance sheet policy with interest rate policy and how each of their effects depends importantly on the assumptions made about the setting of the other policy instrument.

4.1 Scoring the Effects of LSAPs

There are three broad classes of models used to estimate the effects of balance sheet policy on output and inflation. The first, Dynamic Stochastic General Equilibrium (DSGE) models, feature tight linkages to economic theory and allow for a direct assessment of some of the channels mentioned in Section 2. Nevertheless, DSGE models require substantial simplifying assumptions, particularly regarding the structure of financial markets, and do not fully capture some of the potential transmission channels.

Chen et al. (2012) study the effects of the second LSAP program in a DSGE model which incorporates segmented financial markets along with a preferred habitat approach so that central bank asset purchases can affect the risk premium.[21] They find only modest effects of the second LSAP program on the level of output: at most, a 0.1 percent increase in the level of GDP. Of all the studies surveyed here, this is the smallest estimated effect, reflecting that the estimated degree of segmentation is small and that the policy rate, responding according to a Taylor-type rule, can increase after a few quarters. Consistent with the modest increase in output, the corresponding increase in inflation is negligible and likewise is the lower bound of the studies surveyed here.

Gertler and Karadi (2013) also use a DSGE model to study the effects of the Fed's balance sheet policies. Like Chen et al. (2012), their model features imperfect asset substitutability; however, it arises because financial intermediaries face capital constraints and they intermediate both longer-term government securities as well as private securities. Gertler and Karadi find a

[20]The BOJ recently announced a new "quantitative and qualitative monetary easing program with yield curve control" in which they plan to control the shorter- and longer-term interest rates through asset purchases. In addition, the BOJ pledged to expand the monetary base in order to overshoot its 2 percent inflation objective. While no formal analysis of the effect of these programs is available, the market reaction at the time of the announcement was muted.

[21]The risk premium arises because some households face transactions costs in the market for long-term bonds.

quantitatively larger role than Chen et al. (2012): The peak effect of a balance sheet intervention along the lines of the second LSAP is about an additional 1 percent on the level of real output.

A second set of models is Structural Vector Autoregressions (SVARs). Compared to DSGE models, SVARs are extremely flexible: They place minimal assumptions on structural relationships underpinning the economy. The cost of this flexibility is that it is more difficult to ascribe any of the estimated effects to a particular transmission channel. To study the effects of the first LSAP, Baumeister and Benati (2013) use an SVAR in which they define an unconventional policy as one that moves the spread between long and short rates while leaving the level of short rates unchanged. They find very large effects of the balance sheet policy in part because the SVAR is engineered to match the Treasury yield estimates of asset purchases of Gagnon et al. (2011), whose estimates are at the upper range of the literature. The level of GDP was about 3 percent higher at its peak than it would have been absent the intervention, while the inflation rate was about 1 percentage point higher.[22] Moreover, their estimates indicate that policy also mitigated the risk of a severe recession accompanied by large deflation.

The third set of models is large-scale "structural" models. For example, Federal Reserve staff have used the FRB/US model to examine the effects of balance sheet policies on the macroeconomy. Engen, Laubach, and Reifschneider (2015) use FRB/US to study the effects of the Federal Reserve's asset purchases and forward guidance for the federal funds rate through 2014. They translate the balance sheet programs into a fall in longer-term Treasury yields through a reduction of the term premium component that is consistent with the estimates of Ihrig et al. (2012). They find that the collective effect of all of the Federal Reserve's asset purchase programs and forward guidance policies had a peak effect of subtracting 1.2 percentage points from the unemployment rate in early 2015 and would have had a peak effect of raising inflation by 0.5 percentage point in 2016.[23] Importantly, the authors' methodology does not allow them to distinguish between the effects on expected future short rates due to forward guidance or to the signaling effect of asset purchases.

Because the FRB/US model provides a fairly flexible way to model the expectations of private sector agents, Engen et al. emphasize the importance of private-sector beliefs in determining the impact of balance sheet policies on the macroeconomy. They note that, if households and firms do not anticipate the effects of balance sheet policies on longer-term rates, the effects on real GDP and the unemployment rate are noticeably smaller. Accordingly, their results highlight the importance of communicating to the public the likely path of a central bank's asset purchases and its likely effect on assets supplied to the public.

[22]Using an SVAR with different identifying assumptions, Weale and Wieladek (2015) find similar effects.
[23]Chung, Laforte, Reifschneider, and Williams (2011) use FRB/US to score the effects of the first two LSAPs along with forward guidance for the federal funds rate. They find larger effects than Engen et al. (2015), reflecting a larger portfolio balance effect and the use of an interest-rate reaction function that provides a smaller offset to the balance sheet programs. Engen et al. (2015) model the post-crisis slump as largely unanticipated, which dampens the effects of balance sheet policy.

4.2 Effects of Balance Sheet Policy at and away from the ELB

The estimates in the previous subsection hinge critically on the assumption for the interest-rate reaction function. In constructing their estimates, Chen et al. (2012) and Gertler and Karadi (2013) assume that the federal funds rate remains fixed at the ELB for one year. Baumeister and Benati (2013) define the unconventional policy as one in which standard policy rate does not move over the entire horizon of the program. These differences help rationalize the small estimated effect of Chen et al. (2012) and Gertler and Karadi (2013) relative to Baumeister and Benati (2013). They also point to a consensus in the literature: more accommodative conventional policy amplifies the effects of the balance sheet policy. Across these studies, when conventional policy is allowed to operate independently of balance sheet policy, and is not constrained by the ELB, the effects of balance sheet policy are, roughly speaking, between 20 and 50 percent smaller than the estimates reported above. This finding is also echoed in Kiley (2014), who finds that in a model where some investors have a preference for longer-term assets a reduction in long-term rates through the term premium is less efficacious than through the policy rate, suggesting a muted role for the balance sheet away from the ELB.

Although these macroeconomic models point to smaller effects away from the ELB, they may understate the effects arising from channels relevant for normal times. These models do not incorporate, for instance, the movements in term premium resulting from the duration-risk channel whose effects on term premiums are larger away from the ELB. Moreover, even in normal times, there are distortions and frictions present that may give rise to independent effects of balance sheet policy separate from interest-rate policy. For example, Schabert (2015) demonstrates that with sticky prices, cash-in-advance constraints, and collateral constraints on open market operations,[24] a combination of interest rate and balance sheet policy tools can reduce allocative distortions and improve welfare relative to the interest rate tool alone. Another example is Araujo, Schommer, and Woodford (2015), who examine conditions under which central bank purchases of a risky asset (one can think of this as an asset-backed security) can relax financial constraints and increase aggregate demand in a framework similar to Geanakoplos and Zame (2014) where all financial claims need to be collateralized. Woodford (2016) demonstrates that QE policies can increase the public supply of safe assets and reduce incentives for their private issuance: Equilibrium real yields on risky assets fall and financial conditions improve, expanding aggregate demand, even if the policy rate is away from the ELB. While these papers are suggestive that balance sheet policy can be actively used in normal times to improve macroeconomic outcomes, further work is necessary to determine the quantitative importance of the mechanisms in these papers.

4.3 International Evidence

International evidence on the macroeconomic effects of central bank asset purchases is broadly consistent with the U.S evidence. Kapetanios, Mumtaz, Stevens, and Theodoridis (2012) employ a suite of VAR models to study the effects of the BOE's 2009 Quantitative Easing program,

[24]That is, total injections of money in the model are limited to a fraction of assets eligible for open market operations (repos and outright purchases).

wherein the Bank purchased about 200 billion pounds in assets (about 14 percent of U.K. GDP). They find that a 100-basis-point reduction in long-term spreads (resulting from the U.K. QE program and in line with Joyce et al. (2011)) leads to an increase in the level of real GDP of around 1.5 percent after about three quarters and an increase in inflation of about 1¼ percentage points after about a year.[25] Similarly, SVAR studies for the euro area by Lenza et al. (2010) and Giannone et al. (2012) find significant positive effects of balance sheet policies. In a calibration exercise, Andrade et al. (2016) use a variant of Gertler and Karadi (2013) to show that the ECB's purchase program of sovereign and private bonds (amounting to 11 percent of euro area GDP) has a peak effect of raising output by 1.1 percentage points and inflation by 40 basis points after about two years.

5. Macroeconomic Costs of Balance Sheet Policies

In evaluating the macroeconomic costs of using balance sheet tools as part of the monetary policy framework, we focus on the case where their use leads to a larger longer-run balance sheet than the pre-financial crisis standard. Besides the costs of a larger balance sheet related to potential direct risks to macroeconomic objectives, there are costs associated with financial stability and the potential negative effects on Federal Reserve income, capital, and independence. The financial stability and fiscal implications memos elaborate on those issues and so we do not discuss them further in this memo.

To the extent that the use of balance sheet tools in normal times implies a larger balance sheet than the pre-crisis norm, a potential cost is a higher risk of (well) above-objective inflation. Bassetto and Phelan (2015) illustrate a possible mechanism. In their model, if excess reserves are high and private agents including banks become concerned about an increase in inflation and stronger aggregate demand, there is an equilibrium where banks attempt to lend excess reserves, even when the central bank pays interest on reserves. This behavior leads to a rapid expansion of liquidity (through mechanisms similar to the textbook money multiplier) that increases aggregate demand and eventually inflation, ratifying banks' initial concerns. Although this analysis suggests there are important inflation risks associated with a large balance sheet, there has been little evidence of such risks in countries that have rapidly expanded the size of their balance sheet; in fact, the concerns continue to be that inflation will remain too low.

Another risk comes from the complexities associated with managing multiple tools in an environment where each tool's impact is uncertain and interconnected. Simple theory suggests using all tools in such an environment, especially when there are multiple policy goals.[26] However, these models ignore the difficulties of coordinating and effectively communicating the settings of multiple tools. In practice, policymakers may face challenges in determining the

[25]Baumeister and Benati (2013) arrive at similar results.
[26]For example, see Tinbergen (1952) and Brainard (1967).

appropriate settings for each tool, which may lead to less desirable outcomes.[27] Arguably, the experience of the late 1960s, when policymakers were attempting to use various tools (the federal funds rate, nonborrowed reserves, Regulation Q, etc.) illustrates these difficulties.

6. Implications of Cost-Benefit Analysis for the Balance Sheet in the Long Run

Given the still-evolving literature on the benefits and costs of balance sheet tools, any assessment of the implications for the balance sheet in the longer-run is necessarily tentative. Nevertheless, a couple of conclusions can be made. Most importantly, it appears that the balance sheet actions taken by the Federal Reserve during the financial crisis and the subsequent ELB episode provided necessary policy accommodation that eased financial conditions and helped improve macroeconomic outcomes. Second, even though balance sheet tools appear to have macroeconomic benefits away from the ELB, those benefits appear to be at least somewhat smaller than at the ELB. At the same time, there are some potential costs that probably increase as the balance sheet becomes larger. Therefore, a key macroeconomic issue is how actively the balance sheet should be used along with the policy rate when short-term interest rates are away from the ELB.

6.1 Case for Less Active Balance Sheet Policy away from the ELB

One approach is to actively use the balance sheet tools to achieve the macroeconomic objectives only when the policy rate is at the ELB and otherwise let the balance sheet adjust passively.[28] Such an approach is consistent with the FOMC's Normalization Principles and Plans.

As discussed in Section 4.2, many of the transmission mechanisms of balance sheet policies appear to be less potent away from the ELB because some frictions and distortions begin to wane. Moreover, we have little experience with using the balance sheet as an active policy tool away from the ELB and its effects on the macroeconomy in such circumstances are more uncertain than for conventional policy.[29] As a result, actively using balance sheet tools away

[27]A related issue is that the theoretical literature that finds macroeconomic benefits from using balance sheet tools assumes that those tools are sufficiently nimble to implement the optimal policy, which may be difficult to execute in practice.

[28]This approach could also be consistent with a relatively small longer-run balance sheet that consists primarily of Treasury securities, even though those decisions can be separate from the active-use decision.

[29]As discussed in Sims (2012), the effects of interest rate policy on key macroeconomic aggregates have been studied for a large variety of countries, time periods, and circumstances. While there is still uncertainty about the exact magnitude of their effects, the mass of these studies has led to a consensus about the qualitative effects of conventional policy. In contrast, we have a more limited amount of experience using balance sheet policy to achieve macroeconomic objectives, and this experience has for the most part been undertaken in economic environments in which the policy rate was at the ELB and for which the balance sheet policy actions have largely been one-sided. Accordingly, it is more difficult to separate the effects of balance sheet policy from confounding factors present in the economy including forward guidance for the policy rate.

from the effective lower bound could result in less precise adjustments of the overall stance of policy than if such adjustments were made primarily with the policy rate.[30]

Another consideration is that the new "normal" may involve more frequent and protracted spells at the ELB, so that active use of the balance sheet could lead to an extremely large balance sheet that would ultimately raise costs and thus hinder its use. Holston, Laubach and Williams (2016) and Johannsen and Mertens (2016) have emphasized that there has been a secular downward trend in the "equilibrium" real rate, as illustrated in Figure 1. With a 2 percent inflation objective, a persistently low equilibrium real rate would imply a low longer-run level of the policy rate.

Consequently, there may be less room than in the past to cut policy rates following a recessionary shock. Even so, using the FRB/US model, Reifschneider (2016) finds that a combination of forward guidance on the federal funds rate and $2-4 trillion of asset purchases can compensate for a limited scope to reduce the federal funds rate during a severe recession. However, political economy considerations may constrain the ability to execute an asset purchase program of that size with Federal Reserve assets already above $4 trillion. Moreover, in models such as Araujo, Schommer, and Woodford (2015), the macroeconomic benefits of asset purchases can diminish as the central bank holds an increasing share of assets in a particular market, making prices in that market less relevant for determining aggregate private spending. (The appendix examines the macroeconomic consequences of diminishing LSAP effectiveness using the FRB/US model.) These factors imply that it is desirable to maintain "headroom" through a smaller balance sheet that is not actively used outside of ELB episodes.

6.2 Case for More Active Balance Sheet Policy away from the ELB

An alternative approach is to use a combination of balance sheet tools and policy rate tools away from the ELB to achieve the FOMC's macroeconomic objectives, a change from the procedures prior to the financial crisis.[31]

Although some balance sheet transmission channels appear to be less powerful away from the ELB, other channels still appear to be operative and the duration-risk channel may even by more potent away from the ELB. In addition, because significant distortions and frictions in the financial system exist even away from the ELB, balance sheet policy affects the economy through channels that are distinct from those that work through short term interest rates and can, in principle, be used to complement interest-rate policy.[32] As a result, policymakers may be able

[30]This conclusion is consistent with Williams (2013), who finds in a stylized macroeconomic model under uncertainty the optimal strategy is to use the instrument with least uncertainty (policy rate) to its fullest extent before turning to other instruments (balance sheet) associated with greater uncertainty.

[31]This approach could also be consistent with a relatively large longer-run balance sheet, even though that decision can be separate from the active use decision.

[32]If balance sheets tools and the policy rate are complements, then the application of the Brainard (1967) principle would suggest that the central bank use both tools even if one has less powerful and more uncertain effects: "Attenuation" with multiple tools implies diversification across tools. This conclusion is in contrast to the Williams (2013), whose model assumes that balance sheet policy is a noisier version of interest rate policy.

to achieve more favorable tradeoffs across their multiple objectives.[33] These benefits may outweigh the costs.

Finally, it is not necessarily the case that less active use of the balance sheet away from the ELB would provide more headroom to respond to a crisis or ELB episode. Similar to the analysis of Caballero and Farhi (2016), some observers have argued the central bank balance sheet can be used to increase the supply of safe assets, reduce risk premiums and raise the equilibrium real rate. Consequently, active balance sheet policy could provide additional room to cut policy rates in the event of a recessionary shock. Thus, by limiting the frequency and duration of ELB-constrained periods, more active balance sheet policy could provide more headroom to react to those episodes than under a less active balance sheet policy.

6.3 Other Outstanding Issues

The discussion above shows that there is much to learn about how to use balance sheet policy to best achieve the Committee's macroeconomic objectives. Here, we conclude with a few other issues of note regarding the use of the balance sheet in a long-run framework.

The issue of whether a larger longer-run balance sheet can induce a permanent reduction in the term premium and a higher equilibrium real short rate remains unresolved. Although such effects are theoretically possible in models in which longer-term bonds are imperfect substitutes for shorter-term securities, the empirical evidence discussed earlier is consistent with persistent but not permanent effects of balance sheet policy on the term premium.[34] Still, more work is necessary to reach a firm conclusion on this issue, as it is particularly difficult to estimate the long-run effects of a larger balance sheet and separate those effects from other ongoing structural changes that may influence the equilibrium real rate.

Given the uncertainty surrounding the long-run effects of balance sheet policy, other options outside the scope of the long-run framework project to reduce occurrences of a binding ELB could be preferable. One such option is to raise the FOMC's longer-run inflation objective. Although a change in the inflation objective would involve substantial communication and credibility challenges, it is perhaps a more direct way to mitigate the ELB constraint. The policy actions to support a higher objective could still require use of the balance sheet however.

Because balance sheet actions have fiscal implications, it could be preferable for the fiscal authority to be the agent to implement such actions. These would include adjustment to the maturity structure of the issuance of Treasury securities as well as fiscal policy, especially at the

[33]With the Federal Reserve's dual mandate, the Tinbergen (1952) principle would suggest using multiple tools to achieve those objectives. The Brainard (1967) principle suggests that multiple tools (if available) should be used even if there is a single objective under uncertainty about the effects of each of the tools.

[34]In Andres, Lopez-Salido, and Nelson (2004), long-term bonds are imperfect substitutes for money and short-term bonds. If their model is modified so that short-term bonds also provide liquidity services, then the size and composition of the central bank's balance sheet can matter for the steady-state levels of the term premium and the real short rate. If only money provides liquidity services (as specified in their original model), the central bank's balance sheet can affect the steady-state term premium but not the steady-state real short rate.

ELB. Of course, these fiscal options as well as the higher inflation objective option have their own set of risks and costs.

In sum, many relevant issues for determining the appropriate size and composition of the Federal Reserve's balance sheet remain unresolved and considerable uncertainty remains about the benefits and costs of using balance sheet tools to achieve the FOMC's macroeconomic objectives. Accordingly, the appropriate longer-run configuration of the Federal Reserve's balance sheet from a macroeconomics perspective is likely to remain a contentious issue.

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Table 1. Effect on 10-year Treasury Yield from an Unexpected $100 Billion Purchase Program
(Impact in basis points)

	DK(13)	CDLS (13)[1]	DELN(12)[1]	LW(13)	HW(12)	BR(14)	K(16)
Channel							
Imperfect-substitutability	-10	-4	-6.2				
Duration-risk[5]		-4	-2.3	-4.9	-3.25		-1.7
Signaling						-2.15	-5.2
Programs evaluated	LSAPI	LSAPI/II[3] MEP	LSAPI/II	LSAPI/II MEP	MEP	LSAPI	LSAPI/II/III[6] MEP
Estimation Period	2009	2009-12	2002-08	1994-2007	1990-2007	1985-2009	1981-2015
Methodology used							
Event-study		√					
Cross-sect./panel regress.	√	√					
Time-series model			√	√	√	√	√

Note: DK(13) refers to D'Amico and King(2013); CDLS(13) refers to Cahill, D'Amico, Li, and Sears (2013); DELN(12) refers to D'Amico, English, Lopez-Salido, and Nelson (2012); LW(13) refers to Li and Wei (2013); HW(12) refers to Hamilton and Wu (2012); BR(14) refers to Bauer and Rudebusch (2014); and K(16) refers to King (2016).

1. Incorporates only the effects of Treasury purchases.
2. The duration-risk effect depends on how the purchases are allocated across maturities, which explains some of the differences across estimates
3. Also includes the reinvestment program of August 2010.

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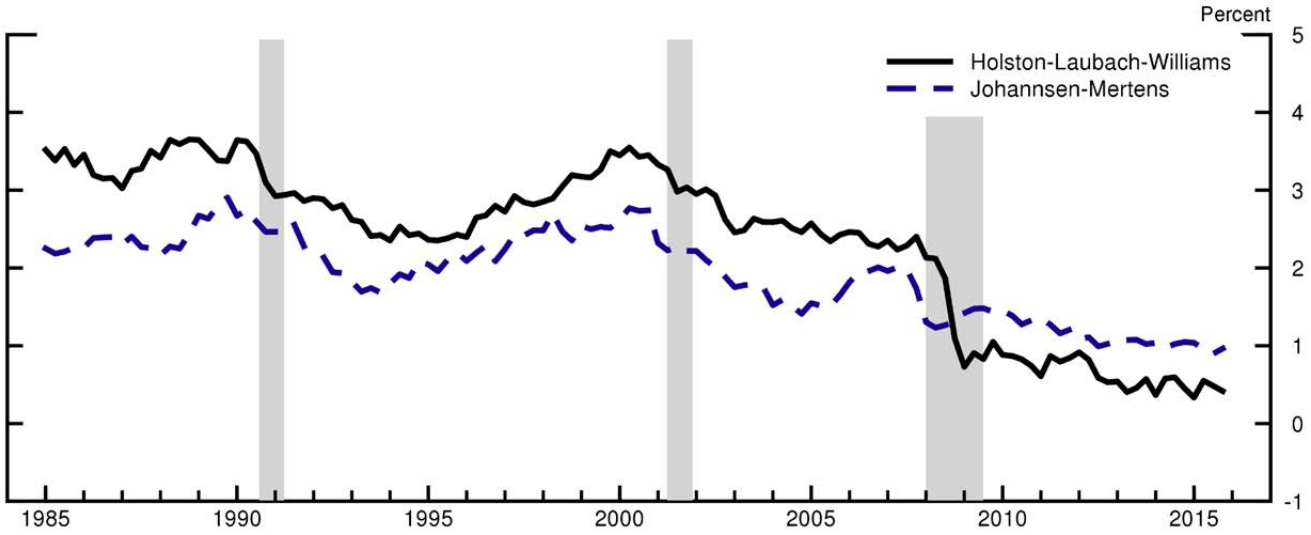
Figure 1. Estimates of the Natural Rate of Interest



Note: See Holston, Laubach, and Williams (2016) and Johannsen and Mertens (2016). Shading denotes NBER-defined recessions.

Appendix: The Effects of Diminishing Benefits to Asset Purchases

To give a quantitative impression of the macroeconomic consequences of diminishing LSAP effectiveness, Figure 2 shows the effects of asset purchases in a recessionary scenario through the lens of FRB/US. The recession is induced by unanticipated adverse shocks that occur in both 2017:Q1 and 2018:Q2. As shown by the solid black line in the upper left panel, assuming no asset purchases, the federal funds rate falls to the ELB in 2017:Q1 and remains there until 2020. The unemployment rate climbs to 6.5 percent at the end of 2017, begins to recover a bit, but then rises to above 8 percent following the second shock (upper right panel). Inflation remains modestly below the FOMC's 2 percent objective through 2020 (lower right panel).

The dashed blue lines, labeled "More Effective 2nd LSAP", shows the effects of these shocks when there is an announcement of $1.5 trillion in purchases of longer-term Treasury securities at the start of the recession followed by an additional $1.5 trillion of purchases when the recession deepens in 2018.[35] In the scenario, assets on the Federal Reserve's balance sheet expand from their current level of $4.3 trillion at par value to close to $6 trillion just before the announcement of the second round of purchases and peak at about $7.5 trillion in 2020. These asset purchases result in a notable decline in 10-year Treasury yield, which leads to a smaller rise in the unemployment rate than in the scenario without asset purchases. Inflation is higher although the effect is small because the low responsiveness of inflation to resource utilization in FRB\US.

The dashed-dotted red lines, labelled "Less Effective 2nd LSAP", show the effects under the assumption that the term premium effects of the purchases diminish as the size of the balance sheet expands. Specifically, the second LSAP that begins in 2018 is assumed to be only half as effective as it is in the first scenario. As a consequence, the 10-year Treasury yield is only 55 basis points below the no LSAP scenario in 2018:Q4 compared to 85 basis points for the more effective LSAP scenario. Accordingly, the unemployment rate is almost 20 basis points higher, on average, in 2021-22 in this scenario than in the more effective LSAP scenario.

[35] In the simulation, the term premium effects are calibrated to be consistent with the estimates in Ihrig et al. (2012). In particular, the two LSAP programs together have a peak effect on the term premium for the 10-year Treasury yield at the beginning of the second programs of about 100 basis points. In comparison, in the scenario in which the second LSAP program is less effective, the term premium only declines 70 basis points. Thus, we assume that the term premium effects are smaller the larger the size of the balance sheet to capture the possibility that the amount of stimulus could diminish with the size of the balance sheet.

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Figure 2. The Effects of Asset Purchases in a Recessionary Scenario