Impact of Foreign Official Purchases of U.S. Treasuries on the Yield Curve

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Abstract

Foreign governments went from owning 10% of publicly held U.S. Treasury debt in 1985 to over 50% in 2008. Recently, foreign governments have reduced their Treasury positions. This paper employs a Gaussian affine term structure model, augmented with macro variables, to test whether purchases of Treasuries by foreign governments have effected U.S. interest rates. The advantage of using a term structure model is it allows us to examine the impact of shocks over the entire yield curve, as opposed to a single maturity. To identify shocks to foreign official purchases of Treasuries, I embed a structural vector autoregression of macroeconomic variables in the model. I find foreign official purchases have shifted the entire yield curve down with the largest impacts on the 2-year Treasury yield.

Keywords: Foreign official purchases, Treasury securities, yields, term structure.

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1 Introduction

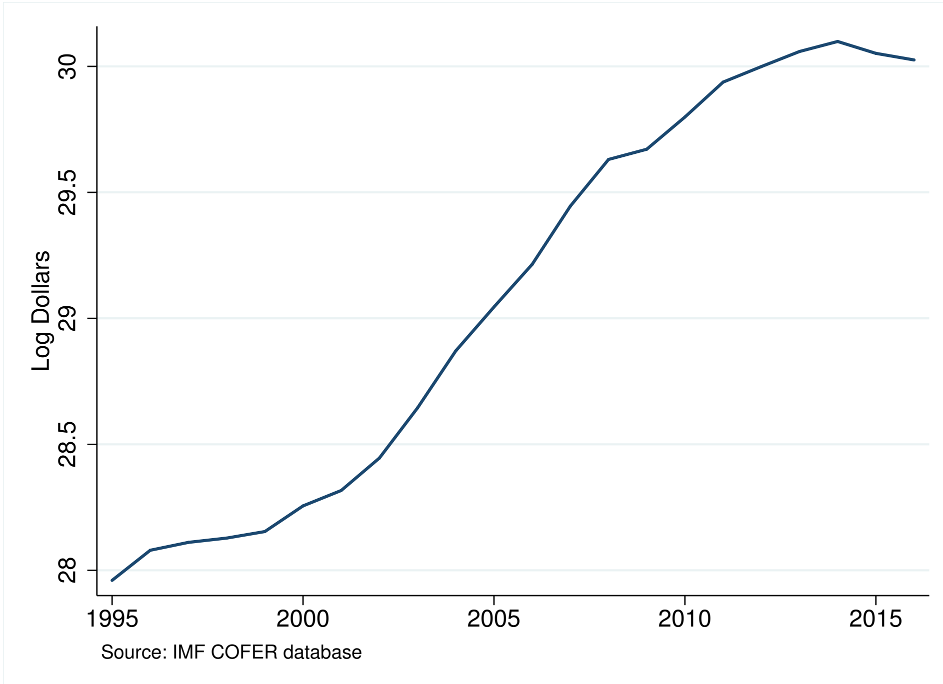
In 2005, Ben S. Bernanke, Chairman of the Federal Reserve, coined the term "global saving glut" in a speech highlighting the abundance of global savings financing the acquisition of foreign claims rather than domestic investment. Much of this global saving glut has its origins in the 1997 Asian financial crisis, where Asian emerging market economies suffered a loss of lender confidence and subsequently an outflow of capital. Since then, several countries in Asia that were previously net borrowers morphed into net lenders, building up their foreign reserves to use as a buffer against capital outflows in the wake of another crisis.

Figure 1 plots the rate of foreign reserve accumulation of all countries starting in 1995. The series displays a steeper slope in the early 2000s, suggesting the rate at which governments acquired foreign exchange reserves increased after the Asian financial crisis. More recently the rate of accumulation has tapered, yet the total change over the last two decades is still over 1000%. In 1995 reserves totaled about $1 trillion, today they are over $10 trillion.

Although the composition of foreign exchange reserves is often not publicly available, it is believed the majority of Asia's international reserves are held in U.S. dollar assets. U.S. securities are particularly attractive to foreign governments because they are safe, liquid products denominated in the currency many emerging market economies use as a reference point on the foreign exchange market. Figure 2 plots the percent of publicly held Treasury securities owned by foreigners. In 1985, foreigners owned 15 percent or $100 billion of U.S. publicly held Treasury debt, while in 2014 they owned over 60 percent or $5 trillion. The growth in foreign holdings since the 1990s is remarkable and China and Japan's acquisitions (blue and red regions), following the Asian financial crisis, account for a significant fraction of that growth.

To gauge how much of these foreign inflows are held by foreign governmental entities, Figure 3 plots the percent of publicly held Treasuries outstanding owned by foreign official agencies. Note, I will refer to flows into Treasuries by foreign governments as foreign official purchases. After the Asian financial crisis, the percent of Treasuries held by foreign officials

Figure 1: Global Foreign Exchange Reserves



immediately increased. In 2008, over 50 percent of U.S. publicly held federal debt was owned by foreign governments. More recently, foreign governments have reduced their positions of U.S. Treasuries. After comparing Figures 2 and 3, we see that the majority of foreign-held Treasury securities are in the possession of governments.

The massive increase of foreign official flows into U.S. securities begs the question of whether these purchases have depressed interest rates and altered the yield curve. This question has several important policy implications. The first regards monetary policy. If U.S. interest rates are increasingly determined by international financial markets, then it may be more difficult for the Federal Reserve to implement its interest rate policy. For instance, the Fed may find it desirable to use unconventional monetary policies to offset the effects of foreign official purchases, particularly, if these effects are concentrated at the long-end of the yield curve.. Additionally, if foreign governments decide to sell off their sizable Treasury positions—as they appear to be doing since 2008—and the Fed is not prepared to implement counteractive measures, U.S. interest rates may increase and have a contractionary effect on

Figure 2: Percent of Treasuries Held by Foreigners

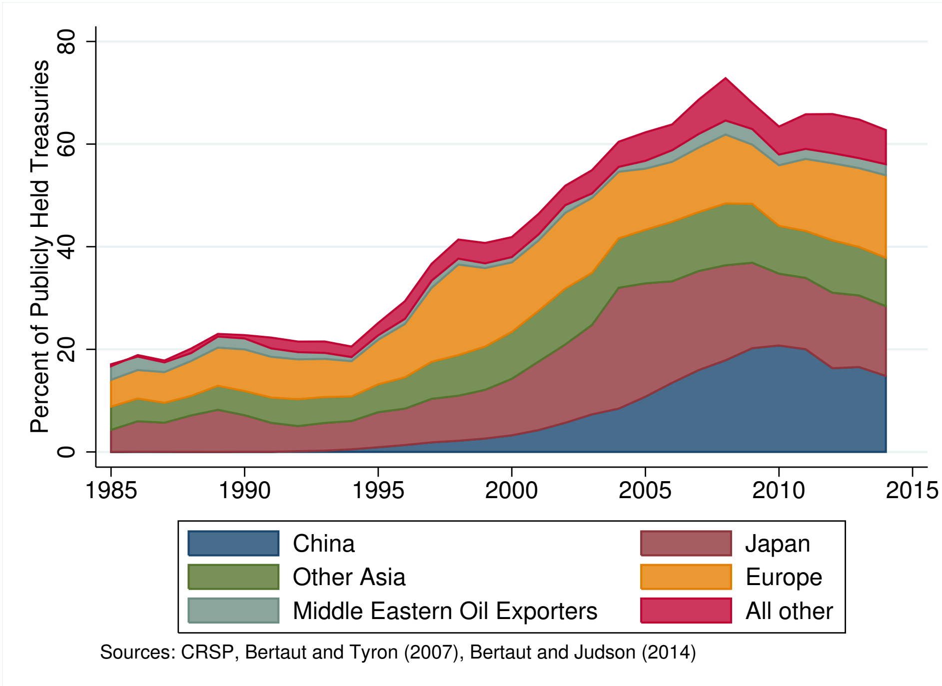
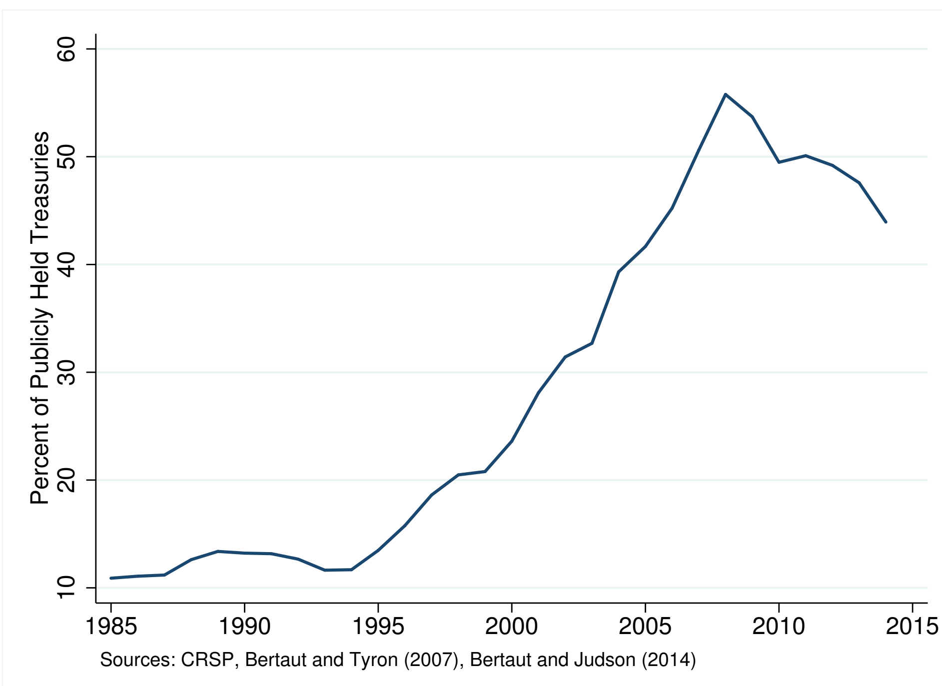


Figure 3: Percent of Treasuries Held by Foreign Governments



the economy.

The second policy implication regards global financial stability. It is widely believed the recent financial crisis, at least in part, was caused by persistently low interest rates in the early 2000s, of which some economists attribute to stimulative monetary policy (see Taylor (2009); Gambacorta (2009); Maddaloni and Peydró (2011)). However, if foreign official purchases of Treasuries are part of the story for why interest rates were so low, then they too may have contributed to the financial crisis.

Previous work has asked whether the influx of foreign investment into U.S. securities has pushed down long-term interest rates in the U.S. This paper goes beyond that and asks how foreign official investment has affected the entire yield curve. I do this by estimating a Gaussian affine term structure model (ATSM), augmented with macro variables. ATSMs exploit no arbitrage in financial markets to identify factors explaining the yield curve. By embedding a structural vector autoregression (SVAR) of macro variables—one of which is foreign official purchases of Treasuries—in the model, I uncover how macro variables, in addition to three latent factors, explain the dynamics of the U.S. yield curve.

Section 2 reviews some key works in the foreign official positions literature and ATSM literature; Section 3 outlines the basic framework of ATSMs and their application to the question at hand; Section 4 describes the data; Section 5 explains the estimation strategy; Section 6 presents and discusses the results; and Section 7 concludes.

2 Related Literature

2.1 Foreign Official Purchases

One of the most widely cited works investigating the impact of foreign official purchases on U.S. Treasury securities is Warnock and Warnock (2009). They regress the 10-year Treasury rate on foreign official purchases for the period January 1984 to May 2005, including a number of control variables, such as short-term interest rates, inflation expectations, growth expectations, the federal deficit, and a variable capturing the interest rate risk premium. They conclude each $100 billion Treasury purchase reduced the 10-year yield by 68 basis points. From specifications with alternative dependent variables, they also conclude foreign inflows have depressed U.S. corporate bond rates and mortgage rates, potentially fueling the financial and housing bubbles. Their identification strategy, however, relies on assuming foreign official purchases are exogenous. Although foreign officials may not maximize returns the way private investors do, their actions are likely systematic and respond to economic circumstances.

Bernanke, Reinhart, and Sack (2004) use an event study approach to circumvent this exogeneity assumption and find a similar impact of foreign inflows on U.S. yields. Using Japanese announced foreign exchange interventions between 2000 and 2004, they find each $100 billion intervention in the Treasury market reduced the 10-year yield by 66 basis points. Martin (2014) also uses high frequency data, but finds larger effects. Using a new measure of surprise Chinese official Treasury purchases, Martin (2014) finds the 10-year yield fell by over 100 basis points in response to a $100 billion intervention.

Lastly, Beltran, Kretchmer, Marquez, and Thomas (2013) use instrumental variables to relax the assumption that foreign official purchases are exogenous. They estimate the short-run impacts of foreign official purchases on the 5-year term premium with two-stage-least-squares, where instruments include an oil-specific supply shock variable, Japanese foreign exchange interventions, and the Chinese trade balance. Using data from January 1994 to June 2007, they find a smaller impact of foreign official purchases on yields. In particular, if foreign official purchases were to decrease by $100 billion, the 5-year Treasury rate would immediately rise by 40-60 basis points. To estimate the long-term impact of foreign official purchases, after private investors react to the yield change, they employ a co-integrated VAR and find the effect is about a 20 basis point rise in yields.

This paper contributes to the foreign official purchases literature by accounting for the possibility that foreign official purchases are not exogenous and systematically examining how the entire yield curve responds instead of a particular maturity, such as the 5- or 10-year rate.

2.2 ATSM Literature

By incorporating an ATSM, this paper is the first to document the response of the entire yield curve to foreign official purchase shocks. ATSMs exploit the convenient property of bonds that different maturities of the same asset are traded at the same time. This allows the researcher to compare bond prices of varying maturities and infer something about investors' risk preferences. Specifically, ATSMs assume any gap between long-term yields and the expected value of future short-term yields is the price of risk and not an arbitrage opportunity. ATSMs essentially assume no arbitrage; and in deep markets, like the U.S. Treasury market, it is likely all arbitrage opportunities are instantaneously traded away. By imposing restrictions across maturities so long rates equal risk-adjusted future short rates, the researcher attains a parsimonious model of the entire yield curve based on only a few parameters.[1]

Originally, ATSMs were used to uncover latent factors explaining the yield curve. The norm was to include three latent factors and interpret them as “level,” “slope,” and “curvature” (see Dai and Singleton (2000), (2002); Duffee (2002); Kim and Orphanides (2005); Kim and Wright (2005)). However, Ang and Piazzesi (2003) popularized the inclusion of both observable and unobservable factors in ATSMs. Specifically, they include observed inflation and economic growth factors, along with three latent factors, to investigate how macro variables contribute to bond prices and the yield curve. They find that macro factors explain a significant portion of movements in the yield curve (up to 85%), particularly for short- and middle-length maturities.

Pericoli and Taboga (2008) similarly study ATSMs including observed macro variables. They suggest a less restrictive set of identifying restrictions than Ang and Piazzesi (2003),

[1] See Piazzesi (2010) for a thorough survey of the literature.

namely, macro variables need not be orthogonal to latent factors. Nevertheless, they also conclude shocks to output and inflation explain a significant portion of yield-curve dynamics.

Hamilton and Wu (2012) show both Ang and Piazzesi (2003) and Pericoli and Taboga's (2008) canonical representations are not identified. Hamilton and Wu suggest additional restrictions and an alternative method for uncovering structural parameters from reduced-form estimates. Their minimum-chi-square approach is asymptotically equivalent to the commonly used maximum likelihood, but advantageously allows the researcher to know if estimates are at a global or only local optimum.

In what follows, I estimate an ATSM using four observed macro variables—one of which is foreign official purchases—and three unobserved latent factors. I use Hamilton and Wu's suggested identification restrictions along with their minimum-chi-square estimation.

3 Gaussian Affine Term Structure Model

3.1 The General Case

In typical macro models where a representative agent maximizes expected utility and smooths consumption using one-period bonds, the following consumption Euler equation holds:

$$P_{1,t} = \beta E_t \frac{U'(C_{t+1})}{U'(C_t)} \Pi_{t+1}^{-1}, \tag{1}$$

where $P_{1,t}$ is the price of a one-period bond at time t; β is the discount rate; $U'(C_t)$ is the marginal utility of consumption; and Π_t is the inflation rate. The right-hand side of the equation is the expected discounted value of one dollar delivered at $t+1$. Let us define the pricing kernel M_{t+1} to be the stochastic discount factor in equation (1), i.e.

$$M_{t+1} \equiv \beta \frac{U'(C_{t+1})}{U'(C_t)} \Pi_{t+1}^{-1}. \tag{2}$$

Using this pricing kernel, we can price the return of bonds. Specifically, an n-period bond is the expected discounted value of an $n-1$ period bond,

$$P_{n,t} = E_t M_{t+1} P_{n-1,t+1}. \tag{3}$$

Equation (3) provides a recursive condition linking bond prices across maturities.

Now let us rewrite the price of an n-period bond $P_{n,t}$ paying one dollar at time $t+1$ in terms of the risk-free, one-period interest rate r_t. For a continuously compounded $1, 2, ..., n$-period bond at time t, we can compute prices as follows:

$$\begin{aligned}
P_{1,t} &= E_t M_{t+1} = e^{-r_t} \\
P_{2,t} &= E_t M_{t+1} P_{1,t+1} = \underbrace{E_t M_{t+1} E_t P_{1,t+1}}_{e^{-r_t} E_t e^{-r_{t+1}}} + \underbrace{Cov(M_{1+t}, P_{1,t+1})}_{\text{risk-adjustment}} \\
&\vdots \\
P_{n,t} &= E_t M_{t+1} P_{n-1,t+1}.
\end{aligned} \tag{4}$$

The equations in (4) illustrate the price of a long-term bond is equal to the price a risk-neutral investor would pay plus a risk-adjustment term. In the absence of the risk-adjustment term these equations can be interpreted as no-arbitrage conditions for a risk-neutral investor. ATSMs impose this no-arbitrage condition while accounting for the risk component of bond prices.

In order to bring this structure to data, we assume a particular functional form for the pricing kernel. Affine term structure models assume the following:

$$M_{t+1} = \exp[-r_t - \frac{1}{2}\lambda_t' \lambda_t - \lambda_t' u_{t+1}], \tag{5}$$

where λ_t characterizes investor attitude toward risk. Note that $\lambda_t = 0$ corresponds to risk neutrality and the strong form of the expectations hypothesis.[2]

Gaussian affine term structure models make four additional assumptions. First, factors underlying interest rates, denoted F_t, are assumed to be an affine function of their lags,

$$F_t = c + \rho F_{t-1} + \Sigma u_t. \tag{6}$$

Next, the residuals of equation (6) are assumed to be Gaussian,

$$u_t \sim \text{i.i.d.} N(0, I), \tag{7}$$

which implies that $F_{t+1}|F_t, F_{t-1}, ..., F_1 \sim N(\mu_t, \Sigma\Sigma')$ for $\mu_t = c + \rho F_t$. ATSMs further assume the market price of risk is itself an affine function of F_t,

$$\lambda_t = \lambda_0 + \lambda_1 F_t. \tag{8}$$

Lastly, ATSMs assume the short rate r_t is an affine function of the factors,

$$r_t = \delta_0 + \delta_1' F_t. \tag{9}$$

Given assumptions (5)-(9), it can be shown an n-period bond yield (defined as $y_{n,t} \equiv -\frac{1}{n} \ln P_{n,t}$) can be written as an affine function of the factors,[3]

$$y_{n,t} = \alpha_n + \beta_n' F_t, \tag{10}$$

[2]The strong form of the expectations hypothesis is in contrast to what Gürkaynak and Wright (2012) refer to as the weak form, which allows for maturity-specific term premia to be constant over time.

[3]See Ang and Piazzesi's (2003) Appendix A for a derivation.

where the constant and slope coefficients take the following recursive formulations:

$$\alpha_n = -\frac{1}{n}(-\delta_0 + \alpha_{n-1} + \beta'_{n-1}c - \beta'_{n-1}\Sigma\lambda_0 + \frac{1}{2}\beta'_{n-1}\Sigma\Sigma'\beta_{n-1}) \tag{11}$$

$$\beta_n = -\frac{1}{n}(-\delta_1 + \beta'_{n-1}\rho - \beta'_{n-1}\Sigma\lambda_1). \tag{12}$$

Equations (10)-(12) reveal that given $\{c, \rho, \lambda_0, \lambda_1, \delta_0, \delta_1, \Sigma\}$ and F_t, we can calculate the yield of any bond.

3.2 The Foreign Official Purchase Application

Following Ang and Piazzesi (2003) and Hamilton and Wu (2012), I estimate a macro finance model. My model differs from the literature by letting $N_m = 4$ observed macro factors explain yields, namely, output growth, inflation, exchange rate movements, and net foreign official purchases of U.S. Treasuries.[4] I stack these variables in a $(N_m \times 1)$ vector f_t^m. In addition, I use $N_\ell = 3$ latent factors stacked in the $(N_\ell, \times 1)$ vector f_t^ℓ.

$$F_t = \begin{bmatrix} f_t^m \\ f_t^\ell \end{bmatrix}, \tag{13}$$

where F_t is a vector containing $N_m + N_\ell$ elements. The factor dynamics in (6) and risk-free yield equation in (9) can be partitioned as follows:

$$f_t^m = c_m + \rho_{mm} f_{t-1}^m + \rho_{m\ell} f_{t-1}^\ell + \Sigma_{mm} u_t^m \tag{14a}$$

$$f_t^\ell = c_\ell + \rho_{\ell m} f_{t-1}^m + \rho_{\ell\ell} f_{t-1}^\ell + \Sigma_{\ell m} u_t^m + \Sigma_{\ell\ell} u_t^\ell \tag{14b}$$

$$r_t = \delta_0 + \delta'_{1m} f_t^m + \delta'_{1\ell} f_t^\ell. \tag{14c}$$

Since data is monthly, (14a) is better suited as a VAR(12) in macro variables, rather

[4] Ang and Piazzesi (2003), Pericoli and Taboga (2008), and Smith and Taylor (2009) use $N_m = 2$ observed macro factors, namely, inflation and a measure of output.

than a VAR(1), so I impose this assumption. I also follow the literature and impose three types of identifying restrictions to equations (14a-c).

First, I assume macro dynamics are independent of the unobserved latent factors (i.e. $\rho m\ell, \rho\ell m = 0$). Then, I assume a Cholesky identification scheme for the macro variables (i.e. Σ_{mm} is lower triangular). This implies that variables ordered last in vector f_t^m do not contemporaneously impact the other macro variables. The goal of this paper is to identify shocks of foreign official purchases, so I order this variable last to allow foreign officials to react to contemporaneous growth, inflation, and volatility, but not vice versa. Together these first two assumptions allow me to estimate a SVAR in the macro variables, which is independent from the latent variables, to identify how innovations in foreign official purchases impact macro outcomes. I then feed these predictions into the ATSM model—since equations (10)-(12) give closed-form solutions for how macro factors influence yields—to trace out the implied path of yields.

The next set of identifying assumptions are normalizations. I assume $\rho_{\ell\ell}$ is lower triangular with diagonal elements ordered as follows $\rho_{\ell\ell(1,1)} \geq \rho_{\ell\ell(2,2)} \geq \rho_{\ell\ell(3,3)}$. As discussed in Hamilton and Wu (2012), without restrictions on $\rho_{\ell\ell}$, there are multiple parameter configurations of the latent variables leading to observationally equivalent yields. I choose one set of restrictions so the model is identified, but this is without economic content since other choices would result in the same implied path for yields. Additionally, I assume $\Sigma_{\ell\ell} = I_{N_\ell}$, meaning the 3 latent factors are orthogonal to each other. Last, I assume $c_\ell, c_m = 0$, which is inconsequential since it normalizes the latent factors and, as stated in the next section, I demean the macro variables.

The final set of restrictions ensures there is not an overabundance of structural parameters to recover from the reduced form in Section 5. Ang and Piazzesi (2003) attempt to improve the efficiency of their model by fixing parameters with large standard errors in the first stage to zero, but Hamilton and Wu (2012) show at least one of these restrictions is in fact needed for their model to be identified. Therefore, I impose one of Ang and Piazzesi's ad-hoc zero restrictions for identification purposes. In particular, I set the last element of λ_0 to zero.[5] This means the time-varying risk associated with the third latent factor, which is the (1,7) element of λ_t, is not an affine function of the factors (i.e. $\lambda_{t(1,7)} = \lambda_{0(1,7)} + \lambda_{1(1,7)} F_t$), but rather a linear combination of the factors (i.e. $\lambda_{t(1,7)} = \lambda_{1(1,7)} F_t$).[6]

By altering the lag structure and including the above identifying restrictions, (14a-c) becomes:

$$f_t^m = \rho_1 f_{t-1}^m + \rho_2 f_{t-2}^m + ... + \rho_{12} f_{t-12}^m + \Sigma_{mm} u_t^m \tag{15a}$$

$$f_t^\ell = \rho_{\ell\ell} f_{t-1}^\ell + u_t^\ell \tag{15b}$$

$$r_t = \delta_0 + \delta_{1m}' f_t^m + v_t. \tag{15c}$$

Since I assume the latent factors f_t^ℓ are orthogonal to the macro factors f_t^m, the short rate r_t in equation (15c) can be interpreted as arising from a version of the Taylor rule, where the error $v_t = \delta_{1\ell}' f_t^\ell$ is the unpredictable component of monetary policy. The policy rule recommended by Taylor (1993) specifies how the central bank should react to changes in output and inflation when setting the short rate. Here, I allow the central bank to react to all macro variables in f_t^m, namely, output growth, inflation, exchange rates, and foreign demand for Treasuries. The Federal Reserve considers hundreds of variables when conducting monetary policy. This approach is simply a more general treatment of the monetary policy rule assumed by Ang and Piazzesi (2003).[7] I directly obtain values of δ_0 and δ_{1m} from OLS estimation of equation (15c). Recovering the remaining parameters is more involved and

[5] Following Ang and Piazzesi (2003) I assume parameters in λ_0 and λ_1 correspond to only current macro and latent variables, not lagged macro variables, so that λ_0 contains $N_m + N_\ell = 7$ parameters.

[6] Ang and Piazzesi (2003) assume that the risk associated with all the macro factors and all but the first latent factor is a linear combination of the factors rather than an affine function. They also impose additional ad-hoc zero restrictions on the slope parameters of latent factor risk $\lambda_{1\ell\ell}$.

[7] Ang and Piazzesi perform specification tests for including lags of inflation and real activity in their Taylor rule estimation. They find mixed results and thus estimate two ATSMs, one including a Taylor rule based on only contemporaneous variables, which they refer to as the "Macro Model" and another including a Taylor rule that incorporates lags, which they refer to as the "Macro Lag Model." I estimate an ATSM with a monetary policy rule that only depends on contemporaneous variables, but includes four rather than two macro variables.

Section 5 describes the process.

4 Data

Time series data for net foreign official purchases of U.S. Treasury securities is from Bertaut and Tryon (2007) and Bertaut and Judson (2014).[8] Treasury International Capital (TIC) system reports foreign and foreign official net purchases, but as acknowledged by Warnock and Warnock (2009) and others, there are major issues with the data. For example, the system cannot differentiate between foreign official investors and private investors when the transaction goes through a third-country intermediary. This is potentially a very confounding feature because governments of oil-exporting countries are thought to accumulate large amounts of Treasuries through intermediary countries. Bertaut and Tryon (2007) and Bertaut and Judson (2014) work with other sets of cross-boarder securities data to correct these issues and publish an adjusted series of monthly purchases. The exact variable I use in this analysis is net foreign official purchases, scaled by the value of Treasuries outstanding held by the public. Data for total Treasury securities outstanding minus the amount held in U.S. government accounts and Federal Reserve Banks is from the Center for Research in Security Prices (CRSP) and is the historical 12-month moving average to eliminate seasonality. Appendix A shows why scaling net foreign official purchases by Treasuries outstanding is necessary to obtain a stationary series.

Data for the remaining baseline macro factors is from the FRED database of the Federal Reserve Bank of St. Louis. This includes U.S. output growth and inflation, which are the 12-month percentage change in industrial production and CPI. Since the Japan hold a large share of U.S. Treasuries, the baseline exchange rate factor is the Yen/USD rate. I check robustness to a broad measure of U.S. exchange rates in Appendix D.

The $N_\ell = 3$ latent factors are estimated using monthly data on $N = 6$ bond yields.

[8] Data is available for download at `http://www.federalreserve.gov/pubs/ifdp/2007/910/ticdata.zip` and `http://www.federalreserve.gov/pubs/ifdp/2014/1113/ifdp1113_data.zip`.

In order to explain 3 latent factors using 6 yields, I follow the literature and assume 3 yields contain measurement error. Specifically, I assume the 1-, 3-, 6-year bond yields are priced *without* error, $Y_t^1 = (y_t^{12}, y_t^{36}, y_t^{72})'$ and the 2-, 4-, 5-year bond yields are priced *with* error, $Y_t^2 = (y_t^{24}, y_t^{48}, y_t^{60})'$. I use the 1-year yield y_t^{12} as a proxy for the observed short rate r_t.[9] Yields are constructed using zero-coupon yields from Gürkaynak et al. (2007) and are divided by 1200 in order to convert to monthly fractional rates. The sample period runs from January 1985 through August 2014.[10]

5 Estimation

Hamilton and Wu (2012) show Gaussian affine term structure models, where exactly N_ℓ linear combinations of yields are assumed to be priced without error, can be written as a restricted vector autoregression. Imposing the assumptions outlined in Section 3.2, which allow for one lag of the N_ℓ latent factors and 12 lags of the N_m macro variables, results in the following reduced from:

$$f_t^m = \phi_{mm}^* F_{t-1}^m + u_{mt}^* \tag{16a}$$

$$Y_t^1 = A_1^* + \phi_{1m}^* F_{t-1}^m + \phi_{11}^* Y_{t-1}^1 + \psi_{1m}^* f_t^m + u_{1t}^* \tag{16b}$$

$$Y_t^2 = A_2^* + \phi_{2m}^* F_t^m + \phi_{21}^* Y_t^1 + u_{2t}^*, \tag{16c}$$

where F_t^m is a $12 \times N_m$ element vector of contemporaneous and lagged macro variables; F_{t-1}^m is a $12 \times N_m$ element vector of lagged macro variables; Y_{t-1}^1 is an N_ℓ element vector of the one-month lags of exactly priced yields; and Y_{t-1}^2 is an $N - N_\ell$ element vector of the one-month lags of yields priced with error.

The mapping between the structural and reduced-form parameters for the $N_m = 4$,

[9] Term structure models often use the 3-month yield to proxy for the observed short rate; however, the 3-month and 1-year are highly correlated with a correlation coefficient of 0.994 over 1985-2014.

[10] The sample period ends in August 2014 to exclude the spike in publicly held Treasuries outstanding, starting in September 2014.

$N_\ell = 3$, and $N = 6$ case can be found in Appendix B. The system in Appendix B satisfies the necessary conditions for identification. In fact, the system is over-identified; it contains more estimated reduced-form parameters (535) than unknown structural parameters (516). I obtain the reduced-form coefficients from estimating equations (16a-c) via OLS. I then use Hamilton and Wu's minimum-chi-square estimation strategy to recover the structural parameters. The system converges and is robust to many initializations.

6 Results

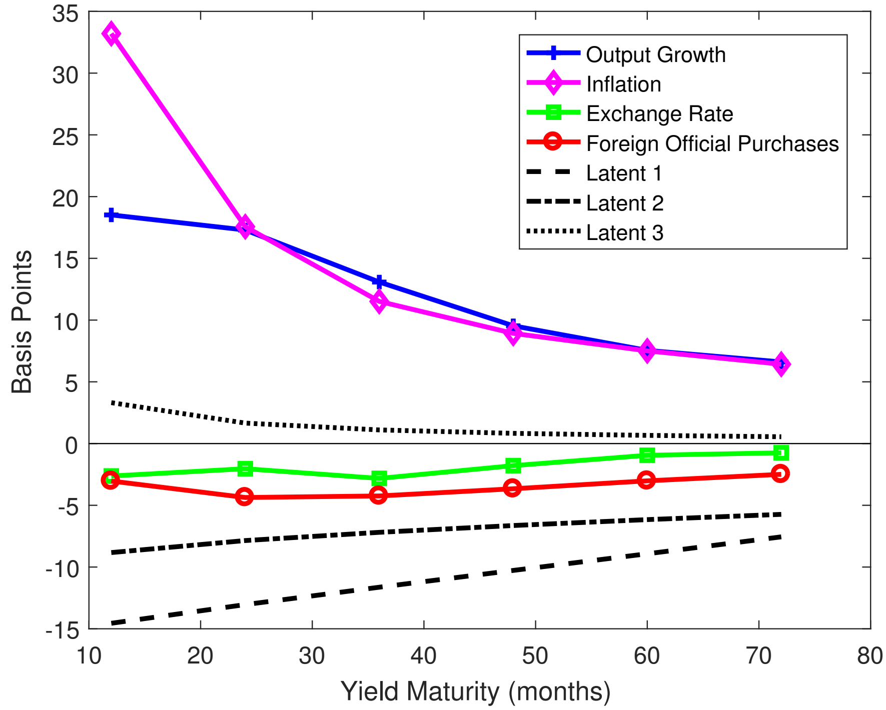
The impact of each factor on an n-length bond is determined by the weights in β_n. The first four rows of β_n are the initial response of yields to shocks in the four factors (recall equation (10)). Figure 4 plots these factor loadings as a function of yield maturity. Responses have been scaled to correspond to movements of a one standard deviation of the factors. Note that β_n is first multiplied by 1200 to annualize and then multiplied by 100 to convert to basis points.

Figure 4 reveals the macro factors, relative to the latent factors, can explain a significant portion of movements in the yield curve. Shocks to inflation shift the entire yield curve up, with the largest impacts at the short end of the curve. Shocks to output growth also shift the yield curve up, but effects are more uniform across maturities. In contrast, shocks to the Yen/USD exchange rate and to foreign official purchases shift the yield curve down. The negative contribution of foreign official purchases aligns with our hypothesis that an increase in demand for Treasuries by foreign governments depresses yields. Moreover, the effect is non-linear in maturity length: the 2-year rate fell more than any other maturity, in response to a foreign official purchase shock.

Figure 5, displays impulse response functions of yields to a one standard deviation shock in the macro variables.[11] Responses of six maturities are plotted. Starting with the upper

[11] See Appendix C for impulse response functions of the macro variables in response to macro shocks, before the implied effects are traced out for yields.

Figure 4: Factor Loadings



left corner, we see output growth is associated with a rise in yields. As the U.S. economy grows, investors pull out of safe assets, such as Treasury securities, resulting in elevated yields.

Moving to the upper right plot, we see inflation is associated with a rise in nominal rates with the largest increases at the short end for he curve. The correlation of yields with inflation is less persistent than that with output growth; within 16 months it subsides to zero. Since nominal rates are the sum of real rates and inflation, it is not surprising there is a positive short-term relationship between the two variables.

The lower left plot shows dollar appreciation against the Yen is associated with a decline of U.S. yields on impact. After controlling for U.S. output and inflation a shock to the Yen/USD exchange rate puts downward pressure on Treasury yields. Japanese policy makers likely respond to a shock of this type by buying U.S. Treasuries with the goal of devaluing the Yen and keeping Japanese exports competitive. In turn, these purchased depress U.S. yields.

Figure 5: Impulse Responses of Yields

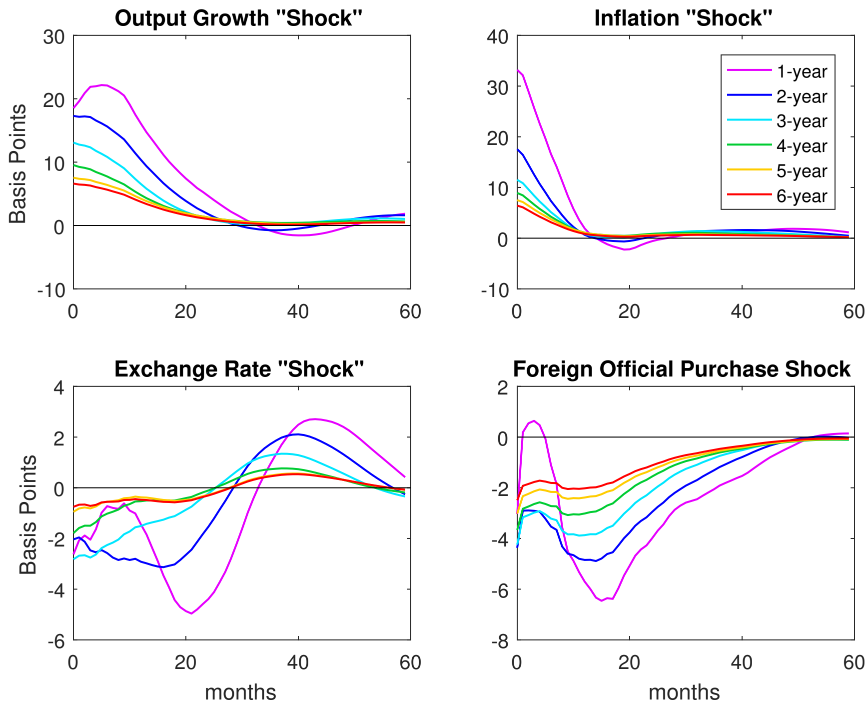
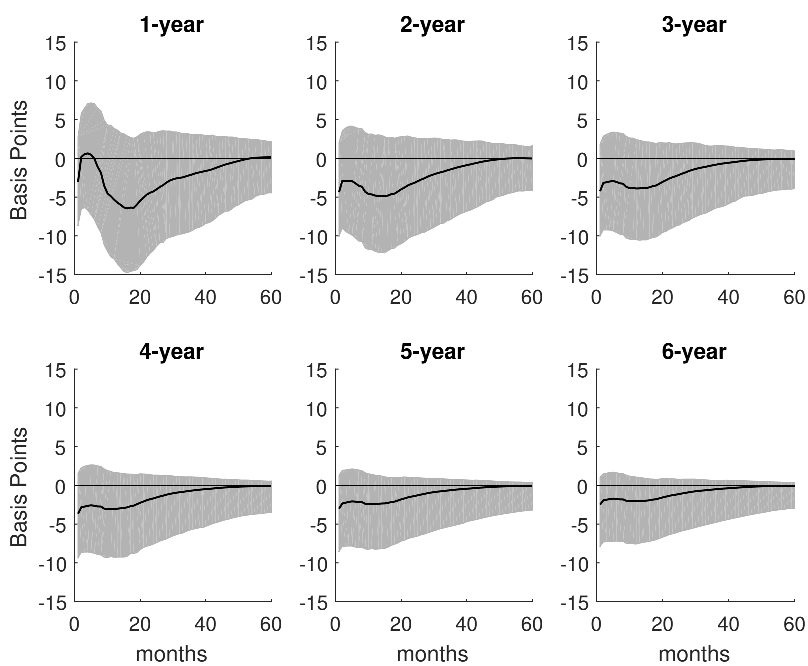


Figure 6: Response of Yields to Foreign Official Purchase Shock [12]



Two years after dollar appreciation, U.S. yields increase. At this point, the effect of private investors dumping U.S. assets because of the elevated exchange rate, likely dominates.

Lastly, we turn to the lower right plot, the plot of interest. A one standard deviation shock to foreign official purchases, after controlling for U.S. growth, inflation, and exchange rate movements, initially reduces the 2-year rate the most by 4.4 basis points, followed by 3-year rate by 4.2 basis points. The 1-year yield initially falls 3.0 basis points, increasing in the subsequent months only to return to negative territory within the year. The longest maturity plotted, the 6-year yield, initially falls by 2.5 basis points in response to a foreign official perchance shock, and like the other longer term rates, gradually returns to zero within 4 years. Since the standard deviation of foreign official purchases is 0.31 of a percentage point, this means an inflow equal to one percent of the amount of publicly held Treasuries outstanding initially lowers the 2-year yield by 14 basis points and the 6-year yield by about 8 basis points.

Figure 6 zooms in on the southeast panel of Figure 5 and plots confidence bands on each maturity's response to a foreign official purchase shocks. Confidence bands are bootstrapped at the 90 percent level and reveal yields of all maturities likely fell and remained depressed for up to 5 years after the shock. Moreover, results are robust to specifications that include alternative sets of macro factors. Appendix D redefines a foreign official purchase shock by replacing the Yen/USD exchange rate in the SVAR with a broad index of the U.S. exchange rate.

Differences in the points estimates between 1-year, 2-year, 3-year, etc. are not statistically significant. Nevertheless, these differences make economic sense. According to TIC, since the early 2000s a large share of foreign-held Treasures were to mature in one to two years.[13] For example, in 2014, 21% of Treasuries held by foreign governments were to mature in one to two years, while 17% were to mature in less than a year, and 19% were to mature in two to three years. Shares of foreign government Treasuries maturing after three years

[13]TIC began publishing a chart of the maturity structure of foreign official holdings in 2004

monotonically decline.[14] In other words, the type of securities foreign governments own the most of are the type of securities whose prices have been most affected by their purchases.

These results are on par with previous work. Recall that Beltran et al. (2013) examine the impact of foreign official purchase shocks on only the 5-year yield. They find that an inflow equal to one percent of the amount of Treasuries outstanding lowers the 5-year yield by 13.5 basis points when using their two-stage-least-squares approach, and 5-6 basis points when using their VAR approach. I find a consistent impact for the 5-year yield of about 10 basis points.

Unlike the aforementioned paper, however, I examine how foreign official purchases influence the dynamics of the entire yield curve. I find the impact of foreign official purchases is statistically significant and depresses rates of all maturities with effects lingering for up to 5 years. Because foreigners buy a large share of 2-year Treasuries, I find the 2-year yield is most affected by foreign official purchases. Foreign governments have accumulated over 40 additional percentage points of publicly held Treasuries outstanding from 1985 to 2008 (as illustrated in Figure 3). The above findings suggest interest rates, especially the 2-year, would have been considerably higher in the absence of foreign official purchases. Moreover, since 2008 foreign governments have offloaded 10 percentage points of publicly held Treasuries. If this trend continues, it may put upward pressure on U.S. interest rates.

7 Conclusion

This paper asks whether the massive acquisition of U.S. Treasury securities, and recent offloading, by foreign official entities has altered the yield curve. Results suggest that yes, in fact, the increase in demand for Treasuries by foreign governments has shifted the entire yield curve down, with the largest effects on the 2-year yield.

This has important policy implications. If foreign officials unexpectedly sell off their sizable Treasury positions, U.S. interest rates will likely rise. Additionally, if the financial

[14] http://ticdata.treasury.gov/Publish/shl2014r.pdf

crisis was fueled by low interest rates in the early 2000s, then foreign official purchases may have been part of the story. Ironically, foreign governments bought U.S. Treasury securities to fend off one type of crisis—another Asian financial crisis—but may have contributed to a different crisis—the global financial crisis.

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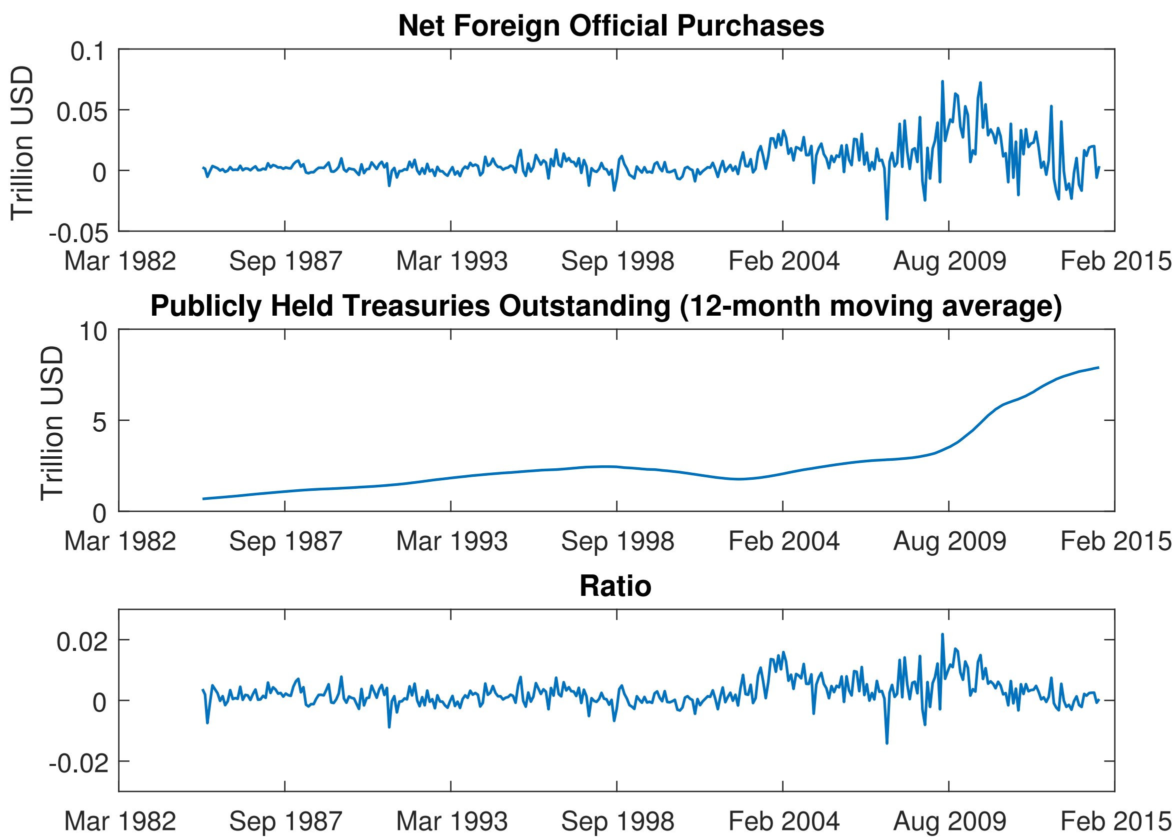
A Appendix: Stationary Variable

Figure 7: Scaling Net Foreign Official Purchases by Treasuries Outstanding



The first panel of Figure 7 plots net Treasury purchases by foreign governments from Bertaut and Tryon (2007) and Bertaut and Judson (2014). To obtain a stationary variable, I follow Beltran et al. (2013) and scale net foreign official purchases by publicly held Treasuries outstanding (the second panel of Figure 7). The third panel, entitled "Ratio" plots the scaled foreign official purchase variable, as used in the analysis. Comparing panel 1 to panel 3, the latter appears more stationary.

B Appendix: Parameter Mapping

The mapping between structural and reduced-form parameters follows:

$$
\begin{aligned}
&\phi^*_{mm} = [\rho_1\ \rho_2\ ...\ \rho_{12}] \\
&A^*_1 = A_1 - B_{1\ell}\rho_{\ell\ell}B^{-1}_{1\ell}A_1 \\
&\phi^*_{1m} = \begin{bmatrix} B^{(1)}_{1m} & 0 \end{bmatrix} - B_{1\ell}\rho_{\ell\ell}B^{-1}_{1\ell}\begin{bmatrix} B^{(0)}_{1m} & B^{(1)}_{1m} \end{bmatrix} \\
&\phi^*_{11} = B_{1\ell}\rho_{\ell\ell}B^{-1}_{1\ell} \\
&\psi^*_{1m} = B^{(0)}_{1m} \\
&A^*_2 = A_2 - B_{2\ell}B^{-1}_{1\ell}A_1 \\
&\phi^*_{2m} = B_{2m} - B_{2\ell}B^{-1}_{1\ell}B_{1m} \\
&\phi^*_{21} = B_{2\ell}B^{-1}_{1\ell} \\
&\text{Var}\begin{bmatrix} u^*_{mt} \\ u^*_{1t} \\ u^*_{2t} \end{bmatrix} = \begin{bmatrix} \Omega^*_m & 0 & 0 \\ 0 & \Omega^*_1 & 0 \\ 0 & 0 & \Omega^*_2 \end{bmatrix} = \begin{bmatrix} \Sigma_{mm}\Sigma'_{mm} & 0 & 0 \\ 0 & B_{1\ell}B'_{1\ell} & 0 \\ 0 & 0 & \Sigma_e\Sigma'_e \end{bmatrix},
\end{aligned}
$$

where $\hat{\Sigma}_{mm}$ is the Cholesky factorization of $\hat{\Omega^*_m}$ and $\hat{\Sigma}_e$ is the square root of the diagonal elements of $\hat{\Omega}^*_2$.[15] Additionally, A_1, A_2, B_1, B_2 are defined as:

$$
\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \begin{bmatrix} \alpha_3 \\ \alpha_{12} \\ \alpha_{120} \\ \alpha_6 \\ \alpha_{24} \\ \alpha_{60} \end{bmatrix}, \begin{bmatrix} B^{(0)}_{1m} & B^{(1)}_{1m} & B_{1\ell} \\ B^{(0)}_{2m} & B^{(1)}_{2m} & B_{2\ell} \end{bmatrix} = \begin{bmatrix} \beta'_3 \\ \beta'_{12} \\ \beta'_{120} \\ \beta'_6 \\ \beta'_{24} \\ \beta'_{60} \end{bmatrix},
$$

where for $i = 1, 2$, $B^{(0)}_{im}$ are (3×4) matrices relating the observed yields to the 4 contemporaneous macro factors. $B^{(1)}_{im}$ are (3×44) matrices relating the observed yields to 11 lags of the 4 macro factors. Lastly, $B_{i\ell}$ are (3×3) matrices relating the observed yields to the latent factors.

[15] Macro variables in f^m_t are ordered as follows: output growth, inflation, exchange rate, foreign official purchases scaled by publicly held Treasuries outstanding.

C Appendix: Macro Variable SVAR

Figure 8: Foreign Official Purchase Shock

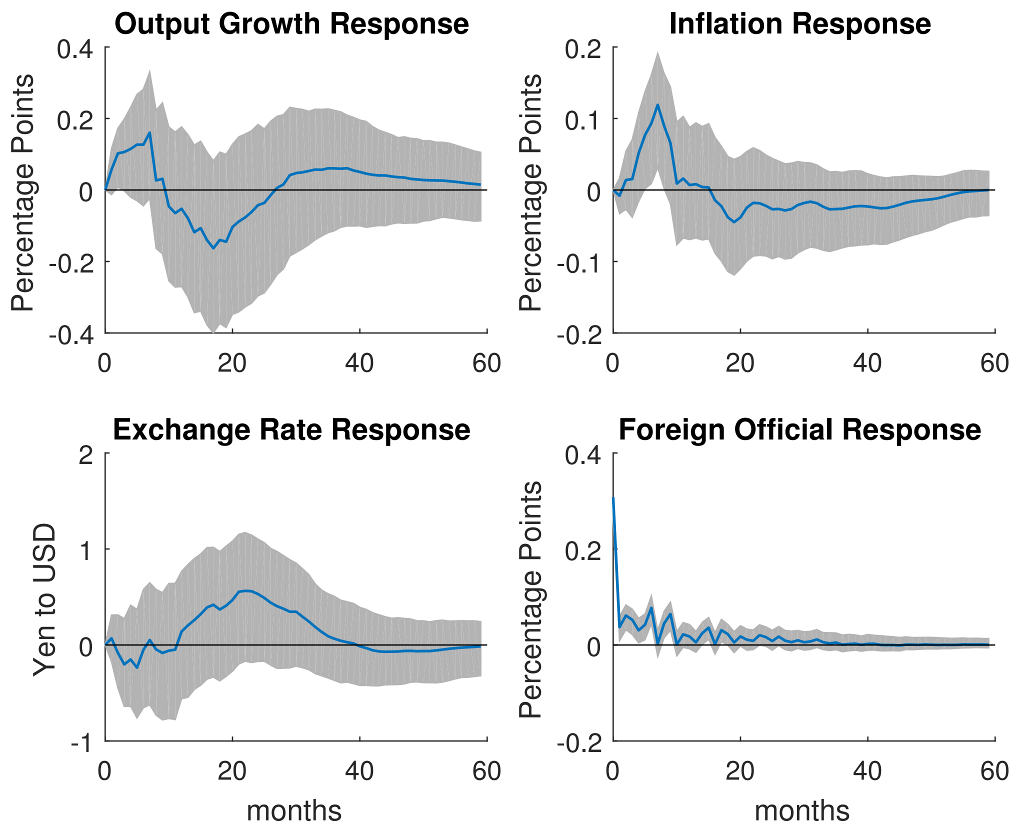
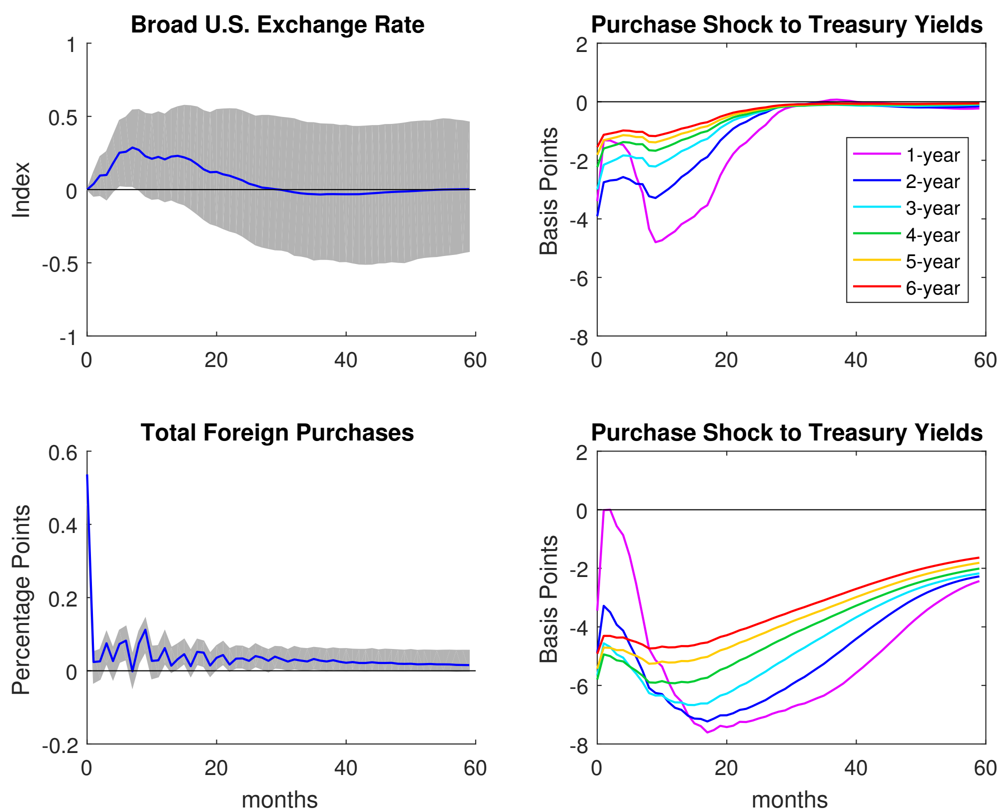


Figure 8 plots impulse response functions from a one standard deviation shock of foreign official purchases to the macro variables. In the analysis, these paths are fed into the ATSM to examine the effect on yields. Panel 1 reveals purchases of U.S. Treasuries by foreign governments are positively correlated with U.S. output growth on impact, but this relation becomes statistically indistinguishable from zero in a matter of months. Inflation in panel 2 spikes a year after the onset of a foreign official purchase shock, just as we would expect an increase in demand for U.S. assets to elevate prices. In panel 3 foreign official purchases have no robust effects on the Yen/USD exchange rate. The last panel of Figure 8 illustrates what a typical shock to foreign official purchases looks like. A shock is a 0.3 percentage point increase in net purchases that does not persist; purchases quickly return to zero.

D Appendix: Alternative Macro Variables

Figure 9: Impulse Responses of Macro Variables and Implied Path for Yields



Each row of Figure 9 corresponds to a specification with a different set of macro variables. The top row replaces the Yen/USD exchange rate with a broad measure of the U.S. dollar as the third variable in the SVAR. This broad index, published by the Federal Reserve, is a weighted average of the foreign exchange values of the U.S. dollar against currencies of major U.S. trading partners.[16] The northwest panel plots the response of the broad exchange rate measure to a foreign official purchase shock and the northeast panel plots the implied path of yields. Overall, results are robust to this alternative specification.

The bottom row replaces foreign *official* purchases with *total* foreign purchases as the last variable in the SVAR. The southwest panel plots a one standard deviation shock to total foreign purchases, which is larger than that to foreign official purchases. The southeast panel plots the implied path of yields. Effects here are larger and more persistent than the baseline because foreign official purchases are a subset of total foreign purchases. Moreover, the 4-year rate instead of the 2-year rate falls the most on impact.

[16] http://www.federalreserve.gov/releases/h10/summary/indexb_m.htm