# Monetary Policy and Balance Sheets

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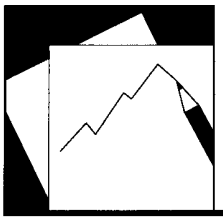

# IMF Working Paper

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*Deniz Igan, Alain Kabundi, Francisco Nadal De Simone, and Natalia Tamirisa*

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Research Department

# Monetary Policy and Balance Sheets

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**Abstract**

This paper evaluates the strength of the balance sheet channel in the U.S. monetary policy transmission mechanism over the past three decades. Using a Factor-Augmented Vector Autoregression model on an expanded data set, including sectoral balance sheet variables, we show that the balance sheets of various economic agents act as important links in the monetary policy transmission mechanism. Balance sheets of financial intermediaries, such as commercial banks, asset-backed-security issuers and, to a lesser extent, security brokers and dealers, shrink in response to monetary tightening, while money market fund assets grow. The balance sheet effects are comparable in magnitude to the traditional interest rate channel. However, their economic significance in the run-up to the recent financial crisis was small. Large increases in interest rates would have been needed to avert a rapid rise of house prices and an unsustainable expansion of mortgage credit, suggesting an important role for macroprudential policies.

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# I. Introduction

Few topics have attracted as much attention in the academic and policymaking literature as the monetary policy transmission mechanism. The impact of monetary policy on economic aggregates has been modeled traditionally through a change in real interest rates: an expansionary monetary policy would decrease real interest rates and, hence, the cost of capital, leading to a rise in investment spending and thereby to an increase in aggregate demand and output. Monetary policy also affects the prices of other assets, namely, equities. As the value of equity held by businesses and households increases following an expansionary monetary policy, investment and consumption get a boost.[1] Given that currency is yet another asset, in an open economy framework, the literature has also viewed the exchange rate as part of traditional channels through which monetary policy could affect international trade and have an effect on domestic output and prices.

The literature on the traditional channels of monetary policy is extensive (see Boivin, Kiley, and Mishkin, 2010, for a review). The theoretical underpinnings go back to seminal papers by Brumberg and Modigliani (1954), Friedman (1957), and Ando and Modigliani (1963), who outlined the life-cycle and permanent-income models of consumption, and to Jorgenson (1963) and Tobin (1969), who developed neoclassical models of investment. In open-economy macroeconomics, seminal work includes papers by Fleming (1962) and Mundell (1963). Although most macroeconomic models are designed to capture the traditional channels of monetary policy, the empirical evidence on the strength of these channels is mixed (see Bernanke and Gertler, 1995, and references therein).

Early on, the observation that the short-run effect of a change in the policy rate on the real economy is much larger than what can simply be explained by the change in the cost of capital, or the interest-rate and asset-price (including the exchange rate) channels, led researchers to the conclusion that frictions in financial intermediation created other channels for monetary policy to be transmitted to the broader economy. In particular, asymmetric information (and the associated costs of verification and enforcement of financial contracts) could create additional channels through which a small change in the policy rate gets magnified.

Several such financial-friction-related or "credit" channels of monetary policy transmission have been identified (see Mishkin, 1996, for a review). The lending channel is concerned with the impact of monetary policy on the *supply* of bank loans. Since deposits and other sources of funding are imperfect substitutes, a rise in the cost of external funding leads liquidity-constrained banks to reduce lending to the private sector, which in turn cuts down investment and consumption. In contrast, the balance-sheet channel relates to the impact of monetary policy on the *demand* for loans. Higher interest rates increase debt service while reducing the present value of assets and collateral. This squeeze on borrowers worsens their creditworthiness and leads to an increase in the external finance premium. With slower credit growth, aggregate demand and output slow down. Finally, the risk-taking channel refers to

[1] Note that equity does not necessarily mean stock, it can also be real estate.

changes in the supply of funding sources owing to policy-induced changes in the risk perceptions or risk tolerance of banks and other financial institutions (Bruno and Shin, 2012). Low interest rates may also encourage institutions to take on more risk than otherwise by triggering a "search for yield" (Borio and Zhu, 2008).[2]

The role of the financial channels reflecting imperfections in credit markets and balance sheet dynamics in the transmission of monetary policy has been less explored in the empirical literature, especially in open-economy macroeconomics, than the role of traditional channels. The theoretical literature on the financial-friction channels is well represented by a paper by Bernanke and Gertler (1995), which emphasizes the role of the external finance premium in determining the supply of credit, and by Kiyotaki and Moore (1997) and Iacoviello (2005), which focus on the similar role of collateral values. While the theoretical literature continues to grow, the nascent empirical evidence on the importance of the financial-friction channels is ambiguous. On the one hand, Gertler and Gilchrist (1993 and 1994), Kashyap and Stein (1995), and Iacoviello and Minetti (2008) find support for the credit channel. Likewise, Berger and Bouwman (2009) show how changes in interest rates affect bank funding and liquidity and, hence, banks' willingness to lend. Interestingly, in a more recent paper by Bluedorn and others (2013), which distinguishes exogenous monetary policy shocks from endogenous, fundamentals-driven changes in interest rates, authors find economically and statistically significant attenuation of estimated lending responses to monetary contractions, accompanied by the shielding of lending associated with bank holding company affiliation, and even sign reversals in the effects when the share of securities in total assets is relatively important, likely due to adverse valuation effects following exogenous monetary policy contractions. Jiménez and others (2007), Adrian and Shin (2011), and Bruno and Shin (2012) demonstrate how risk-taking incentives could link loose monetary policy and credit booms. On the other hand, Ramey (1993) and Carlino and Defina (1998) question the strength of the credit channel and provide evidence countering its existence (also see Altunbaş, Fazylov, and Molyneux, 2002, and references therein).

The recent financial crisis reinforced the urgency of revisiting the monetary policy transmission mechanism, and, in particular, of better understanding the balance-sheet and risk-taking channels. Easy monetary policy before the crisis might have contributed to the buildup of vulnerabilities in the housing and financial sectors, in addition to weaknesses in financial regulation and supervision. During and after the crisis, monetary policy transmission might have been impaired by deleveraging in the household and financial sectors of the economy. Looking forward, understanding the operation of the credit channel is crucial for formulating recommendations on the role and coordination of monetary and macroprudential policies in preventing a buildup of financial excesses, for example, as a result of housing or other asset mispricing and credit overextension, with the ultimate objective of preserving financial and macroeconomic stability.

[2] For the sake of simplicity, in what follows, we refer to the lending, balance sheet, and risk-taking channels as "credit channels" in general. We reserve the term "asset price channels" for the exchange rate, stock price, and house price channels, and keep the "interest rate channel" separate.

This paper contributes both to the empirical literature on the importance of financial frictions and the credit channel and to the policy literature on the interface between monetary and macroprudential policies. We evaluate the strength of monetary policy transmission through balance sheets of financial intermediaries, households, and nonfinancial firms during 1990Q1 – 2008Q2. The choice of the time period allows us to focus on the monetary transmission mechanism over a long period following the abolition of interest rate ceilings (Regulation Q) in 1986. The end of the sample period coincides with the Fed's reaching the zero lower bound of policy interest rates and the introduction of quantitative easing during the recent financial crisis.

The methodological framework is a well-established FAVAR model proposed by Bernanke, Boivin, and Eliasz (2005)—henceforth, BBE. The model is estimated on a broad array of macroeconomic and financial data. The novelty of our modeling approach lies in augmenting the dataset with balance sheet variables for the financial sector, households, and nonfinancial firms. This approach is necessary for exploring the impact of interest rate changes on the private sector balance sheets and the role played by the financial frictions channels in the transmission of monetary policy to the broader economy—these are our main research objectives. The inclusion of balance sheet variables in the FAVAR data set raises a number of technical issues, for example, the appropriate treatment of these variables in the FAVAR setting, and we discuss these issues in the paper.

Our analysis lends support to recent theories emphasizing the importance of financial frictions in the economy and their implications for the monetary policy transmission mechanism. Including balance sheet variables in the dataset provides a richer understanding of the monetary policy transmission mechanism. Specifically:

- The credit channels are statistically and economically significant. Balance sheets of all financial intermediaries—banks, asset-backed-security (ABS) issuers, money market funds (MMFs), and security brokers and dealers—are sensitive to changes in interest rates, albeit at varying degrees. Banks and ABS issuers are the most responsive, while security brokers and dealers are the least responsive.

- Likewise, monetary policy affects households' and firms' balance sheets. Assets and liabilities of both groups of economic agents decline, as does outstanding credit market debt, owing to an increase in interest rates. These balance-sheet developments are driven by financial frictions reflected in changes in the external finance premium as well as in asset prices (for stocks and housing).

The rest of the paper is organized as follows. Sections II and III describe the FAVAR methodology and data, respectively. We discuss the technical issues that arise when including balance sheet variables in a FAVAR setting. Appendix I provides the list of data series used in estimation and Appendix II discusses their order-of-integration properties. Section IV presents the empirical results for the credit channels of monetary policy. Results for the traditional channels of monetary policy, which have been explored extensively in the literature, are discussed in Appendix III. Section V concludes with some policy implications.

# II. FAVAR Methodology and Balance Sheet Variables

Since the seminal work of Sims (1980), Vector Autoregressive (VAR) models have become standard tools in modern empirical macroeconomics. The reduced form of a VAR can be expressed as follows:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \varepsilon_t \,, \tag{1}$$

where $y_t' = [z_t', r_t]$ is an $M \times 1$ vector of variables representing the economy such as, output, inflation, a monetary aggregate, the exchange rate; $r_t$ is the control variable or the policy instrument[3], and $\varepsilon_t$ is an *i.i.d.* $N(0, \Omega)$ stochastic error term. The issue with model (1) is that it can only accommodate a few variables, in general not more than 20, to avoid the *curse of dimensionality* which results in parameter instability.[4] Generally, the number of variables in a VAR model does not exceed 10. Hence, the VAR is not parsimonious enough. BBE and Banbura, Giannone, and Rechlin (2010) demonstrate that empirical models containing large information sets tend to do away with the puzzling results observed in small traditional VARs.

In addition, as BBE put it, central banks examine hundreds of variables in their decision-making process. Ignoring this multidimensionality in information gathering leads to results that are far from the expectations shaped by theory. The solution they suggest is to use factor models which reduce the information set from hundreds of variables to only a few variables, while at the same time the information content of the large panel remains unchanged. In addition to the observed variables included in the VAR process, the Factor-Augmented VAR (FAVAR) proposed by BBE contains few unobserved factors that encapsulate both the common components and the associated loadings of all the variables included in the panel. As a result, the approach conveniently summarizes all the information of the large panel into a much smaller dimension set of estimated factors. The panel can, therefore, accommodate more than one hundred economic variables, which is particularly appealing for our objective of modeling and also to capture the international side of the economy. The FAVAR model is represented as:

$$y_{it} = \lambda_{0i} + \lambda_i f_t + \beta_i z_t + \gamma_i r_t + u_{it} \tag{2}$$

where $f_t$ is a $k \times 1$ vector of latent factors, $z_t$ is a $l \times 1$ vector of observed variables, $r_t$ is the policy instrument, $u_t \sim N(0, \Sigma)$, $\lambda$ is a $n \times k$ matrix of factor loadings, $\beta$ is a $n \times l$ matrix

[3] In this paper, we use the federal funds rate as the policy instrument.

[4] The only case where a VAR can accommodate more variables is when a Bayesian shrinkage is used to avoid over-fitting, a common problem in large systems. Banbura, Giannone, and Reichlin (2010), Giannone, Lenza, and Primiceri (2012), and Koop (2013) use large Bayesian VARs which can contain more than 100 variables.

of coefficients of observed macroeconomic variables, $\gamma$ is a $n \times 1$ vector of coefficients of the control variable.

BBE assume $z_t = 0$, which implies that the policy instrument is the only observed variable. However, this assumption is too restrictive in the context of the formulation and implementation of monetary policy. In this paper, we follow instead the approach suggested by Koop and Korobilis (2010) that $z_t \neq 0$ and contains variables like the unemployment rate and the inflation rate, which are observed by the policymaker, albeit with a short lag.

The FAVAR model follows a VAR (*p*) process:

$$\begin{bmatrix} f_t \\ z_t \\ r_t \end{bmatrix} = \Theta(L) \begin{bmatrix} f_{t-1} \\ z_{t-1} \\ r_{t-1} \end{bmatrix} + \Xi_t \tag{3}$$

where $\Xi_t \sim N(0, \Psi)$, $\Theta(L) = I - \Theta_1 L - \cdots - \Theta_p L^p$ matrix polynomial of order *p*. The VAR model is estimated using the Bayesian approach as described in BBE and Koop and Korobilis (2010). We, of course, examine the robustness of the results to changes in the number of factors and lags.

As is common in FAVAR modeling, we follow the same identification strategy as BBE do.[5] We use a Cholesky or lower triangular identification scheme for the three observed variables. We order the federal funds rate last and treat its innovations as the policy shocks. Other variables are divided into two groups: "slow-moving" and "fast-moving." Variables that react slowly to a monetary policy shock, such as real variables and prices, are treated as slow-moving. Fast-moving variables, such as financial indicators and asset prices, are those that react contemporaneously to a monetary policy shock. This is consistent with the traditional macroeconomic model assumption that asset prices adjust much more rapidly to shocks than goods and services prices.

An important question that arises when balance sheet variables are included in the data set is whether to treat them as fast- or slow-moving. There are arguments favoring both approaches but the balance of arguments appears to be on the fast-moving side. Balance sheet variables may be slow moving if information processing and execution of transactions take time to alter the composition of assets and liabilities. Yet, balance sheet variables are expected to be fast moving if they are marked to market and reflect valuation changes immediately rather than with delay after portfolio reallocation is completed. This is likely to be the case for

[5] Alternative identification strategies include using sign restrictions, or a large Bayesian VAR, such as in Banbura, Giannone, and Reichlin (2010), or following Romer and Romer (2004)'s narrative approach. Using either of these strategies would require modifying the methodological framework used in this paper considerably, and is therefore left for future research. A comparison among different identification strategies is not the objective of this paper.

financial intermediaries, especially issuers of asset-backed securities (ABS) and security brokers & dealers, which are required to mark to market their assets and liabilities. The same holds for many categories of commercial banks' and nonfinancial firms' balance sheets. Although no specific mark-to-market requirements exist for the balance sheets of households, important items of their balance sheets are affected by valuation changes because they are reported at market values. Even if these valuation changes are recognized with a delay, households are likely to adjust their behavior in light of them. Hence, treating balance sheet variables in the same way as asset prices are treated appears to be more appropriate.

Another consideration for deciding on how to treat balance sheet variables is consistency with previous studies. Previous studies have typically included data on commercial bank credit and treated it as a fast-moving variable. For consistency, balance sheet variables of other financial intermediaries may need to be treated similarly. In light of the above, we treat balance sheet variables as fast-moving variables in the baseline estimations, and then explore the robustness of our results to assuming that they are slow-moving variables instead.

The impulse responses of all variables in the panel to policy shocks associated with the federal funds rate, $r_t$, can easily be computed in a fashion similar to the traditional VAR:

$$\begin{bmatrix} f_t \\ z_t \\ r_t \end{bmatrix} = \begin{bmatrix} \lambda & \beta & \gamma \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f_t \\ z_t \\ r_t \end{bmatrix} + u_t \tag{4}$$

where the error term, $u_t$, is serially uncorrelated. Equation (4) can be written as a vector moving average (VMA):

$$\begin{bmatrix} f_t \\ z_t \\ r_t \end{bmatrix} = \Theta(L)^{-1} \Xi_t \tag{5}$$

Substituting (5) into (4), we have:

$$\begin{aligned} \begin{bmatrix} f_t \\ z_t \\ r_t \end{bmatrix} &= \begin{bmatrix} \lambda & \beta & \gamma \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \Theta(L)^{-1} \Xi_t + u_t \\ &= B(L)\eta_t \end{aligned} \tag{6}$$

The FAVAR model allows us to obtain impulse responses for any variable included in the dataset. In this paper, we focus on variables relevant as sources of financial frictions embedded in the credit channels, such as credit, asset prices, and assets and liabilities of various financial institutions and the nonfinancial private sector.

# III. Macroeconomic and Balance Sheet Data

Our database covers the period between 1990Q1 to 2008Q2 at quarterly frequency. Most of the series were downloaded from the Federal Reserve Bank of St. Louis' FRED database and the Federal Reserve Board's Flow of Funds database. For house prices, we use the S&P/Case–Shiller U.S. National Home Price Index, which has the advantage of adjusting for the quality of housing.

The behavior of the flow-of-funds data mirrors the familiar trends in house prices as it reflects a buildup of vulnerabilities in the balance sheets of financial institutions and households in the run-up to the recent crisis (Figure 1). Real estate lending through issuers of asset-backed securities and commercial banks accelerated notably since 2003, fueled by accommodative monetary conditions, rising house prices, and weakening risk management and relaxation in lending standards. A rapid rise in house prices and real estate loans was accompanied by an increase in households' real estate assets, particularly steep since 2005. By contrast, lending to the nonfinancial corporate sector and assets of this sector grew at a steadier and slower pace. Low interest rates in the United States, combined with high liquidity in its financial markets, encouraged foreign financial institutions to borrow in the United States and invest in U.S. securities, including asset-backed securities. Transfers due to foreign affiliates rose as a result. These developments in the balance sheet and flow–of-funds variables and how they were impacted by monetary policy settings are the focus of this study.

All series were seasonally adjusted either in the original source or by us via applying to the non-seasonally adjusted series a quarterly X11 filter based on an AR(4) model (after testing for seasonality). Some series in the database were observed on a monthly basis, and quarterly values were computed by averaging the monthly values over the quarter.

Following BBE, the fast-moving variables are interest rates, stock returns, exchange rates, commodity prices, and balance sheet variables (as discussed in Section II). The rest of the variables in the dataset are the slow-moving variables. The complete list of variables is provided in Appendix I.

The econometric estimation approach followed in this paper needs covariance stationary time series. To that end, after removing the seasonal component, we diligently determine the degree of integration of each series. Given the well-known low power of currently available unit root tests against the alternative of a deterministic trend, and the well-established result that first differencing affects a series' data generation process (DGP), care should be exercised not to bias the results.[6] We use two of the tests with the highest power available in the literature of unit root testing: the ERS (Elliott, Rothenberg, and Stock, 1996) unit root test and the KPSS (Kwiatkowski, Phillips, Schmidt, and Shin, 1992) unit root test. The ERS test is a generalized least squares unit root test, which is more powerful than standard Dickey-Fuller tests. The KPSS test provides a robust cross-check on the ERS test as it uses stationarity as the null hypothesis instead of nonstationarity, as it is the case of the ERS test.

[6] Chapter 4 in Koopmans (1974), and Harvey and Jaeger (1992).

The unit root tests conducted always included a constant and a deterministic trend.[7] The number of lags was chosen using the Schwarz information criterion and ensuring that no serial correlation was left in the residuals. For most time series, this approach was able to distinguish with reasonable statistical confidence among I(0), I(1), and I(2) DGPs. However, for about 20 percent of the series, judgment had to be used as the two unit roots tests yielded contradictory results. The results of unit root tests are shown in Appendix II together with the transformation of the time series.

Determining the correct degree of integration of time series is a point seldom acknowledged in applied econometrics, and it is one that can affect results from both statistical and policymaking viewpoints.[8] A very pertinent and topical illustration is that real house price series are found to be I(2) and so is household debt. The degree of integration of the time series has implications for modeling, forecasting, and policy analysis. For example, if a real house price series is I(2), first-differencing it and using it together with other first-differenced series for which the true DGP is I(1) will render spurious results. In contrast, second-differencing a time series considered to be I(2), but for which the true DGP is I(1), will result in over-differencing and will weaken the analysis. From a policy perspective, an I(2) real house price series implies that shocks to house price changes have a lasting effect. A shock such as a natural catastrophe or a hardening of housing supply constraints introduced by tightening of zoning regulations, for example, given housing demand, may have a lasting effect on the rate of real house price changes of an I(2) time series. If this feature is ignored in a model, a persistent growth rate of real house prices might be interpreted as a misalignment of house prices by a model that considers that the above shocks only have lasting effects on the *level* of real house prices and not on the *growth rate* of real house prices as well.[9] In other words, wrong diagnostics about the degree of integration of a time series may bias the allocation of variance between trend (equilibrium) and cycle, confuse persistent shocks in rates of growth with misalignment, and thus lead to wrong policy prescriptions. If real house prices DGP is I(2), trend disequilibrium and misalignment from "fundamentals" can be easily confused, and a monetary policymaker targeting "real estate exuberance" risks falling into an economically significant tradeoff between the real economy and the stability of the real estate market.

Regarding the FAVAR estimation, the first task is to determine the number of unobserved factors $f_t$. We use two tests to this end: the Bai and Ng (2002)—henceforth, BN—and the Alessi, Barigozzi, and Capasso (2010)—henceforth, ABC. The BN test, as shown in Table 1,

[7] As most time series trend, a trend was included in the null hypothesis. However, in case of doubt as to the order of integration of the series, the order-of-integration analysis was also done excluding the trend and/or the constant from the null hypothesis.

[8] See Igan and others (2011) for a thorough discussion of the modeling, forecasting and policy consequences of the inappropriate treatment of economic time series' order of integration.

[9] In New Zealand, for example, during the mid-1990s, the Reserve Bank of New Zealand was concerned about the possible "misalignment" of real house prices and viewed the persistent growth of house prices as an unsustainable development. If house prices are I(2), however, those developments need not be unsustainable.

suggests that the information criteria on the criterion functions used by BN, *PC* and the *IC*, do not converge. Using the cumulative variance share, instead, it is noted that the fourth factor has an eigenvalue less than 0.05, which is used as the "contribution" threshold. Hence, based on the cumulative variance share, three factors seem suitable to explain a high share of the variation in the panel, in this case 85 percent. Recently, the BN approach has been improved by the ABC approach, especially useful when working with finite samples. Applying the ABC approach to our database sets the number of factors to three or five. Consequently, we decide to use a FAVAR with three factors and two lags. That said, we check the robustness of the results to changing the number of lags and factors, as well as the sample period and the exclusion of balance sheet variables as discussed below.

# IV. Transmission of A Monetary Shock through Sectoral Balance Sheets

In our analysis, we consider the effects of a 100 basis-point increase in the federal funds rate. Such a shock is approximately equal to one standard deviation of the federal funds rate. However, it is larger than the interest rate shock examined in some papers (for example, BBE consider a 25 basis-point shock). Not surprisingly, the larger magnitude of the shock in part explains the larger effects and greater persistence of impulse responses obtained in this paper. When examining the transmission of the monetary policy shock to the broader economy, we focus on the short-term horizon of 4 quarters and the medium term horizon of 8 to 12 quarters. Beyond this, monetary policy is not expected to have any significant effects on real economic variables.

The monetary policy shock is well-identified. CPI inflation (as well as GDP deflator inflation) falls over the short and medium term, with the peak impact of 0.5 percentage points observed at about 12 quarters. The long-term impact on price inflation is statistically insignificant (after about 16 quarters). Consistent with most empirical studies, the impact on unemployment is statistically insignificant over the short term, possibly owing to nominal rigidities in the economy. Over the medium term, unemployment rises. The peak impact of about 0.8 percent is reached at 12 quarters. Real GDP declines by 0.5 percent over the horizon of up to 8 quarters; after that, the monetary policy impact becomes statistically insignificant (Figure 2). Other real economy variables, for example real final sales of domestic product, behave similarly to GDP. We do not find evidence of a price puzzle, which is not surprising since we are using a factor-augmented model which incorporates the gamut of relevant economic and financial information (see BBE for a more detailed account).

Also consistent with previous studies, traditional channels through consumption, investment and international trade are found to play a role in the transmission of monetary policy shocks (for more details, see Appendix III). Interest rates for government and corporate securities rise across the maturity spectrum in response to an increase in the federal funds rate. Fixed private investment, business investment, and investment in consumer durables all decline. The asset price effects, and the related wealth and consumption-based channels, are also found to be statistically significant, although their economic significance is relatively small. Private residential fixed investment responds more strongly than real house prices to a tightening of monetary policy. Although we do not detect a statistically significant impact on

the real effective exchange rate, the current account improves as the interest rate rise reduces activity and real imports with some minor positive impact on real exports. Gross and net capital flows are also affected, with higher economic uncertainty, as proxied by the VIX index, playing an important role. Specifically, as volatility rises and domestic growth falters, gross capital inflows fall (what Forbes and Warnock, 2011, refer to as "stops") and gross capital outflows increase (what Forbes and Warnock, 2011, call "flights").

Moving to the main focus of the paper, our results underscore that the credit channels are no less important for the transmission of monetary policy to the U.S. economy than the traditional channels. A higher federal funds rate pushes up bank funding costs, reducing the supply of bank loans, the main element of the lending channel. Likewise, a decline in the value of bank assets can discourage banks from lending to businesses and households. Looking at the other side of the equation, higher interest rates increase debt service and reduce asset and collateral present values, squeezing borrowers' creditworthiness and reducing the demand for loans, the main links of the balance-sheet channel.

Let us first look at the commercial banking sector. As displayed in Figure 3, bank lending rates respond strongly to an increase in the federal funds rate: the prime bank rate increases on impact by about 1 percentage point. On impact, total lending through commercial banks slightly rises as borrowers, which are now more liquidity constrained, likely draw on their existing credit lines. Over the short- and the medium-term, however, total bank lending declines by almost 1 percent because banks tighten their lending standards and reduce the supply of new credit. The peak decline in total lending through commercial banks is about 1 percent 10 quarters after the shock.[10]

The decline in bank lending reflects both an increase in the external finance premium (à la Bernanke and Gertler, 1995) and a reduction on bank assets owing to lower collateral values (à la Kiyotaki and Moore, 1997). The external finance premium—the wedge between the cost of funds raised externally and the opportunity cost of internal funds reflecting the principal-agent problem between lenders and borrowers—rises, with a peak impact of about 0.5 percentage points at 9 quarters. The increase in the external finance premium partly reflects a decline in collateral values. The peak decline in stock and house prices is around 0.5 percent. Other factors, for example, the health of borrowers' balance sheets also influence the external finance premium. As discussed below, households' and nonfinancial firms' assets decline sharply in response to a monetary policy shock, contributing to a rise in the external finance premium.

Real estate lending through commercial banks responds strongly to interest rate changes. Real estate loans decline by about 0.75 percent after 9 quarters. An increase in interest rates reduces the supply of credit through commercial banks, which, as discussed earlier, dampens

[10] Since the FAVAR model is not structural, impulse responses reflect the combined effect of changes in supply and demand. When interpreting results, one needs to consider effects on a broad set of variables to get an indication of whether the impulse response of a given variable is driven mainly by demand or supply factors and which type of the credit channel may be at play.

private residential fixed investment and housing starts. However, given the important role played by security broker-dealers and ABS issuers in real estate lending before the financial crisis of 2007-09, it would be important to examine the effect of monetary policy changes on the balance sheets of these intermediaries when assessing the effectiveness of monetary policy in influencing the mortgage market. This is the topic we turn to next.

The response of ABS issuers' balance sheets is quantitatively and qualitatively similar to that of commercial banks: total mortgage assets decline by about 1 percent after 7 quarters (Figure 4). Financial liabilities of ABS issuers decline even for a longer period. ABS issuers deleverage shrinking their balance sheets over the entire policy horizon, consistent with a decline in real estate lending through commercial banks and a decline in residential investment, housing starts, and house prices.

The interest rate shock also affects assets and liabilities of security brokers & dealers. The peak decline in their credit market assets is about 0.2 percent after 10 quarters (Figure 4). The balance sheet sensitivity of brokers & dealers to interest rate changes is not surprising. Before the crisis, these financial institutions funded themselves mostly through repurchase agreements (repos). They held collateralized short-term financing instruments, such as repos, on the liability side and tradable securities on the asset side. Broker-dealer assets thus tended to rise and fall in lockstep with repo growth, which in turn responded to changes in the federal funds rate. Adrian and Shin (2009) observe that broker-dealer repos and commercial paper outstanding grew at the same rate as M2 (while M1 was quite stable). They also argue that market-based credit, which has become relatively more important over time, suffered most during the crisis. It is, therefore, important from a policymaking viewpoint that the balance sheets of these financial intermediaries have been part and parcel of the monetary policy transmission mechanism.

The balance sheets of money market funds (MMFs) are also sensitive to changes in monetary policy (Figure 4). MMF assets rise initially, possibly because the yield paid by MMFs tends to track closely the federal funds rate, and a higher federal funds rate boosts the supply of funds to MMFs. However, the increase wears off after about 9 quarters, likely reflecting reduced demand for funding on the part of banks and other financial institutions. MMFs tended to finance banks in the run-up to the financial crisis of 2007-09 by buying their commercial paper.[11]

We also detect some changes in borrowing by foreign financial institutions in response to a rise in U.S. interest rates. Borrowing by foreign financial institutions (as reflected in interbank transfers of foreign bank offices (FBOs) in the United States due to foreign affiliates) declines over the policy horizon, consistent with an increase in the cost of

[11] The so-called "shadow banks" (i.e., hedge funds, structured investment vehicles, special purpose entity conduits, and other non-bank financial institutions such as security lenders and finance companies) were also funded, at least partially, through the commercial paper market. The balance sheets of these other financial intermediaries are not considered in this paper because of problems with data availability.

borrowing (Figure 5).[12] The peak decline is about 0.5 percent at 9 quarters. These results suggests that, to the extent that borrowing by foreign financial institutions was a channel for spillover of vulnerabilities from U.S. financial institutions to their European counterparts before the crisis, as suggested also by Adrian and Shin (2009), changes in U.S. policy rates would have had some effect on this spillover channel. Payments of U.S. financial institutions to their foreign offices (net due to related foreign offices) are not affected in a significant way, possibly because U.S. institutions tend to substitute more expensive interbank loans with other funding sources (for example, bond financing) (Adrian, Colla, and Shin, 2012).[13]

Finally, let us consider the balance sheets of the nonfinancial private sector. An increase in interest rates affects households' balance sheets almost as strongly as those of financial institutions (Figure 6). Household financial assets decline over the policy horizon, with the peak impact of about 0.75 percent at 7 quarters. This result is consistent with the statistically significant effects of monetary policy on stock prices. The impact on households' real estate assets is similar, again consistent with the impact of monetary policy on house prices. Households not only experience valuation losses on their real estate assets but also may be forced to sell these assets and switch to renting because of lower income and rising unemployment (the latter composition effect would reinforce the former effect as forced sales by some households may drive down the house values for the rest). Household debt declines with a peak impact of about 0.5 percent at 4 quarters as higher borrowing costs reduce the demand for credit.

Like households, nonfinancial firms shrink their balance sheets in response to higher interest rates (Figure 7). Both assets and liabilities of nonfinancial businesses fall over the policy horizon, with peak impacts of about 1 percent at around 9 quarters. Debt of nonfinancial firms rises over the first 3 quarters following the shock as businesses resort to borrowing in the face of declining cash flows. However, over the longer horizon up to 12 quarters, a higher external finance premium causes corporate businesses to reduce debt.

# V. Robustness Analysis

Next, we explore the sensitivity of results to changes in model specification as well as the implications of including balance sheet variables in the model.[14] A change in the number of lags or factors (we considered 2–4 lags and/or 2–4 factors) does not change significantly the conclusions, but makes impulse response functions less stable, an undesirable outcome. In addition, treating the balance sheet variables as slow-moving increases the response lags, but does not alter the shape of impulse response functions.

[12] Declines in these series mean that FBOs in the United States are reducing transactions with their affiliates abroad.

[13] "Net due to related foreign offices" is a measure of financial flows between domestic and foreign offices of related institutions. Positive numbers represent an inflow of money to the U.S. offices, which will be due back to foreign offices, and negative numbers represent flows out of the United States to foreign offices.

[14] The detailed robustness tests are not reported in the interest of brevity, but are available from the authors upon request.

Results of the robustness checks relating to the role of the balance sheet variables in the FAVAR model depend on the sample period used. Excluding balance sheet variables from the dataset does not seem to affect the majority of the impulse responses of key macroeconomic variables when the sample period is 1990Q1–2008Q2. However, an analysis of the factor loadings and the variance share of other variables does show statistically significant changes.

A comparison of the variance shares in the FAVAR model with and without balance sheet variables suggests that during the sample period in question the information content of the balance sheet variables was not fully reflected in other data. For example, when balance sheet variables are excluded, the share of variance explained by macroeconomic variables and measures of expectations rises, while the share of variance explained by the variables describing banks' funding costs declines (Table 2). Similar results are obtained when contributions of variables to explaining variance are estimated using a bivariate regression analysis (Table 3).

Excluding balance sheet variables from the dataset may thus create an "omitted variable" problem and misrepresent the importance of different channels in the monetary policy transmission mechanism. When studies examine the relative importance of different channels in the monetary policy transmission mechanism, care is needed in the selection of variables for the dataset as conclusions are likely to depend on the composition of the dataset.

When the model is estimated with the balance sheet variables on a sample covering the recent financial crisis, 1990Q1–2011Q4, the impact of the monetary policy shock on inflation becomes significantly larger and lasts one quarter longer. The impact on output is largely similar in magnitude and duration. Although the peak effect on unemployment is also similar, unemployment starts rising later and is less persistent. The financial frictions mechanisms affecting the private sector balance sheets appear to augment the effects of a monetary policy shock on inflation and affect the profile of unemployment in periods when the private sector balance sheets are impaired.

When balance sheet variables are excluded from a sample covering the recent financial crisis, there are also significant differences. In the period 1990Q1–2011Q4, the monetary policy shock effect on inflation is more persistent, i.e., it lasts one year more; the effect on output is relatively smaller and less persistent; unemployment is not affected at all while in the period 1990–2008 it increases during almost three quarters. The results covering the recent crisis are subject to a caveat, however, that interest rates, the traditional operating target of monetary policy, were supported by a massive recourse to what came to be known as "quantitative easing."

All in all, our results suggest that the monetary policy transmission mechanism should be examined including the balance sheet variables in the dataset, especially when covering periods during which the private sector balance sheets are impaired. Otherwise, it seems from our sample that the effectiveness of monetary policy in controlling inflation may be overestimated and the output loss may be underestimated.

# VI. Conclusion

The analysis in this paper suggests that, in addition to the traditional channels of monetary policy transmission, financial frictions operating through the private sector balance sheets play an important role in the transmission of monetary policy to the broader economy. Monetary policy has statistically significant effects on the balance sheets of financial institutions, especially banks, issuers of asset-backed securities, and money market funds, and, to a lesser extent, on security brokers and dealers. Households' and nonfinancial firms' balance sheets are also affected, albeit less than the balance sheets of financial institutions. Changes in the external finance premium à la Bernanke and Gertler (1995) and the collateral price effects described by Kiyotaki and Moore (1997) are the key mechanisms underlying changes in the private sector balance sheets in response to changes in policy rates. Among the traditional channels of monetary policy transmission, the interest-rate channel is most powerful, as is apparent in the dynamics of residential investment and housing starts.

At the first glance, this evidence may suggest that monetary policy can influence the buildup of credit and leverage during financial booms and that a tightening of monetary policy before the recent financial crisis may have helped to slow down growth in mortgage loans and leverage of house lenders. However, the economic significance of the private sector balance sheet "multipliers" of monetary policy appears small. Even a large increase in interest rates (100 basis points) is found to have only a small effect on the balance sheets of mortgage lenders (as well as house prices and residential investment). Given that house prices rose by about 40 percent in the run-up to the crisis, very large increases in interest rates would have been needed to stop the housing boom through monetary policy alone.

Therefore, the paper lends support to the need for coordinating monetary policy with macroprudential policies to ensure financial stability. In an overheating economy experiencing a housing boom, a tightening of monetary policy can help to restore price stability and to attenuate credit growth exuberance because higher interest rates discourage residential investment and real estate lending and dampen the balance sheet expansion of financial intermediaries. However, the large changes in interest rates necessary to quench a credit boom indicate that, independently of whether price stability is or is not at risk, there is a role for macroprudential policy to play in keeping financial excesses in check. From a historical perspective, a corollary is that, even if one believes that monetary policy before the crisis was excessively loose, it is likely that monetary policy contributed more as an enabling environment than as a major cause of the housing boom and the subsequent crisis.

That said, the analysis in this paper is a positive analysis and leaves many normative questions unaddressed. In particular, this paper does not discuss whether using monetary policy to manage financial sector balance sheets and "prick" credit bubbles is desirable. Among other considerations, such policy goals are outside the mandate of most central banks, including the Federal Reserve, which is charged to focus on maximizing employment growth against the backdrop of price stability. Central banks, thus, find it difficult to respond to rapid growth of credit, unless resource slack is low and inflation is high. The analysis in this paper is also *ex post* and does not address policy issues such as whether real-time

forward-looking robust identification of disequilibria in real estate markets is feasible, or what the eventual trade-off between output and interest rate volatility would be. These issues are left for future research.

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# Appendix I. Data and Sources

| Acronym | Series Name | No. | Source |
|---|---|---|---|
| houst | Housing Starts: Total: New Privately Owned Housing Units Started | 61 | Federal Reserve Bank of St. Louis |
| houstne | Housing Starts in Northeast Census Region | 62 | Federal Reserve Bank of St. Louis |
| houstmw | Housing Starts in Midwest Census Region | 63 | Federal Reserve Bank of St. Louis |
| housts | Housing Starts in South Census Region | 64 | Federal Reserve Bank of St. Louis |
| houstw | Housing Starts in West Census Region | 65 | Federal Reserve Bank of St. Louis |
| houst1f | Privately Owned Housing Starts: 1-Unit Structures | 66 | Federal Reserve Bank of St. Louis |
| permit | New Private Housing Units Authorized by Building Permit | 67 | Federal Reserve Bank of St. Louis |
| nonrevsl | Total Nonrevolving Credit Outstanding, SA, Billions of Dollars | 68 | Federal Reserve Bank of St. Louis |
| usgsec | U.S. Government Securities at All Commercial Banks | 69 | Federal Reserve Bank of St. Louis |
| othsec | Other Securities at All Commercial Banks | 70 | Federal Reserve Bank of St. Louis |
| totalsl | Total Consumer Credit Outstanding | 71 | Federal Reserve Bank of St. Louis |
| busloans | Commercial and Industrial Loans at All Commercial Banks | 72 | Federal Reserve Bank of St. Louis |
| consumer | Consumer (Individual) Loans at All Commercial Banks | 73 | Federal Reserve Bank of St. Louis |
| loans | Total Loans and Leases at All Commercial Banks | 74 | Federal Reserve Bank of St. Louis |
| loaninv | Total Loans and Investments at All Commercial Banks | 75 | Federal Reserve Bank of St. Louis |
| invest | Total Investments at All Commercial Banks | 76 | Federal Reserve Bank of St. Louis |
| realln | Real Estate Loans at All Commercial Banks | 77 | Federal Reserve Bank of St. Louis |
| bogambsl | Board of Governors Monetary Base, Adjusted for Changes in Reserve Req. | 78 | Federal Reserve Bank of St. Louis |
| trarr | Board of Governors Total Reserves, Adjusted for Changes in Reserve Req. | 79 | Federal Reserve Bank of St. Louis |
| bognonbr | Non-Borrowed Reserves of Depository Institutions | 80 | Federal Reserve Bank of St. Louis |
| reqresns | Required Reserves, Not Adjusted for Changes in Reserve Requirements | 81 | Federal Reserve Bank of St. Louis |
| resbalns | Reserve Balances with Fed. Res. Banks, Not Adj. for Changes in Res. Req. | 82 | Federal Reserve Bank of St. Louis |
| borrow | Total Borrowings of Depository Institutions from the Federal Reserve | 83 | Federal Reserve Bank of St. Louis |
| excresns | Excess Reserves of Depository Institutions | 84 | Federal Reserve Bank of St. Louis |
| nforbres | Net Free or Borrowed Reserves of Depository Institutions | 85 | Federal Reserve Bank of St. Louis |
| m1sl | M1 Money Stock | 86 | Federal Reserve Bank of St. Louis |
| currsl | Currency Component of M1 | 87 | Federal Reserve Bank of St. Louis |
| currdd | Currency Component of M1 Plus Demand Deposits | 88 | Federal Reserve Bank of St. Louis |
| demdepsl | Demand Deposits at Commercial Banks | 89 | Federal Reserve Bank of St. Louis |
| tcdsl | Total Checkable Deposits | 90 | Federal Reserve Bank of St. Louis |
| tvckssl | Travelers Checks Outstanding | 91 | Federal Reserve Bank of St. Louis |
| m2sl | M2 Money Stock | 92 | Federal Reserve Bank of St. Louis |
| m2own | M2 Own Rate | 93 | Federal Reserve Bank of St. Louis |
| svstcbsl | Savings and Small Time Deposits at Commercial Banks | 94 | Federal Reserve Bank of St. Louis |
| svstsl | Savings and Small Time Deposits - Total | 95 | Federal Reserve Bank of St. Louis |
| svgcbsl | Savings Deposits at Commercial Banks | 96 | Federal Reserve Bank of St. Louis |
| svgti | Savings Deposits at Thrift Institutions | 97 | Federal Reserve Bank of St. Louis |
| savingsl | Savings Deposits - Total | 98 | Federal Reserve Bank of St. Louis |
| stdcbsl | Small Time Deposits at Commercial Banks | 99 | Federal Reserve Bank of St. Louis |
| stdti | Small Time Deposits at Thrift Institutions | 100 | Federal Reserve Bank of St. Louis |
| stdsl | Small Time Deposits - Total | 101 | Federal Reserve Bank of St. Louis |
| m2msl | M2 Minus Small Time Deposits | 102 | Federal Reserve Bank of St. Louis |
| m2mown | M2 Minus Own Rate | 103 | Federal Reserve Bank of St. Louis |
| mzmsl | MZM Money Stock | 104 | Federal Reserve Bank of St. Louis |
| dddfcbns | Demand Deposits Due to Foreign Commercial Banks | 105 | Federal Reserve Bank of St. Louis |
| dddfoins | Demand Deposits Due to Foreign Official Institutions | 106 | Federal Reserve Bank of St. Louis |
| usgvddns | U.S. Government Demand Deposits and Note Balances - Total | 107 | Federal Reserve Bank of St. Louis |
| usgdcb | U.S. Government Demand Deposits at Commercial Banks | 108 | Federal Reserve Bank of St. Louis |
| currcir | Currency in Circulation | 109 | Federal Reserve Bank of St. Louis |
| tb3ms | 3-Month Treasury Bill: Secondary Market Rate | 110 | Federal Reserve Bank of St. Louis |
| tb6ms | 6-Month Treasury Bill: Secondary Market Rate | 111 | Federal Reserve Bank of St. Louis |
| gs1 | 1-Year Treasury Constant Maturity Rate | 112 | Federal Reserve Bank of St. Louis |
| gs3 | 3-Year Treasury Constant Maturity Rate | 113 | Federal Reserve Bank of St. Louis |
| gs5 | 5-Year Treasury Constant Maturity Rate | 114 | Federal Reserve Bank of St. Louis |
| gs10 | 10-Year Treasury Constant Maturity Rate | 115 | Federal Reserve Bank of St. Louis |
| mprime | Bank Prime Loan Rate | 116 | Federal Reserve Bank of St. Louis |

| Acronym | Series Name | No. | Source |
|---|---|---|---|
| aaa | Moody's Seasoned AAA Corporate Bond Yield | 117 | Federal Reserve Bank of St. Louis |
| baa | Moody's Seasoned BAA Corporate Bond Yield | 118 | Federal Reserve Bank of St. Louis |
| stb3ms | TB3MS - FEDFUNDS | 119 | Federal Reserve Bank of St. Louis |
| stb6ms | TB6MS - FEDFUNDS | 120 | Federal Reserve Bank of St. Louis |
| sgs1 | GS1 - FEDFUNDS | 121 | Federal Reserve Bank of St. Louis |
| sgs3 | GS3 - FEDFUNDS | 122 | Federal Reserve Bank of St. Louis |
| sgs5 | GS5 - FEDFUNDS | 123 | Federal Reserve Bank of St. Louis |
| sgs10 | GS10 - FEDFUNDS | 124 | Federal Reserve Bank of St. Louis |
| smprime | MPRIME - FEDFUNDS | 125 | Federal Reserve Bank of St. Louis |
| saaa | AAA - FEDFUNDS | 126 | Federal Reserve Bank of St. Louis |
| sbaa | BAA - FEDFUNDS | 127 | Federal Reserve Bank of St. Louis |
| exszus | Switzerland / U.S. Foreign Exchange Rate | 128 | Federal Reserve Bank of St. Louis |
| exjpus | Japan / U.S. Foreign Exchange Rate | 129 | Federal Reserve Bank of St. Louis |
| reer | Real Effective Exchange Rate | 130 | IMF International Financial Statistics |
| ppiaco | Producer Price Index: All Commodities | 131 | Federal Reserve Bank of St. Louis |
| ppicrm | Producer Price Index: Crude Materials for Further Processing | 132 | Federal Reserve Bank of St. Louis |
| ppifcf | Producer Price Index: Finished Consumer Foods | 133 | Federal Reserve Bank of St. Louis |
| ppifcg | Producer Price Index: Finished Consumer Goods | 134 | Federal Reserve Bank of St. Louis |
| pfcgef | Producer Price Index: Finished Consumer Goods Excluding Foods | 135 | Federal Reserve Bank of St. Louis |
| ppifgs | Producer Price Index: Finished Goods | 136 | Federal Reserve Bank of St. Louis |
| ppicpe | Producer Price Index Finished Goods: Capital Equipment | 137 | Federal Reserve Bank of St. Louis |
| ppieng | Producer Price Index: Fuels & Related Products & Power | 138 | Federal Reserve Bank of St. Louis |
| ppiidc | Producer Price Index: Industrial Commodities | 139 | Federal Reserve Bank of St. Louis |
| ppiitm | Producer Price Index: Intermediate Materials: Supplies & Components | 140 | Federal Reserve Bank of St. Louis |
| cpiaucsl | Consumer Price Index For All Urban Consumers: All Items | 141 | Federal Reserve Bank of St. Louis |
| cpiufdsl | Consumer Price Index for All Urban Consumers: Food | 142 | Federal Reserve Bank of St. Louis |
| cpiengsl | Consumer Price Index for All Urban Consumers: Energy | 143 | Federal Reserve Bank of St. Louis |
| cpilegsl | Consumer Price Index for All Urban Consumers: All Items Less Energy | 144 | Federal Reserve Bank of St. Louis |
| cpiulfsl | Consumer Price Index for All Urban Consumers: All Items Less Food | 145 | Federal Reserve Bank of St. Louis |
| cpilfesl | Consumer Price Index for All Urban Cons.: All Items Less Food & Energy | 146 | Federal Reserve Bank of St. Louis |
| oilprice | Spot Oil Price: West Texas Intermediate | 147 | Federal Reserve Bank of St. Louis |
| umcsentsa | U. Of Mich. Index Of Consumer Expectations | 148 | Federal Reserve Bank of St. Louis |
| napmnoi | NAPM New Orders Index | 149 | Federal Reserve Bank of St. Louis |
| napmsdi | NAPM Vendor Deliveries Index | 150 | Federal Reserve Bank of St. Louis |
| napmii | NAPM Inventories Index | 151 | Federal Reserve Bank of St. Louis |
| acdgno | New Orders (Net) - Consumer Goods & Materials | 152 | Federal Reserve Bank of St. Louis |
| adxdno | New Orders, Nondefense Capital Goods | 153 | Federal Reserve Bank of St. Louis |
| hp | Real Home Price Index | 154 | Robert Shiller |
| vxo | Volatility Index S&P100 | 155 | Haver Analytics |
| oa67mor5 | Asset-Backed Security Issuers: Assets; Total Mortgages | 156 | Federal Reserve Board |
| ol67tao5 | Asset-Backed Security Issuers: Total Financial Liabilities | 157 | Federal Reserve Board |
| ol75aay3 | Foreign Bank Offices in U.S.: Liabilities; Interbank Transfers due to Foreign Affiliates | 158 | Federal Reserve Board |
| oa63tcr5 | Money Market Mutual Funds: Assets; Credit Market Instruments | 159 | Federal Reserve Board |
| oa66tcr5 | Security Brokers & Dealers: Assets; Credit Market Instruments | 160 | Federal Reserve Board |
| ndfo | Net due to Related Foreign Offices and Foreign-Related Institutions | 161 | Federal Reserve Board |
| sp500 | S&P 500 Index | 162 | Haver Analytics |
| capin | Capital Inflows, gross | 163 | Bureau of Economic Analysis |
| capout | Capital Outflows, gross | 164 | Bureau of Economic Analysis |
| efp | External Finance Premium | 165 | Federal Reserve Bank of St. Louis |
| nfncl | Nonfinancial Noncorporate Business: Liabilities | 166 | Federal Reserve Board |
| nfnca | Nonfinancial Noncorporate Business: Assets | 167 | Federal Reserve Board |
| nfcl | Nonfinancial Corporate Business: Liabilities | 168 | Federal Reserve Board |
| nfca | Nonfinancial Corporate Business: Assets | 169 | Federal Reserve Board |
| hhatfa | Household Sector: Assets; Total Financial Assets | 170 | Federal Reserve Board |
| hharea | Household Sector: Assets; Real Estate Assets | 171 | Federal Reserve Board |
| nfclcmdo | Nonfinancial Corporate Business: Liabilities; Credit Market Debt Outstanding | 172 | Federal Reserve Board |
| cab | Current Account Balance | 173 | Bureau of Economic Analysis |
| pce | Personal Consumption Expenditures | 174 | Federal Reserve Bank of St. Louis |
| inf | Inflation | 175 | Federal Reserve Bank of St. Louis |
| unrate | Unemployment Rate: All Workers, 16 Years & Over | 176 | Federal Reserve Bank of St. Louis |
| fedfunds | Effective Federal Funds Rate | 177 | Federal Reserve Bank of St. Louis |

# Appendix II. Unit Root Tests and Analysis of Time Series' Degree of Integration

| Acronym | Series Name | No. | Lags | ERS | KPSS | Decision | Treatment | Slow-Fast |
|---|---|---|---|---|---|---|---|---|
| cbi | Change in Private Inventories | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| finsal | Final Sales of Domestic Product | 2 | 2 | 1 | 1 | 1 | 5 | 1 |
| fsdp | Final Sales to Domestic Purchasers | 3 | 1 | 1 | 1 | 1 | 5 | 1 |
| gdp | Gross Domestic Product, 1 Decimal | 4 | 1 | 1 | 1 | 1 | 5 | 1 |
| gdpc96 | Real Gross Domestic Product, 3 Decimal | 5 | 2 | 1 | 1 | 1 | 5 | 1 |
| finslc96 | Real Final Sales of Domestic Product, 3 Decimal | 6 | 3 | 1 | 1 | 1 | 5 | 1 |
| fgce | Federal Consumption Expenditures & Gross Investment | 7 | 1 | 1 | 1 | 1 | 5 | 1 |
| fgsl | Federal Grants-in-Aid to State & Local Governments | 8 | 1 | 1 | 1 | 1 | 5 | 1 |
| dgi | Federal National Defense Gross Investment | 9 | 2 | 1 | 1 | 1 | 5 | 1 |
| ndgi | Federal Nondefense Gross Investment | 10 | 1 | 1 | 1 | 1 | 5 | 1 |
| tgdef | Net Government Saving | 11 | 1 | 1 | 1 | 1 | 2 | 1 |
| slinv | State & Local Government Gross Investment | 12 | 1 | 1 | 1 | 1 | 5 | 1 |
| slexpnd | State & Local Government Current Expenditures | 13 | 1 | 1 | 1 | 1 | 5 | 0 |
| expgsc96 | Real Exports of Goods & Services, 3 Decimal | 14 | 1 | 1 | 1 | 1 | 5 | 1 |
| impgsc96 | Real Imports of Goods & Services, 3 Decimal | 15 | 1 | 1 | 1 | 1 | 5 | 1 |
| civa | Corporate Inventory Valuation Adjustment | 16 | 1 | 1 | 1 | 1 | 2 | 1 |
| cp | Corporate Profits After Tax | 17 | 1 | 1 | 1 | 1 | 5 | 1 |
| cncf | Corporate Net Cash Flow | 18 | 1 | 0 | 0 | 0 | 4 | 1 |
| dividend | Net Corporate Dividends | 19 | 2 | 1 | 1 | 1 | 5 | 0 |
| rentin | Rental Income of Persons with Capital Consumption Adjustment | 20 | 1 | 1 | 1 | 1 | 5 | 1 |
| gdpdef | Gross Domestic Product: Implicit Price Deflator | 21 | 3 | 1 | 1 | 1 | 5 | 1 |
| fpi | Fixed Private Investment | 22 | 2 | 1 | 1 | 1 | 5 | 1 |
| ggsave | Gross Government Saving | 23 | 1 | 0 | 1 | 1 | 2 | 1 |
| gsave | Gross Saving | 24 | 1 | 1 | 1 | 1 | 5 | 1 |
| prfi | Private Residential Fixed Investment | 25 | 2 | 1 | 1 | 1 | 5 | 1 |
| cmdebt | Household Sector: Liabilities; Household Credit Market Debt Outstanding | 26 | 3 | 0 | 1 | 2 | 6 | 0 |
| indpro | Industrial Production Index | 27 | 2 | 1 | 1 | 1 | 5 | 1 |
| napm | ISM Manufacturing: PMI Composite Index | 28 | 1 | 0 | 0 | 0 | 4 | 1 |
| hcompbs | Business Sector: Compensation Per Hour | 29 | 1 | 1 | 1 | 1 | 5 | 1 |
| hoabs | Business Sector: Hours of All Persons | 30 | 2 | 1 | 1 | 1 | 5 | 1 |
| rcphbs | Business Sector: Real Compensation Per Hour | 31 | 1 | 1 | 1 | 1 | 5 | 1 |
| ulcbs | Business Sector: Unit Labor Cost | 32 | 2 | 1 | 1 | 1 | 5 | 1 |
| compnfb | Nonfarm Business Sector: Compensation Per Hour | 33 | 1 | 1 | 1 | 1 | 5 | 1 |
| hoanbs | Nonfarm Business Sector: Hours of All Persons | 34 | 2 | 1 | 1 | 1 | 5 | 1 |
| comprnfb | Nonfarm Business Sector: Real Compensation Per Hour | 35 | 1 | 1 | 1 | 1 | 5 | 1 |
| ulcnfb | Nonfarm Business Sector: Unit Labor Cost | 36 | 1 | 1 | 1 | 1 | 5 | 1 |
| uemplt5 | Civilians Unemployed for less Than 5 Weeks | 37 | 1 | 1 | 1 | 1 | 5 | 1 |
| uemp5to14 | Civilian Unemployed for 5-14 Weeks | 38 | 1 | 1 | 1 | 1 | 5 | 1 |
| uemp15ov | Civilians Unemployed for 15 Weeks and Over | 39 | 2 | 0 | 1 | 1 | 5 | 1 |
| uemp15t26 | Civilians Unemployed for 15-26 Weeks | 40 | 3 | 0 | 1 | 1 | 5 | 1 |
| uemp27ov | Civilians Unemployed for 27 Weeks and Over | 41 | 2 | 0 | 1 | 1 | 5 | 1 |
| manemp | Employees on Nonfarm Payrolls: Manufacturing | 42 | 2 | 1 | 1 | 1 | 5 | 1 |
| ndmanemp | All Employees: Nondurable Goods Manufacturing | 43 | 2 | 1 | 1 | 1 | 5 | 1 |
| srvprd | All Employees: Service-Providing Industries | 44 | 1 | 1 | 1 | 1 | 5 | 1 |
| ustpu | All Employees: Trade, Transportation & Utilities | 45 | 1 | 1 | 1 | 1 | 5 | 1 |
| uswtrade | All Employees: Wholesale Trade | 46 | 1 | 0 | 1 | 1 | 5 | 1 |
| ustrade | All Employees: Retail Trade | 47 | 2 | 1 | 1 | 1 | 5 | 1 |
| usfire | All Employees: Financial Activities | 48 | 2 | 1 | 1 | 1 | 5 | 1 |
| usehs | All Employees: Education & Health Services | 49 | 2 | 1 | 1 | 1 | 5 | 1 |
| uspbs | All Employees: Professional & Business Services | 50 | 1 | 1 | 1 | 1 | 5 | 1 |
| usinfo | All Employees: Information Services | 51 | 2 | 1 | 1 | 1 | 5 | 1 |
| usserv | All Employees: Other Services | 52 | 1 | 1 | 1 | 1 | 5 | 1 |
| uspriv | All Employees: Total Private Industries | 53 | 2 | 1 | 1 | 1 | 5 | 1 |
| usgovt | All Employees: Government | 54 | 1 | 1 | 1 | 1 | 5 | 1 |
| uslah | All Employees: Leisure & Hospitality | 55 | 3 | 1 | 1 | 1 | 5 | 1 |
| ahecons | Average Hourly Earnings: Construction | 56 | 4 | 0 | 1 | 1 | 5 | 1 |
| aheman | Average Hourly Earnings: Manufacturing | 57 | 1 | 1 | 1 | 1 | 5 | 1 |
| ahetpi | Average Hourly Earnings: Total Private Industries | 58 | 2 | 1 | 1 | 1 | 5 | 1 |
| awotman | Average Weekly Hours: Overtime: Manufacturing | 59 | 1 | 1 | 1 | 1 | 2 | 1 |
| awhman | Average Weekly Hours: Manufacturing | 60 | 1 | 0 | 0 | 0 | 4 | 1 |

| Acronym | Series Name | No. | Lags | ERS | KPSS | Decision | Treatment | Slow-Fast |
|---|---|---|---|---|---|---|---|---|
| houst | Housing Starts: Total: New Privately Owned Housing Units Started | 61 | 1 | 1 | 1 | 1 | 5 | 0 |
| houstne | Housing Starts in Northeast Census Region | 62 | 1 | 1 | 1 | 1 | 5 | 0 |
| houstmw | Housing Starts in Midwest Census Region | 63 | 2 | 1 | 1 | 1 | 5 | 0 |
| housts | Housing Starts in South Census Region | 64 | 1 | 1 | 1 | 1 | 5 | 0 |
| houstw | Housing Starts in West Census Region | 65 | 3 | 1 | 1 | 1 | 5 | 0 |
| houst1f | Privately Owned Housing Starts: 1-Unit Structures | 66 | 4 | 0 | 1 | 1 | 5 | 0 |
| permit | New Private Housing Units Authorized by Building Permit | 67 | 1 | 1 | 1 | 1 | 5 | 0 |
| nonrevsl | Total Nonrevolving Credit Outstanding, SA, Billions of Dollars | 68 | 2 | 1 | 1 | 1 | 5 | 0 |
| usgsec | U.S. Government Securities at All Commercial Banks | 69 | 1 | 1 | 1 | 1 | 5 | 0 |
| othsec | Other Securities at All Commercial Banks | 70 | 1 | 0 | 0 | 0 | 4 | 0 |
| totalsl | Total Consumer Credit Outstanding | 71 | 1 | 1 | 1 | 1 | 5 | 0 |
| busloans | Commercial and Industrial Loans at All Commercial Banks | 72 | 2 | 0 | 0 | 0 | 4 | 0 |
| consumer | Consumer (Individual) Loans at All Commercial Banks | 73 | 1 | 1 | 1 | 1 | 5 | 0 |
| loans | Total Loans and Leases at All Commercial Banks | 74 | 1 | 1 | 1 | 1 | 5 | 0 |
| loaninv | Total Loans and Investments at All Commercial Banks | 75 | 1 | 1 | 1 | 1 | 5 | 0 |
| invest | Total Investments at All Commercial Banks | 76 | 1 | 1 | 1 | 1 | 5 | 0 |
| realln | Real Estate Loans at All Commercial Banks | 77 | 2 | 1 | 1 | 1 | 5 | 0 |
| bogambsl | Board of Governors Monetary Base, Adjusted for Changes in Reserve Req. | 78 | 1 | 1 | 1 | 1 | 5 | 0 |
| trarr | Board of Governors Total Reserves, Adjusted for Changes in Reserve Req. | 79 | 1 | 1 | 1 | 1 | 5 | 0 |
| bognonbr | Non-Borrowed Reserves of Depository Institutions | 80 | 2 | 1 | 1 | 1 | 2 | 0 |
| reqresns | Required Reserves, Not Adjusted for Changes in Reserve Requirements | 81 | 1 | 1 | 1 | 1 | 5 | 0 |
| resbalns | Reserve Balances with Fed. Res. Banks, Not Adj. for Changes in Res. Req. | 82 | 10 | 1 | 2 | 1 | 5 | 0 |
| borrow | Total Borrowings of Depository Institutions from the Federal Reserve | 83 | 2 | 0 | 0 | 0 | 4 | 0 |
| excresns | Excess Reserves of Depository Institutions | 84 | 10 | ? | 2 | 1 | 2 | 0 |
| nforbres | Net Free or Borrowed Reserves of Depository Institutions | 85 | 11 | ? | 2 | 2 | 3 | 0 |
| m1sl | M1 Money Stock | 86 | 1 | 1 | 1 | 1 | 5 | 0 |
| currsl | Currency Component of M1 | 87 | 2 | 1 | 1 | 1 | 5 | 0 |
| currdd | Currency Component of M1 Plus Demand Deposits | 88 | 1 | 1 | 1 | 1 | 5 | 0 |
| demdepsl | Demand Deposits at Commercial Banks | 89 | 8 | 1 | 1 | 1 | 5 | 0 |
| tcdsl | Total Checkable Deposits | 90 | 2 | 1 | 1 | 1 | 5 | 0 |
| tvckssl | Travelers Checks Outstanding | 91 | 1 | 1 | 1 | 1 | 2 | 0 |
| m2sl | M2 Money Stock | 92 | 3 | 1 | 1 | 1 | 5 | 0 |
| m2own | M2 Own Rate | 93 | 1 | 0 | 0 | 0 | 1 | 0 |
| svstcbsl | Savings and Small Time Deposits at Commercial Banks | 94 | 3 | 1 | 1 | 1 | 5 | 0 |
| svstsl | Savings and Small Time Deposits - Total | 95 | 3 | 2 | 1 | 1 | 5 | 0 |
| svgcbsl | Savings Deposits at Commercial Banks | 96 | 3 | 2 | 1 | 1 | 5 | 0 |
| svgti | Savings Deposits at Thrift Institutions | 97 | 1 | 1 | 1 | 1 | 5 | 0 |
| savingsl | Savings Deposits - Total | 98 | 3 | 2 | 1 | 1 | 5 | 0 |
| stdcbsl | Small Time Deposits at Commercial Banks | 99 | 1 | 0 | 0 | 0 | 4 | 0 |
| stdti | Small Time Deposits at Thrift Institutions | 100 | 3 | 0 | 1 | 1 | 5 | 0 |
| stdsl | Small Time Deposits - Total | 101 | 1 | 0 | 0 | 0 | 4 | 0 |
| m2msl | M2 Minus Small Time Deposits | 102 | 3 | 2 | 1 | 1 | 5 | 0 |
| m2mown | M2 Minus Own Rate | 103 | 1 | 0 | 0 | 0 | 1 | 0 |
| mzmsl | MZM Money Stock | 104 | 1 | 1 | 1 | 1 | 5 | 0 |
| dddfcbns | Demand Deposits Due to Foreign Commercial Banks | 105 | 0 | 1 | 2 | 1 | 2 | 0 |
| dddfoins | Demand Deposits Due to Foreign Official Institutions | 106 | 5 | 0 | 1 | 1 | 2 | 0 |
| usgvddns | U.S. Government Demand Deposits and Note Balances - Total | 107 | 0 | 0 | 1 | 1 | 2 | 0 |
| usgdcb | U.S. Government Demand Deposits at Commercial Banks | 108 | 6 | 1 | 0 | 1 | 2 | 0 |
| currcir | Currency in Circulation | 109 | 1 | 1 | 1 | 1 | 5 | 0 |
| tb3ms | 3-Month Treasury Bill: Secondary Market Rate | 110 | 1 | 0 | 0 | 0 | 1 | 0 |
| tb6ms | 6-Month Treasury Bill: Secondary Market Rate | 111 | 3 | 0 | 0 | 0 | 1 | 0 |
| gs1 | 1-Year Treasury Constant Maturity Rate | 112 | 3 | 0 | 0 | 0 | 1 | 0 |
| gs3 | 3-Year Treasury Constant Maturity Rate | 113 | 3 | 0 | 0 | 0 | 1 | 0 |
| gs5 | 5-Year Treasury Constant Maturity Rate | 114 | 3 | 0 | 0 | 0 | 1 | 0 |
| gs10 | 10-Year Treasury Constant Maturity Rate | 115 | 1 | 0 | 0 | 0 | 1 | 0 |
| mprime | Bank Prime Loan Rate | 116 | 1 | 0 | 0 | 0 | 1 | 0 |

| Acronym | Series Name | No. | Lags | ERS | KPSS | Decision | Treatment | Slow-Fast |
|---|---|---|---|---|---|---|---|---|
| aaa | Moody's Seasoned AAA Corporate Bond Yield | 117 | 1 | 0 | 0 | 0 | 1 | 0 |
| baa | Moody's Seasoned BAA Corporate Bond Yield | 118 | 0 | 1 | 0 | 1 | 2 | 0 |
| stb3ms | TB3MS - FEDFUNDS | 119 | 0 | 1 | 0 | 1 | 2 | 0 |
| stb6ms | TB6MS - FEDFUNDS | 120 | 1 | 0 | 0 | 0 | 1 | 0 |
| sgs1 | GS1 - FEDFUNDS | 121 | 1 | 0 | 0 | 0 | 1 | 0 |
| sgs3 | GS3 - FEDFUNDS | 122 | 1 | 0 | 0 | 0 | 1 | 0 |
| sgs5 | GS5 - FEDFUNDS | 123 | 1 | 0 | 0 | 0 | 1 | 0 |
| sgs10 | GS10 - FEDFUNDS | 124 | 1 | 0 | 0 | 0 | 1 | 0 |
| smprime | MPRIME - FEDFUNDS | 125 | 0 | 1 | 2 | 1 | 2 | 0 |
| saaa | AAA - FEDFUNDS | 126 | 2 | 0 | 0 | 0 | 1 | 0 |
| sbaa | BAA - FEDFUNDS | 127 | 2 | 0 | 0 | 0 | 1 | 0 |
| exszus | Switzerland / U.S. Foreign Exchange Rate | 128 | 0 | 1 | 1 | 1 | 5 | 0 |
| exjpus | Japan / U.S. Foreign Exchange Rate | 129 | 3 | 2 | 0 | 1 | 5 | 0 |
| reer | Real Effective Exchange Rate | 130 | 2 | 1 | 1 | 1 | 5 | 0 |
| ppiaco | Producer Price Index: All Commodities | 131 | 2 | 1 | 1 | 1 | 5 | 1 |
| ppicrm | Producer Price Index: Crude Materials for Further Processing | 132 | 2 | 1 | 1 | 1 | 5 | 1 |
| ppifcf | Producer Price Index: Finished Consumer Foods | 133 | 0 | 1 | 1 | 1 | 5 | 1 |
| ppifcg | Producer Price Index: Finished Consumer Goods | 134 | 1 | 1 | 1 | 1 | 5 | 1 |
| pfcgef | Producer Price Index: Finished Consumer Goods Excluding Foods | 135 | 1 | 1 | 1 | 1 | 5 | 1 |
| ppifgs | Producer Price Index: Finished Goods | 136 | 1 | 1 | 1 | 1 | 5 | 1 |
| ppicpe | Producer Price Index Finished Goods: Capital Equipment | 137 | 1 | 1 | 1 | 1 | 5 | 1 |
| ppieng | Producer Price Index: Fuels & Related Products & Power | 138 | 2 | 1 | 1 | 1 | 5 | 1 |
| ppiidc | Producer Price Index: Industrial Commodities | 139 | 2 | 1 | 1 | 1 | 5 | 1 |
| ppiitm | Producer Price Index: Intermediate Materials: Supplies & Components | 140 | 2 | 1 | 1 | 1 | 5 | 1 |
| cpiaucsl | Consumer Price Index For All Urban Consumers: All Items | 141 | 1 | 1 | 1 | 1 | 5 | 1 |
| cpiufdsl | Consumer Price Index for All Urban Consumers: Food | 142 | 1 | 1 | 1 | 1 | 5 | 1 |
| cpiengsl | Consumer Price Index for All Urban Consumers: Energy | 143 | 0 | 1 | 1 | 1 | 5 | 1 |
| cpilegsl | Consumer Price Index for All Urban Consumers: All Items Less Energy | 144 | 2 | 2 | 0 | 2 | 6 | 1 |
| cpiulfsl | Consumer Price Index for All Urban Consumers: All Items Less Food | 145 | 1 | 1 | 1 | 1 | 5 | 1 |
| cpilfesl | Consumer Price Index for All Urban Cons.: All Items Less Food & Energy | 146 | 2 | 1 | 1 | 1 | 5 | 1 |
| oilprice | Spot Oil Price: West Texas Intermediate | 147 | 4 | 1 | ? | 1 | 5 | 1 |
| umcsentsa | U. Of Mich. Index Of Consumer Expectations | 148 | 0 | 1 | 1 | 1 | 5 | 1 |
| napmnoi | NAPM New Orders Index | 149 | 1 | 0 | 0 | 0 | 4 | 1 |
| napmsdi | NAPM Vendor Deliveries Index | 150 | 1 | 0 | 0 | 0 | 4 | 1 |
| napmii | NAPM Inventories Index | 151 | 2 | 0 | 0 | 0 | 4 | 1 |
| acdgno | New Orders (Net) - Consumer Goods & Materials | 152 | 1 | 1 | 1 | 1 | 5 | 1 |
| adxdno | New Orders, Nondefense Capital Goods | 153 | 0 | 1 | 1 | 1 | 5 | 1 |
| hp | Real Home Price Index | 154 | 8 | ? | ? | 2 | 6 | 1 |
| vxo | Volatility Index S&P100 | 155 | 0 | 0 | 0 | 0 | 1 | 0 |
| oa67mor5 | Asset-Backed Security Issuers: Assets; Total Mortgages | 156 | 1 | 0 | 1 | 1 | 5 | 0 |
| ol67tao5 | Asset-Backed Security Issuers: Total Financial Liabilities | 157 | 3 | 1 | 1 | 1 | 5 | 0 |
| ol75aay3 | Foreign Bank Offices in U.S.: Liabilities; Interbank Transfers due to Foreign Affiliates | 158 | 0 | 1 | 1 | 1 | 5 | 0 |
| oa63tcr5 | Money Market Mutual Funds: Assets; Credit Market Instruments | 159 | 1 | 1 | 1 | 1 | 5 | 0 |
| oa66tcr5 | Security Brokers & Dealers: Assets; Credit Market Instruments | 160 | 1 | 1 | 1 | 1 | 5 | 0 |
| ndfo | Net due to Related Foreign Offices and Foreign-Related Institutions | 161 | 10 | 2 | 1 | 1 | 2 | 0 |
| sp500 | S&P 500 Index | 162 | 0 | 0 | 0 | 0 | 5 | 0 |
| capin | Capital Inflows, gross | 163 | 1 | 0 | 1 | 0 | 1 | 0 |
| capout | Capital Outflows, gross | 164 | 1 | 0 | 1 | 0 | 1 | 0 |
| efp | External Finance Premium | 165 | 0 | 0 | 0 | 0 | 1 | 0 |
| nfncl | Nonfinancial Noncorporate Business: Liabilities | 166 | 2 | 0 | 1 | 1 | 5 | 0 |
| nfnca | Nonfinancial Noncorporate Business: Assets | 167 | 2 | 0 | 1 | 1 | 5 | 0 |
| nfcl | Nonfinancial Corporate Business: Liabilities | 168 | 2 | 0 | 1 | 1 | 5 | 0 |
| nfca | Nonfinancial Corporate Business: Assets | 169 | 2 | 0 | 1 | 1 | 5 | 0 |
| hhatfa | Household Sector: Assets; Total Financial Assets | 170 | 2 | 0 | 1 | 1 | 5 | 0 |
| hharea | Household Sector: Assets; Real Estate Assets | 171 | 2 | 0 | 1 | 1 | 5 | 0 |
| nfclcmdo | Nonfinancial Corporate Business: Liabilities; Credit Market Debt Outstanding | 172 | 2 | 0 | 1 | 1 | 5 | 0 |
| cab | Current Account Balance | 173 | 2 | 0 | 1 | 1 | 2 | 1 |
| pce | Personal Consumption Expenditures | 174 | 2 | 0 | 1 | 1 | 5 | 1 |
| inf | Inflation | 175 | 2 | 1 | 1 | 1 | 1 | 1 |
| unrate | Unemployment Rate: All Workers, 16 Years & Over | 176 | 2 | 1 | 1 | 1 | 1 | 1 |
| fedfunds | Effective Federal Funds Rate | 177 | 1 | 0 | 0 | 0 | 1 | 0 |

Source: Authors' calculations.

Notes: Lags indicate the number of lags chosen using the Schwarz information criterion and ensuring that no serial correlation is left in the residuals. ERS refers to the Elliott-Rothenberg-Stock (1996) test, that is, the augmented Dickey-Fuller test applied to the times series transformed via a generalized least squares (GLS) regression before performing the test. The null hypothesis is non-stationarity around a constant and a deterministic trend. KPSS refers to the Kwiatkowski–Phillips–Schmidt–Shin (1992) test for the null hypothesis that the series is stationary around a deterministic trend. Decision indicates the level of integration judged to apply to a particular series based on the results of the ERS and KPSS unit root tests. Treatment shows how the series is transformed before being added to the database, with 1 = level; 2 = difference in level; 3 = second difference in level; 4 = log level; 5 = log difference; 6 = second log difference. Slow-fast indicates where the series is treated as a slow- or fast-moving variable, with 1 = slow and 0 = fast, respectively.

## Appendix III. Investment, Consumption, and Trade-Based Channels

Consistent with the theoretical and empirical literature, traditional channels of monetary policy play a significant role in the transmission of monetary policy. These channels relate to the response of private investment, consumption, and international trade to changes in interest rates, exchange rates and asset prices. In addition, M1 falls in the short term as a result of the higher yield of alternative assets and rises in the medium term as the effect of the shock on interest rates dies out; M2 is marginally affected in the short term.

The interest-rate channel operates through the increase in interest rates which raises the cost of capital and causes a decline in business and household investment spending (Jorgenson, 1963; and Tobin, 1969). Indeed, interest rates for government and corporate securities rise across the maturity spectrum in response to an increase in the federal funds rate. The increase in short- and medium-term rates mirrors that in the federal funds rate while long-term rates rise by less than one percent. As a result, the yield curve becomes flatter. Owing to a rise in interest rates across the spectrum, private fixed investment, business investment, and investment in consumer durables decline (Appendix Figure 1).

The short-run elasticity of fixed private investment to changes in interest rates is estimated at about -0.5, while the medium-term elasticity is about -1.0. The fact that the short-run elasticity is lower than that over the medium term is consistent with the literature. The absolute values of elasticities are also broadly consistent with the literature (see Boivin, Kiley, and Mishkin, 2010). However, our estimate of the short-run elasticity is on the high side owing to a significant response of private residential fixed investment (see below). The short-run elasticity for the latter is about -1, which reflects a high sensitivity of housing starts to changes in interest rates. This finding is consistent with Leamer (2007), who demonstrates that abnormal changes in private residential investment signal turning points in the business cycle.

The asset-price effects, and the related wealth and consumption-based channels, are moderately strong. Stock prices are not affected in the short run, possibly because of anticipation effects, but decline over the medium term (Appendix Figure 2). The magnitude of the decline is small: less than 0.5 percent. House prices also decline in response to a rise in interest rates. This effect is more immediate than for stock prices, but is short-lived. There are several possible reasons why the response of real house prices to changes in interest rates is muted. Feedback effects in this market may be two-way in practice rather than only from prices to investment, as theory suggests. Indeed, private residential fixed investment and housing starts decline sharply in response to the monetary policy shock, possibly offsetting the impact of monetary policy on house prices. More generally, non- interest rate factors may also play an important role in determining house price dynamics, for example, securitization, borrower constraints, or loan eligibility requirements such as loan-to-value ratios. Indeed, several relevant variables, for example, real estate lending and household financial and real estate assets, decline strongly in response to an increase in interest rates.

By contrast to the interest-rate and asset-price channels, the international-trade channel as driven by changes in the exchange rate does not appear to be significant (Appendix Figure 3).

The real effective exchange rate appreciation on impact is not statistically significant; and it remains so over the entire policy horizon. The weakness of the exchange-rate channel is consistent with the large size and the relatively low degree of trade openness of the U.S. economy as well as the low rates of exchange rate pass-through documented in a number of studies (for instance, Campa and Goldberg, 2005).[1] More fundamentally, it may be due to the observation that U.S. short-term rates lead major countries' interest rates within the minor business cycle periodicities, i.e., up to 4 years. This may explain the weakness of uncovered interest rate parity effects (Igan and others, 2011). Notwithstanding statistically insignificant effects on the real effective exchange rate, exports do rise over the short term and decline by about 0.5 percent over the medium term. Imports decline over the entire policy horizon by about 0.75 percent, mainly owing to a decline in domestic income. The trade balance and the current account balance improve over the policy horizon.

Capital flows respond strongly to a rise in U.S. policy rates (Appendix Figure 4). Despite a rise in interest rates, gross capital inflows decline, with a trough of 0.75 percent at about 9 quarters. The dampening effect stemming from a slowdown in economic growth, increased uncertainty (proxied here by the VIX), and declining house prices apparently dominates the stimulating effect of higher interest rates on capital inflows, consistent with Forbes and Warnock (2011). This result is consistent with explanations of the causes of the recent financial crisis that emphasize the role of private and public capital inflows in the United States in search of yield and safety. These capital flows reportedly reflected large savings of economies running external surpluses, particularly emerging economies such as China. The behavior of gross capital outflows mirrors that of capital inflows, with a rise of about 0.75 percent over the medium term. Again, increased uncertainty appear to be more important drivers than the interest rate or the exchange rate. On a net basis, capital inflows decline, and the capital and financial surplus shrinks.

[1] The weakness of the exchange-rate channel of monetary policy transmission may come as a surprise considering the increased pace of globalization and consequent increased openness of the U.S. and other economies. The documented weakness is consistent with other studies such as Barran, Coudet, and Mojon (1996), and Boivin, Kiley, and Mishkin (2010).

Table 1. Determining the Number of Factors (*k)*

| *k* | *PCp1* | *PCp2* | *PCp3* | *ICp1* | *ICp2* | *ICp3* | Cumulated Variance Share |
|---|---|---|---|---|---|---|---|
| 1 | 0.3627 | 0.3629 | 0.3622 | -0.9521 | -0.9443 | -0.9730 | 0.635 |
| 2 | 0.2211 | 0.2215 | 0.2201 | -1.3906 | -1.3749 | -1.4323 | 0.780 |
| 3 | 0.1555 | 0.1560 | 0.1540 | -1.6925 | -1.6689 | -1.7551 | **0.848** |
| 4 | 0.1154 | 0.1161 | 0.1135 | -1.9488 | -1.9174 | -2.0323 | 0.890 |
| 5 | 0.0804 | 0.0813 | 0.0780 | -2.2893 | -2.2500 | -2.3936 | 0.927 |
| 6 | 0.0626 | 0.0637 | 0.0597 | -2.5326 | -2.4854 | -2.6578 | 0.946 |
| 7 | 0.0530 | 0.5430 | 0.0496 | -2.6995 | -2.6445 | -2.8456 | 0.957 |
| 8 | 0.0461 | 0.0476 | 0.0423 | -2.8545 | -2.7917 | -3.0215 | 0.966 |
| 9 | 0.0415 | 0.0431 | 0.0371 | -2.9901 | -2.9193 | -3.1779 | 0.972 |
| 10 | 0.0384 | 0.0402 | 0.0336 | -3.1058 | -3.0272 | -3.3145 | 0.977 |

Note: In **bold** denotes the minimum based on Bai and Ng (2002) criteria.

Table 2. Importance of Variables in the Transmission of Monetary Policy: Factor Loadings and Variance Shares
(In percentage points)

| Category | Factor 1 | | Factor 2 | | Factor 3 | | Variance Share | |
|---|---|---|---|---|---|---|---|---|
| | With Balance Sheet Variables | Without Balance Sheet Variables | With Balance Sheet Variables | Without Balance Sheet Variables | With Balance Sheet Variables | Without Balance Sheet Variables | With Balance Sheet Variables | Without Balance Sheet Variables |
| Macroeconomy | 0.25 | 0.89 | 0.91 | 0.77 | 0.70 | 0.80 | 0.31 | 0.63 |
| Expectations | 0.00 | 0.04 | 0.00 | 0.08 | 0.00 | 0.05 | 0.00 | 0.00 |
| Funding Costs | 0.33 | 0.07 | 0.03 | 0.00 | 0.03 | 0.10 | 0.44 | 0.29 |
| Funding Quantities | 0.42 | 0.00 | 0.06 | 0.15 | 0.27 | 0.05 | 0.25 | 0.09 |
| Number of variables in category | 24 | 28 | 34 | 13 | 33 | 20 | 32 | 35 |

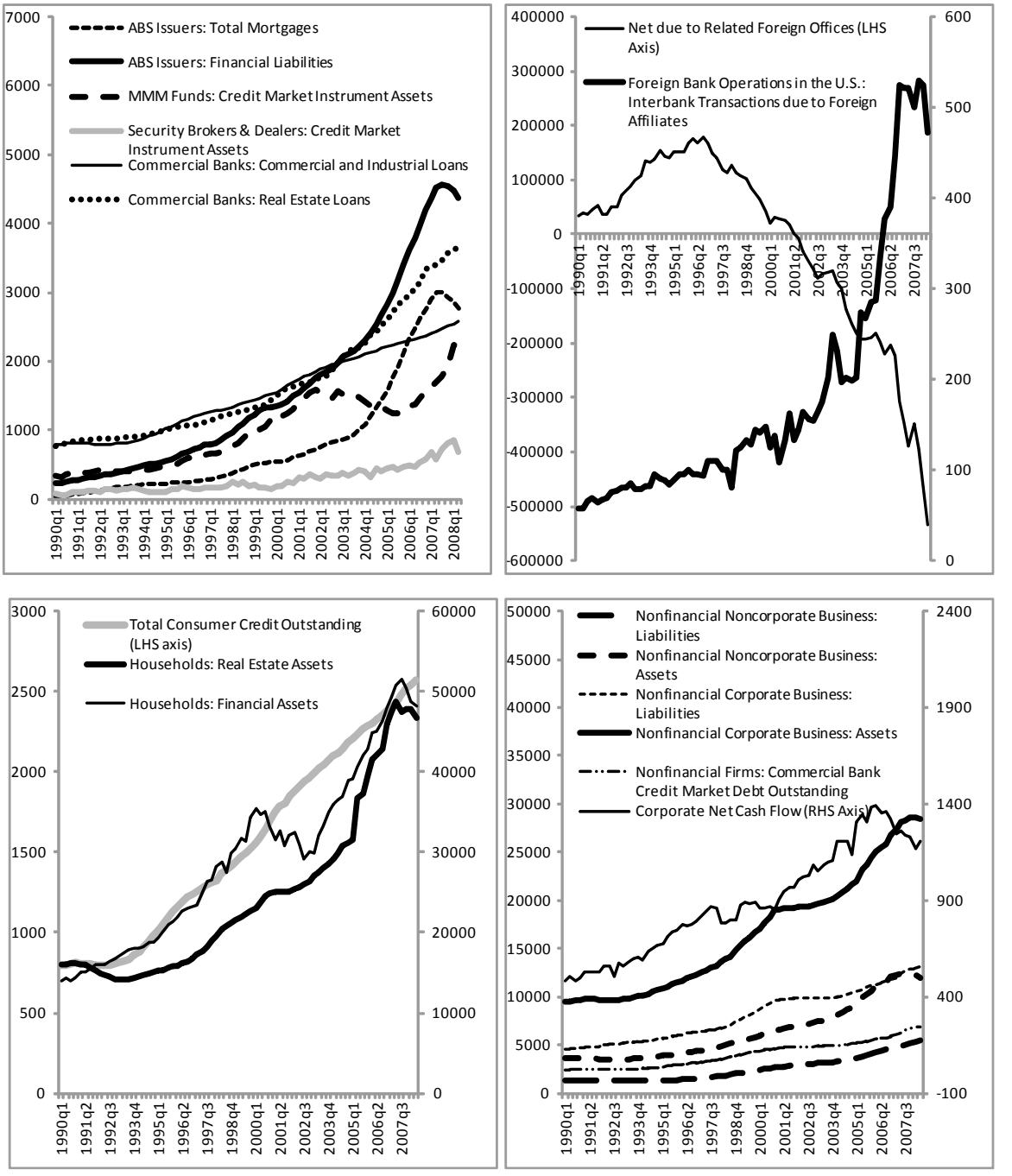
Note: For each factor, the table shows the percentage represented by each category of variables with a factor loading above 1.0. For the variance share, the table shows the percentage represented by each category of variables with an explanatory power of at least 80 percent. The category "Funding Costs" includes interest rates and bond yields, the category "Expectations" consumer expectations, the category "Funding Quantities" comprises monetary aggregates, capital flows, and their components. Other variables are part of the category "Macroeconomy."

Table 3. Importance of Variables in the Transmission of Monetary Policy: Regression Analysis
(In percentage points)

| Category | Factor 1 | | Factor 2 | | Factor 3 | |
|---|---|---|---|---|---|---|
| | With Balance Sheet Variables | Without Balance Sheet Variables | With Balance Sheet Variables | Without Balance Sheet Variables | With Balance Sheet Variables | Without Balance Sheet Variables |
| Macroeconomy | 0.08 | 1.00 | 1.00 | 1.00 | 0.75 | 0.92 |
| Expectations | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Funding Costs | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Funding Quantities | 0.75 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 |
| Number of variables in category | 12 | 15 | 14 | 12 | 12 | 12 |

Note: The table shows the variance shares obtained by regressing each variable on each common factor. They represent the explanatory power of 50 percent for Factor 1 and Factor 2 and the top 12 for Factor 3. The category "Funding Costs" includes interest rates and bond yields, the category "Expectations" consumer expectations, the category "Funding Quantities" comprises monetary aggregates, capital flows, and their components. Other variables are part of the category "Macroeconomy."

Figure 1. Balance Sheet Variables, q1 1990 – q2 2008
(In billions of U.S. dollars)




Source: Federal Reserve Board, and authors' estimates.

Figure 2. Interest Rate, Inflation, Unemployment, and GDP

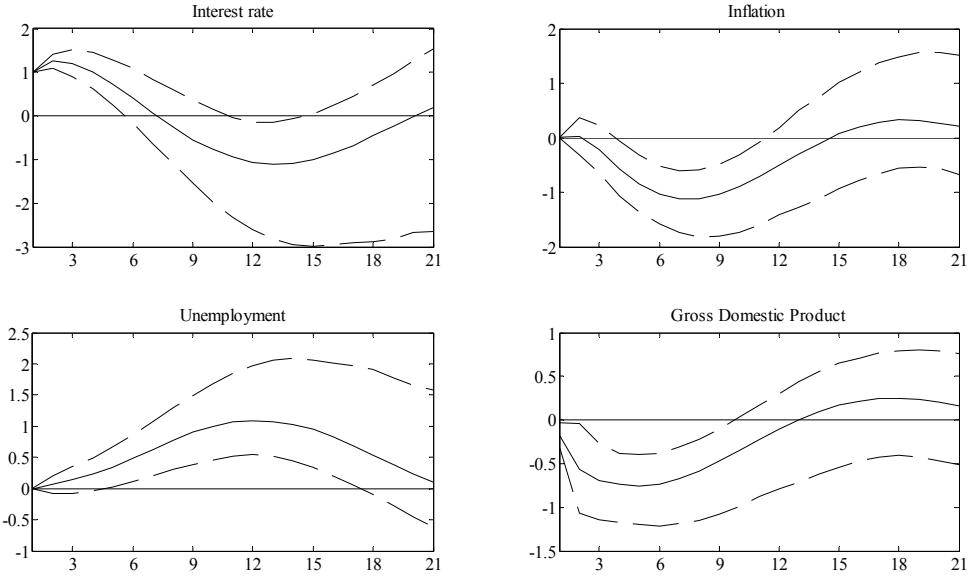



Figure 3. Bank Lending Rates, External Finance Premium, Real Estate Loans, and Business Loans

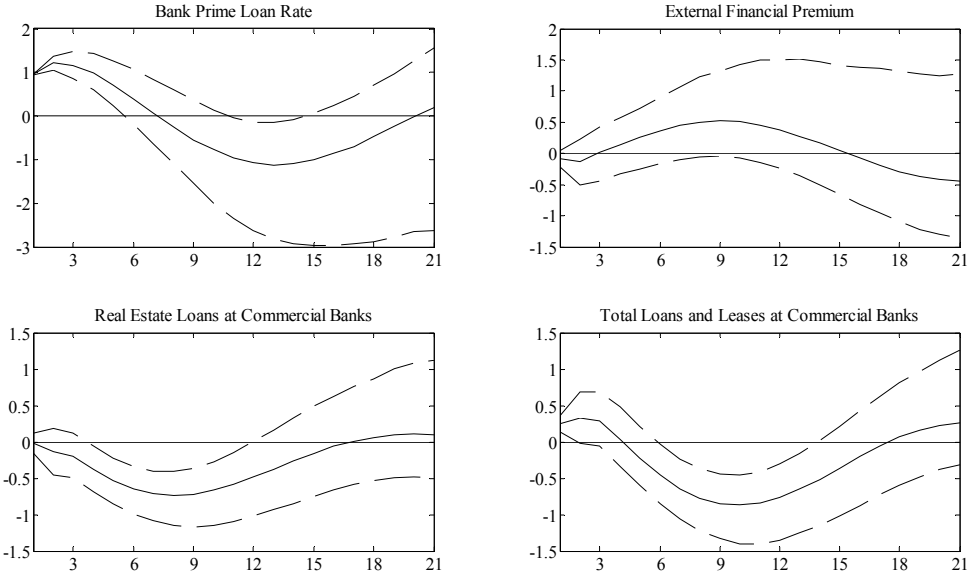


Figure 4. Balance Sheets of Asset-Backed Securities Issuers, Money Market Funds, and Security Brokers & Dealers

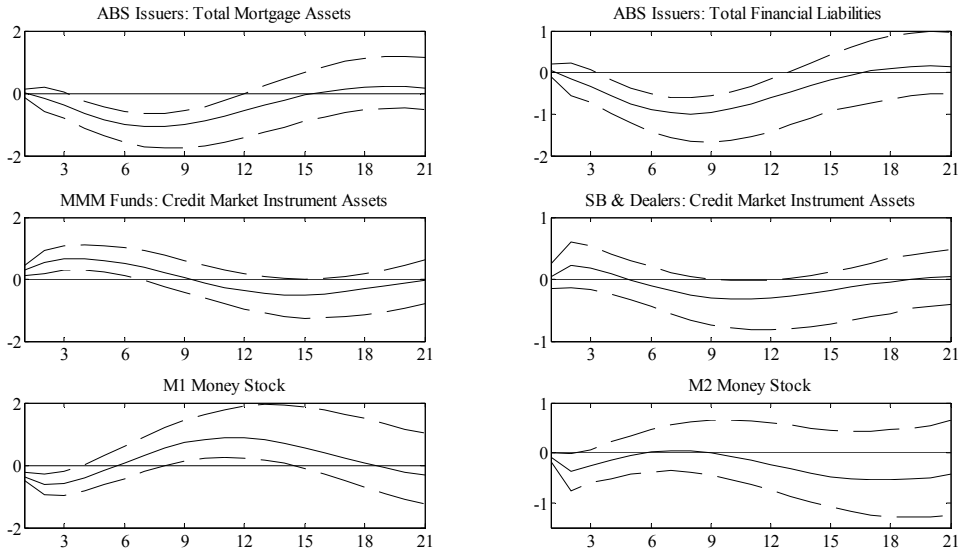



Figure 5. Foreign Borrowing and Lending

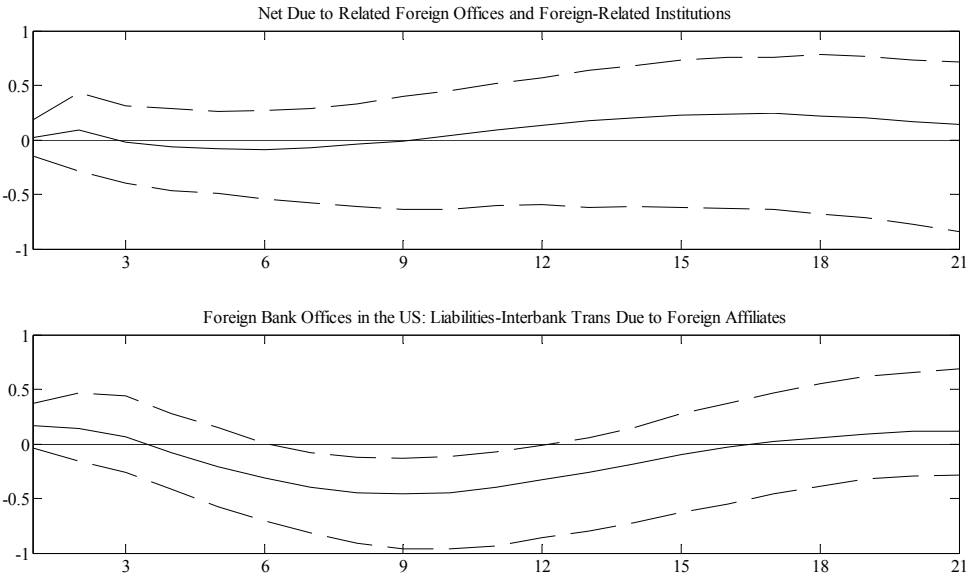


Figure 6. Balance Sheets of Households

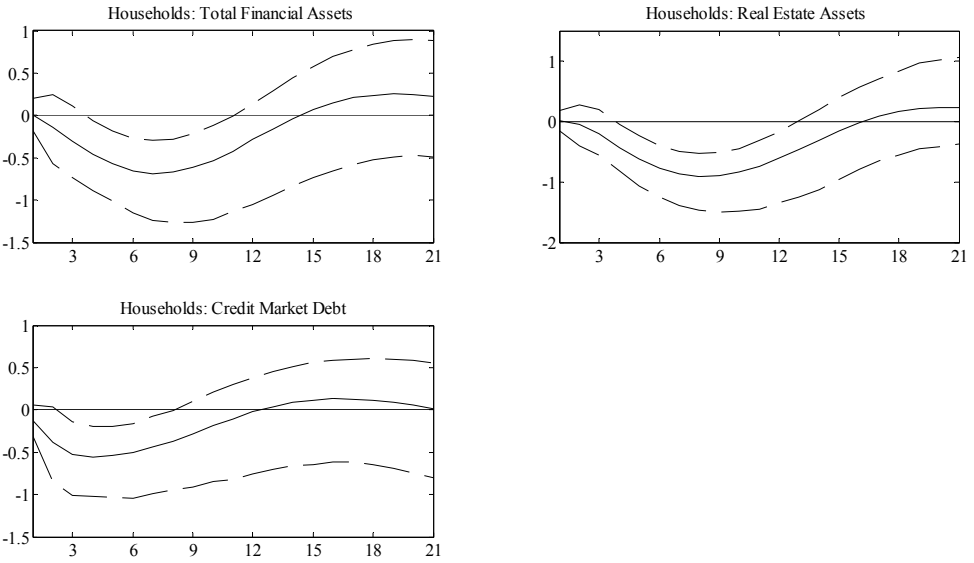
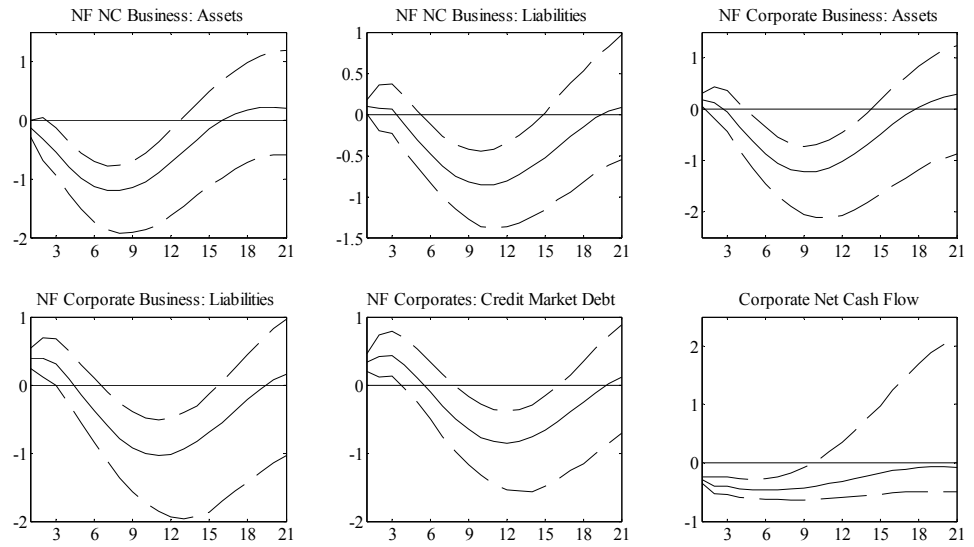
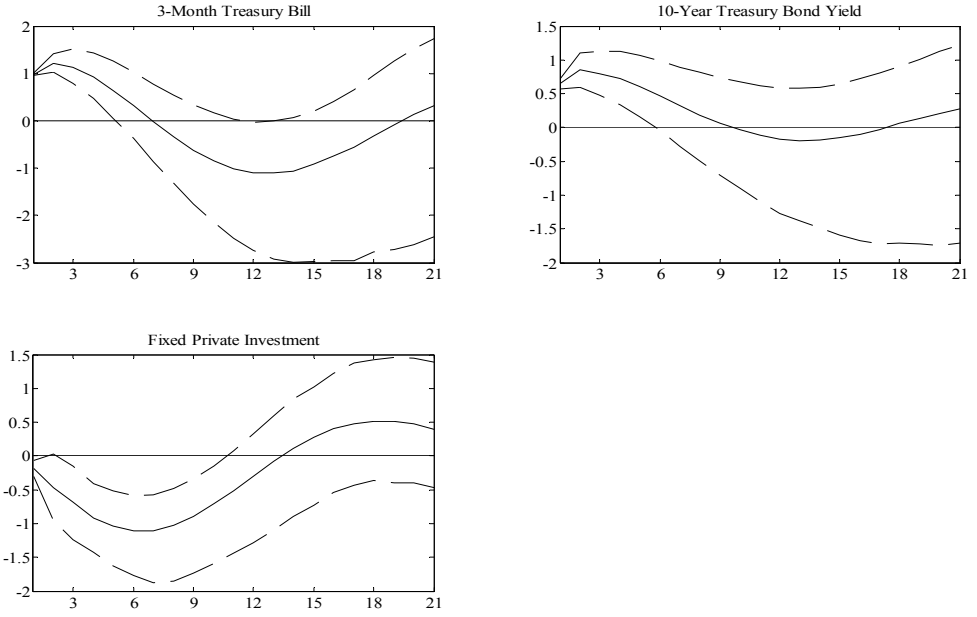


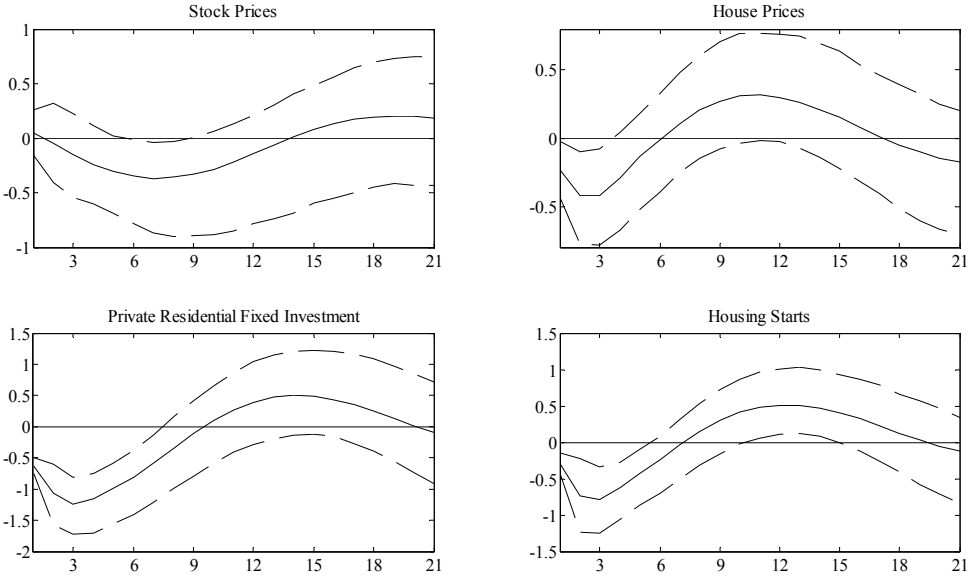

Figure 7. Balance Sheets of Nonfinancial Firms



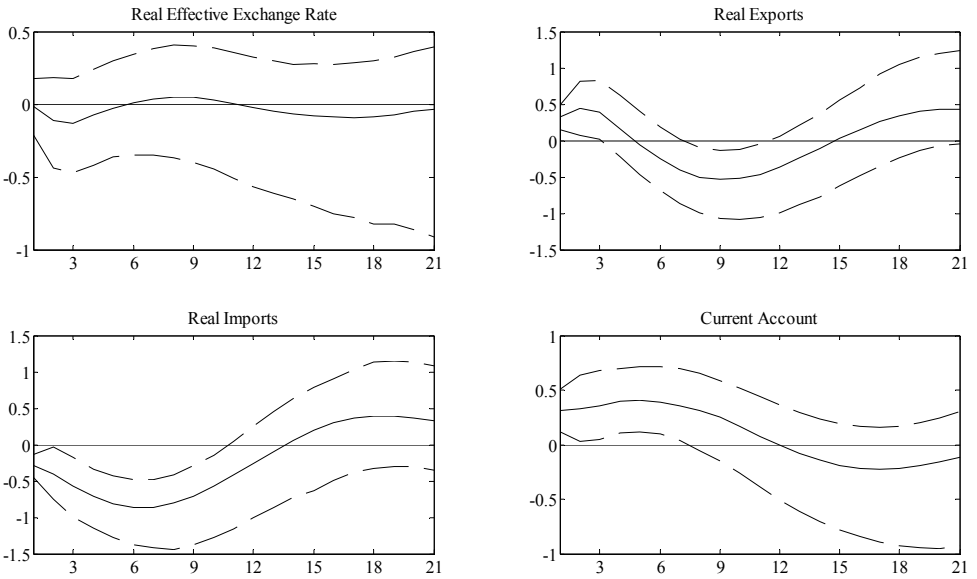
Appendix Figure 1. Interest Rates and Fixed Private Investment




Appendix Figure 2. Stock Prices, House Prices, and Residential Investment



Appendix Figure 3. Real Effective Exchange Rate, Exports, and Imports




Appendix Figure 4. VIX, Capital Inflows, and Outflows