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Andre Varella Mollick and Gokce Soydemir

Abstract

This article connects net Japanese purchases of U.S. Treasury securities and the U.S. 10-year Treasury bond yields to the yen/dollar exchange rate. VAR estimations suggest that a one-time increase in net Japanese purchases has an immediate negative effect on U.S. long bond yields but a short-lived delayed yen depreciation. Further, a one-time increase in the U.S. long yield leads to an immediate yen depreciation. Our results support the hypothesis that Japanese investors, who are major holders of U.S. debt and face extremely low interest rates domestically, influence the dollar/yen rate in a financially integrated world.

KEYWORDS: foreign exchange markets, net purchases of U.S. Treasury bonds, VAR, yen/dollar

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1. Introduction

Japanese investors have been lately subject to a sluggish economy at home compared to a more vibrant U.S. economy, which in an integrated world becomes a viable option for receiving their funds. Despite the gradual recovery, the Japanese economy has been growing at a much lower rate than the United States. With this in mind, it is useful to look at benchmark long-term bonds in perspective. Figure 1 shows the annual percentage of the long-term bonds in the U.S. and Japan (in their own currency) from 1992 to 2006. The beginning date of the sample comes right after the Japanese "bubble" bursts in real estate and equity markets. The much higher 10-year government interest rates in the U.S. versus Japan can be observed in Figure 1 (in early 2007, staying at right below 5% in the U.S. and below 2% in Japan). Movements of both rates also seem to mirror each other. Short-term interest rates have been higher in the U.S. as well during the same period. In January of 2007 overnight funds rate was targeted at 5.25% in the U.S. versus 0.25% in Japan. Interest rate differentials of this magnitude for prolonged periods have brought arbitrage opportunities in a global economy. In financial markets, investors have been able to profit from Japan's low interest rates by borrowing in yen, and then investing in a country that has higher rates, in what became to be known as "carry-trade". The operation weakens the yen because the investors short sell yen to convert it to other currencies.

Figure 1. Long-Term Trends of Japanese 10-year Government Yields (JGB10) and U.S. 10-year Government Yields (i10) in % p.a.: 1992:2 to 2007:2.
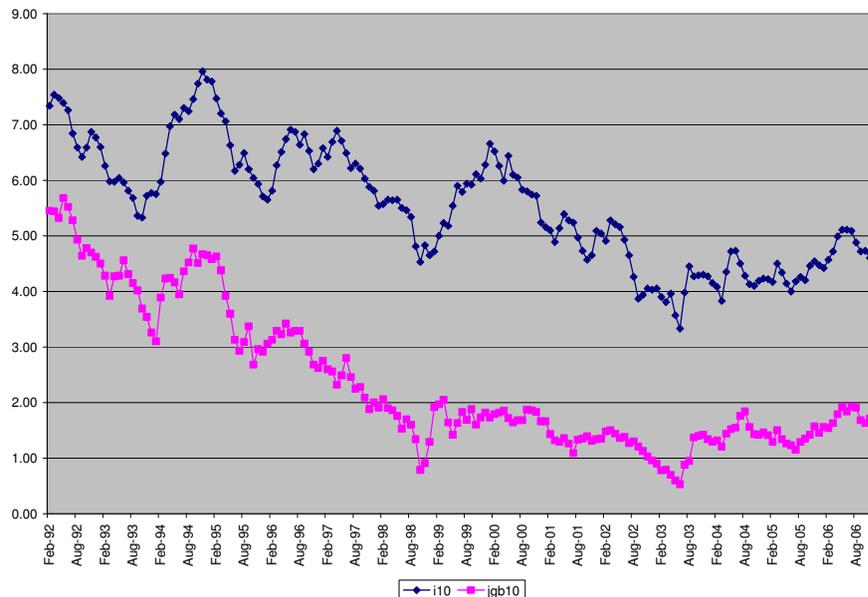
Figure 2 suggests a strong negative correlation between net purchases of U.S. securities and the yield on 10-year long-term bond. There is a similar pattern for net purchases of U.S. corporate bonds. The details on the construction of these variables are provided below. One interpretation of this chart is that, as net purchases of U.S. Treasuries and corporate bonds have become significantly positive more recently, the long-term yields have come down, eventually reaching the historically low of 4% in 2004. We conjecture in this paper that net capital inflows from Japan (i.e., purchases of U.S. securities as part of "carry-trade") is one likely cause of the U.S. dollar (USD) strengthening with perhaps some delay.

Figure 2. Net Purchases of U.S. Treasuries by Japanese Investors (left scale in USD millions) against 10-Year U.S. Treasury Yield (right scale in %).
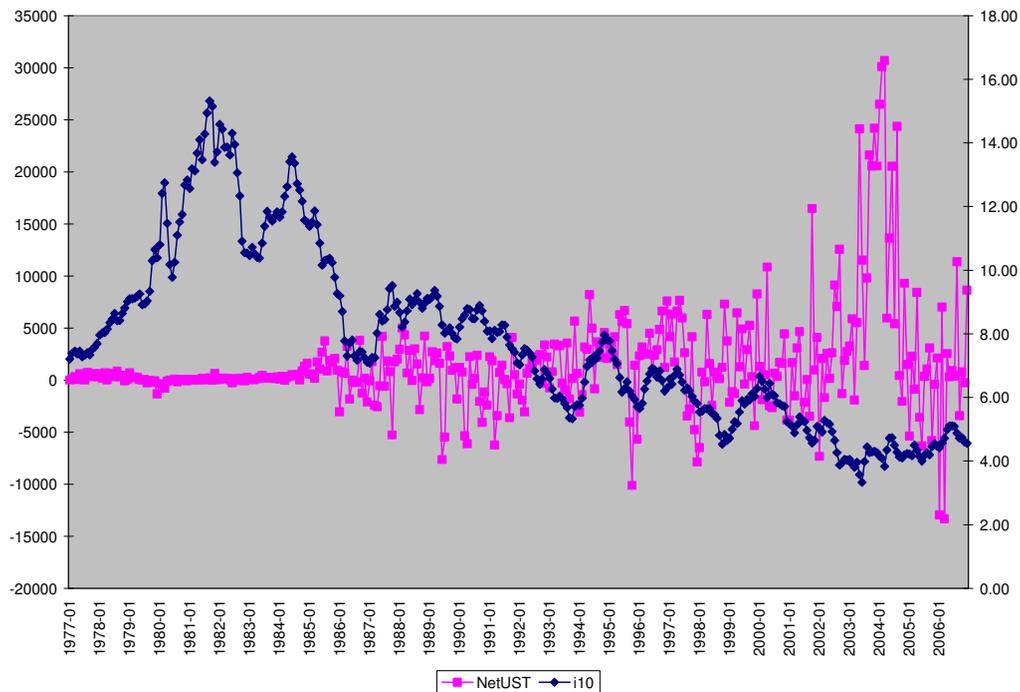
Our focus on Japanese investors can be contrasted to other forces in global financial markets that may have exerted a different effect on the USD. For example, the possibility of central banks diversifying away from the USD has been recently added to the list of fundamental causes of the dollar's decline. While the *central bank diversification hypothesis* has attracted great attention by

traders and market analysts as a demand-based mechanism, former Fed Chairman Greenspan proposed a different explanation based on supply factors.[1]

Mr. Greenspan's arguments in his semiannual Senate testimony on February 16, 2005 were based on the fact that the U.S. Treasury has not issued a 30-year long bond since 2001. The falling mortgage rates then led to decreases in the supply of long-term debt when "homeowners refinance their mortgages, paying off loans that otherwise would have survived as long as 30 years. Bereft of long-term mortgage bonds to buy, investors pile into Treasuries." (The Wall Street Journal, February 17, 2005). In addition to the demand and supply explanations, one might still think of a *discipline argument*. As the Fed monetary policy has become very credible and interest rates increases at a more heightened pace, the market is willing to pay more for long-term U.S. debt than before, driving down long-term rates. (The Wall Street Journal, February 17, 2005).

It is certainly challenging to well understand the functioning of currency markets as surveyed by Frankel and Rose (1995). An additional source of USD weakening comes from the goods market. In any country the current account deficit is financed by the capital account surplus. In the U.S. the current account deficit is mainly financed by long-term sales of U.S. government bonds to foreign countries such as Japan and China. While the U.S. dollar has been weakening lately, it is now an acceptable fact by many that for the U.S current account deficit to be sustainable in the long run the U.S. must rely on the foreign sales of long term government bonds.[2]

In this paper, we examine the extent to which Japanese purchases of long term U.S. debt impact the U.S. dollar/yen exchange rate (JPY/USD).[3] To examine

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[1] Wu (2005, pp. 2-3) argues that "foreign individual investors are at least as active and important as their central banks." As of December 2004, 52% of total U.S. Treasury securities outstanding were held by domestic investors, 23% by official institutions (central bank or government) in the form of foreign notes and bonds, 6% by official institutions in the form of foreign bills, and 19% by private foreign individuals.

[2] A February 2005 meeting between G-7 Finance Ministers and Chinese authorities regarding a possible "yuan revaluation" generated repercussions on New York bond trading desks. The reason for concern by U.S. bond traders goes as follows: "From January through November 2004, the central banks of Japan and China bought about 30% of all the new U.S. securities the U.S. issued to finance its budget deficit, which reached $ 412 billion in fiscal 2004. Japan was initially the largest buyer, but more recently China has taken the lead among Asian countries, increasing its holdings by $18.5 billion from September to November. If China decides to revalue its currency, the logic goes, it won't need to buy as many dollars, and won't need to invest those dollars in Treasury bonds. In the absence of Chinese demand, the price of Treasuries likely would fall, and their yields … would rise." (The Wall Street Journal, February 4, 2005).

[3] Japanese investors are the major holders of U.S. assets on almost all accounts. The data examined below are for net (purchases minus sales) foreign purchases of Treasury notes and bonds, as well as corporate bonds. In order to have a firmer grasp of the major holders of U.S. debt, it is more appropriate to look at **holdings** and not transactions data. The U.S. Department of the Treasury (2006) reports their survey results on major holders of U.S. long and short-term

these issues, we employ vector autoregression (VAR) models. Starting with monthly data from 1977 to 2006, visual data inspection reveals that net purchases of Japanese investors, based on Treasury International Capital (TIC) reporting system of the U.S. Treasury Department, have been flat until the mid-1980s and then started to be more volatile in the 1990s. Picking up the historic peak of JPY/USD around the spring of 1995, we concentrate on the sub-sample from 1995 to 2006. This choice of the start date of the analysis follows the several hikes in short-term interest rates by the U.S. Fed in 1994 that caught markets by surprise. From 1995 to 2005, the data show upward fluctuations in USD (a decreasing trend for JPY), together with a sustained decline in long-term U.S. yields and heavily growing amount of foreign purchases of U.S. securities. We argue that the decreasing yen trend can be explained by the larger appetite for U.S. securities.

Our findings show that the information content in *both* the volume of net U.S. fixed income securities purchased by Japanese investors and the yield of the 10 year-bond matter for the JPY/USD exchange rate. In the more recent period from 1995 to 2006, during which the volume of traded securities was high, the impulse responses show that a once and for all shock to the NetUST affects 10-year U.S. Treasury bond yields negatively (-0.045) within one month of the shock: the increased activity causes prices to rise and yields to fall immediately. The negative response persists until the second month (-0.062). Also, the increase in one standard deviation of 10-year Treasury yields brings about a yen depreciation of 0.427 at one month and of 0.493 after two months of the shock. As the U.S. yields increase, the attractiveness of the USD based assets increase relative to JPY denominated assets, making the JPY/USD to depreciate. In addition to these instantaneous-like responses, net purchases of U.S. Treasuries by Japanese investors contribute to a delayed response on exchange rate changes of 0.721 at three months, which means a strengthening of the dollar against the yen. This delayed response may be tied to asset as well as goods market adjustment, such as in the portfolio balance approach of Branson (1979).

Studies on U.S. monetary policy, such as the unrestricted VAR by Eichenbaum and Evans (1995), the cointegration analysis by Nagayasu (2003), and the structural VAR (SVAR) by Kitamura and Akiba (2006) provide

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securities. As of June 2005, Japan was the top holder of U.S. debt at USD 913 billion (19.34%), followed by China at USD 524 billion (11.11%) and by the U.K. at USD 300 billion (6.36%), out of a total of USD 4,720 billion. In terms of total debt plus equity, Japan is still at the top with USD 1,091 billion (15.89%), followed by U.K at USD 560 billion (8.16%) and by China at USD 527 billion (7.68%), out of a total of USD 6,864 billion. Confining ourselves to major foreign holdings of Treasury Securities only as of August of 2006, Japan is still at the top with USD 644.2 billion (29.95%), followed by China at USD 339 billion (15.76%) and by the U.K. at USD 201.4 billion (9.36%), out of a total of USD 2,150.9 billion. This is also true according to Treasury International Capital of the U.S. Dept. of the Treasury.

comparable results to our paper. Arguments put forth in our paper can be linked to at least two sets of studies on international portfolio flows. The first appears primarily in the analysis of emerging markets. Calvo et al. (1993) show that the U.S. interest rates and other indicators explain about 50 percent of the variability in real exchange rates and FX reserves in ten Latin American economies. Kim (2000) adds domestic factors and finds that the capital and the current accounts are explained by world interest rates. Brennan and Cao (1997) build a model in which the U.S. purchases of equities in developing markets are positively associated with stock market returns. Froot et al. (2001) find that the sensitivity of local stock prices to foreign inflows is positive and large, while Chuhan et al. (1998) report that external variables explain from one third to one half of bond and equity flows from the U.S. to Asian and Latin American countries. Exploring the U.S. federal funds target rate and Mexican M2/Reserves, Mollick (2002) shows that higher U.S. interest rates weaken the real Mexican peso, while Soydemir (2002) finds strong and immediate negative impact of the U.S. T-bill yields on U.S. equities but slow and varying impacts on several Latin American equity markets, except Chile.

A second set of studies typically focuses on daily or intraday studies and employs *order flows*, which are similar to the concept of (monthly) net purchases employed in this paper. Hasbrouck (1991) finds for a sample of NYSE issues that a trade's full price impact arrives only with a protracted lag. This suggests that the full impact of a trade on the security price is not felt instantaneously. An application of this particular model to currency markets is in Payne (2003), while Evans and Lyons (2005) study the difference between the log USD/Euro spot rate and the order flows for euros during a day. They find that news arrivals induce subsequent changes in trading and that these changes remain significant for days.

The remainder of this paper is structured as follows. Section 2 describes the methodology, section 3 summarizes the dataset employed, and section 4 presents the empirical results. Section 5 reviews the work and presents extensions for further study.

2. Methodology

An unrestricted VAR model similar to trade and price models by Hasbrouck (1991), Payne (2003) and Evans and Lyons (2005), relates JPY/USD nominal exchange rate in a given month t (s_t) to a vector of variables (x_t) as follows:

$$x_t = \sum_{i=1}^{k} \alpha_i x_{t-i} + \sum_{i=1}^{k} \beta_i s_{t-i} + \varepsilon^x_t \qquad (1)$$

$$s_t = \sum_{i=1}^{k} \gamma_i x_{t-i} + \sum_{i=1}^{k} \theta_i s_{t-i} + \varepsilon^s_t \qquad (2),$$

where: x_t is a vector of transaction characteristics that comprises either net (buying minus selling) Japanese purchases of U.S. Treasury securities (NetUST) or U.S. Corporate bonds (NetUSC) and price conditions in the U.S. long-term market captured by the 10-year U.S. bond yield (i10). In this paper we will discuss only the VAR with U.S. Treasury securities. Given that JPY/USD is the ultimate goal, we confine our net flow variable to Japanese investors, who are the major (foreign) holders of U.S. fixed income assets.[4]

Since in the present context we do not have any theoretical restriction on the way the series respond to the shocks, equations (1) and (2) form an unrestricted dynamic model that allows lagged terms to appear in the equations in a flexible structure in which lagged values are included as in Hasbrouck (1991).[5] The errors ε^x_t and ε^s_t are zero mean and mutually and serially uncorrelated errors at all leads and lags. We also define Var $(\varepsilon^x_t) = \sigma^2$ and Var $(\varepsilon^s_t) = \Omega$.

The approach in this paper focuses on the *information content* of vector x_t: the price variable of the long-term bond and the (net) inflow of Japanese funds into fixed-income securities. If the innovations to the system are uncorrelated, the VAR is identified. Considering the two variables contained in x_t and the one in s_t, the low dimension of this particular VAR model implies smaller specification biases as Abadir et al. (1999) have shown.

Examples of innovations to the net purchases equation include plans by foreign central banks to purchase more or less of USD FX reserves. Examples of innovations to the i10 equation are shifts in the marginal productivity of capital and changes in monetary policy. The latter includes a more aggressive or accommodative Federal Reserve Board in response to inflation threats and growth

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[4] The model was also estimated with "global investors", representing all foreign investors that purchase and sell U.S. securities. We create NetGUST and NetGUSC and the point estimates of the several VAR models are smaller than the ones reported in this paper. This makes sense as Japanese investors will typically buy U.S. Treasuries with yen. We also removed the Japanese investors from the total of global investors and reestimated the model, without any substantial changes.

[5] In the case of a typical policy variable such as the federal funds target rate (ff$_t$), one could suppose a true economic structure based on the policy variable and the spot rate similar to the system in (1) - (2), following Bernanke and Blinder (1992) and Bernanke and Mihov (1998). In order to identify the effects of exogenous policy shocks, one could assume that policy shocks do not affect the macro variable contemporaneously, setting its coefficient to zero in the VAR model. In our case, however, we combine in x_t the price variable of the bond market and the (net) flow of funds into U.S. fixed-income securities, which are both related to the spot rate in a way not set in advance.

prospects. Clarida et al. (2000), for example, contains evidence that the U.S. Federal Reserve has become stricter in fighting inflation since 1979, when nominal rates started to move up more than proportionately with inflation. Interest rate shocks include permanent disturbances to central bank policymaking due to human actions, such as more aggressive "FED policymaking in the Volcker-Greenspan years, or shifts in general economic efficiency.

As Sims (1980) and Enders (1995) have pointed out, the t-tests from the VAR model estimations on individual coefficients may not be reliable guides for paring down the model. Further, impulse responses are highly non-linear functions of the estimated parameters. This makes calculation of confidence bands by linearization infeasible. The recommended method for hypothesis testing is Monte Carlo integration taking draws for the coefficients and seeing how the responses change. We therefore focus on impulse response functions (IRFs) and variance decompositions (VDCs) from our VAR model estimations. We test the identification condition of no correlation across equations and report the generalized impulse response functions (GIRFs) proposed by Pesaran and Shin (1998) which are not sensitive to the variable VAR ordering.

Given the unit roots commonly present in exchange rates, we use the first-difference of s_t to form the stationary VAR. If $\{x_t , \Delta s_t\}$ are jointly covariance stationary processes, the Wold theorem ensures that the model may be written as a joint moving average (MA) process of infinite order. Refer to the benchmark VAR formulation as **XTreas = [NetUST, i10, Δs]'**, where Δ represents first-differences of data [$\Delta = (1-L)$, where L is the lag operator] and "'" represents the transpose symbol (to be omitted henceforth).[6]

3. The Data

The capital movements data come from the *Treasury International Capital* (TIC) reports of the U.S. Treasury Department. Such data are aggregated according to the type of capital flows and perhaps constitute the most comprehensive data available on a monthly basis. The TIC data represent the U.S. investor's purchases and sales of long-term foreign securities as reported by commercial banks, bank holding companies, brokers and dealers, foreign banks, and non-banking enterprises in the U.S. In this paper, we consider two particular types of U.S. securities: Treasuries and Corporate bonds. Focusing on Japanese investors, we use historical data from the database "U.S. transactions with foreigners in

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[6] In addition to **XTreas**, we compute two other VARs: one with NetUSC as the relevant demand variable that captures the net purchases by Japanese investors of U.S. corporate bonds; and another with a combined four-variable VAR **X = [NetUSC, NetUST, i10, Δs]'**. Their impulse responses match the ones reported in this paper and are available upon request.

long-term securities" from the U.S. Department of the Treasury (http://www.ustreas.gov/tic/).[7]

Bertaut and Griever (2004) show for TIC-based data that the market value of foreign holdings of the U.S. long-term securities has long exceeded that of the U.S. holdings of foreign long-term securities. They also report that residents of Japan and the U.K. are the largest portfolio investors in the U.S. long-term securities, albeit their investment patterns differ.[8]

The complete period of analysis, from 1977 to 2006, comprises various market shifts. The U.S. interest rates reached very high levels in the early 1980s and the very low levels in the early 1990s and between 2002 and 2006. During the early period, however, there were no substantial fluctuations in the net purchases of U.S. securities by foreign investors. We thus start the analysis right after the Plaza Agreement of September 1985 from 1986:1 to 2006:12. We also pay specific attention to the 1995:1 to 2006:12 sub-sample immediately after the several short term hikes by the FED in 1994. Figure 2 plots the behavior of the net purchases of the U.S. Treasuries against the U.S. 10-year yield bond rate for our monthly sample. Figure 3 plots the four basic variables included in this study: JPY/USD, i10, NetUST and NetUSC.

The U.S. 10-year yields represent the Treasury Constant maturity rate (series ID: GS 10) from the Board of Governors of the Federal Reserve System, and is downloaded from the U.S Federal Reserve Bank of Saint Louis (http://research.stlouisfed.org/fred2/). The release is the H.15 "Selected Interest Rates," in "percentage" as well as "average" business days. The JPY/USD foreign exchange rate (series ID: EXJPUS) is from the Board of Governors of the Federal Reserve System. The series is downloaded from the U.S Federal Reserve of Saint Louis. The release is the G.5 "Foreign Exchange Rates", monthly rate, average of daily figures, noon buying rates in New York City for cable transfers payable in foreign currencies. Datastream is the source for long-term (10-year) Japanese government bonds (series code: JAPGLTB) in Figure 1.

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[7] The limitations of the TIC data are usually of conceptual nature. For the problems associated with the attribution of foreign holdings of U.S. securities in TIC data, for example, Bertaut and Griever (2004, p. 20) mention two: i) the case in which the foreign owner of a U.S. security entrusts the safekeeping of the security to an institution that is neither in the U.S. nor in the foreign owner's country; and ii) the case of bearer (unregistered) securities.

[8] Between December 1974 and June 2002, the proportion of the value of outstanding U.S. equities and long-term debt securities that were foreign owned increased from about 5 percent to about 12 percent, while the value of these foreign holdings increased from $67 billion to almost $4 trillion. The U.S. holdings of foreign long-term securities have also increased over the period, but by less, According to Bertaut and Griever (2004, p. 19)], "at $1.8 trillion, the value of U.S. holdings of foreign long-term securities at the end of 2002 was less than half the value of foreign holdings of U.S. securities; this difference resulted in a negative net international position in long-term securities of $2.3 trillion." Their study also shows that the U.K. residents owe slightly more equity than debt and Japanese residents showing a marked preference for U.S. debt (p. 20).

Figure 3. JPY/USD Nominal Exchange Rate (s); U.S. Treasury Bond 10-year Yield (i10); Net Purchases (Buying minus Selling) of U.S. Treasuries by Japanese Investors (NetUST); and Net Purchases of U.S. Corporate Bonds by Japanese Investors (NetUSC).
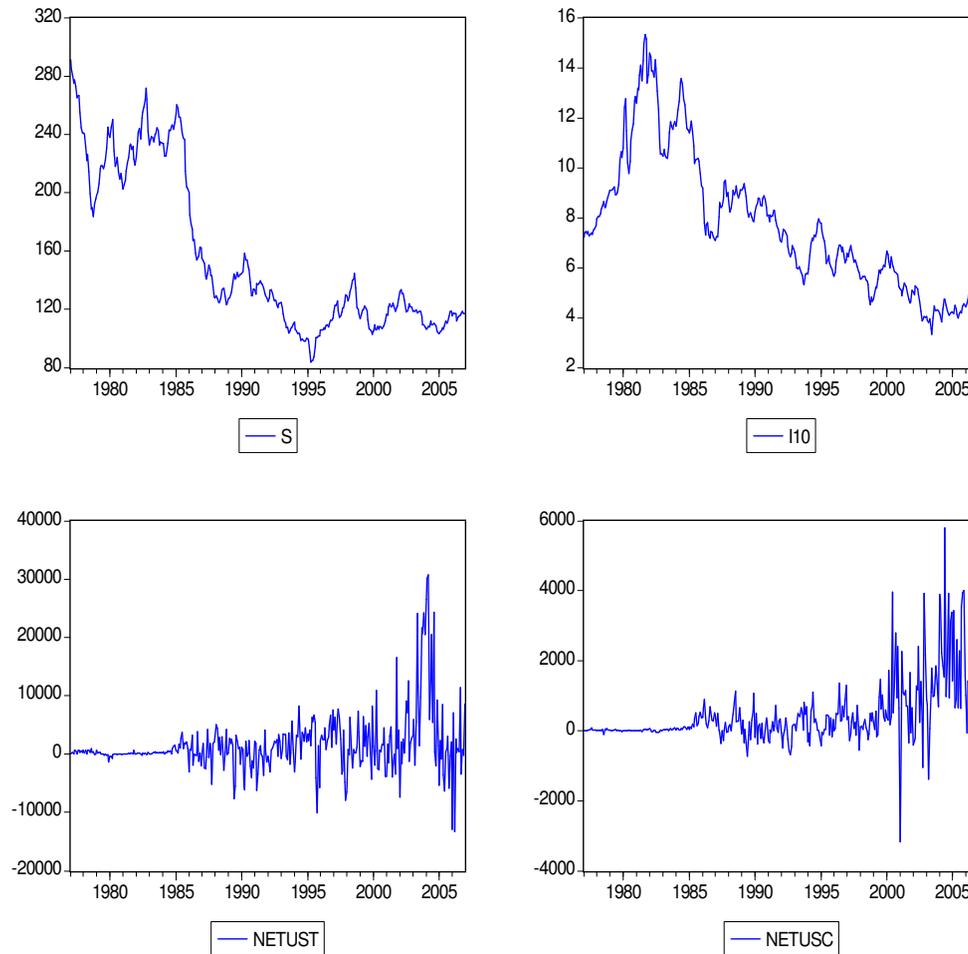
4. Empirical Results

Several unit root tests are provided. The lag selection criterion of the lags in the ADF regressions is based on a data dependent procedure, which usually has more power than when chosen by an information criterion or by an arbitrarily set lag length according to Ng and Perron (1995). We employ the SBIC when implementing the DF-GLS tests as in the original Elliott et al. (1996) and for the

KPSS tests by Kwiatkowski et al. (1992) the truncation is set to k = 4. See the notes to Table 1 for more details.

Unit root tests in Table 1, under the Augmented Dickey-Fuller (ADF), DF-GLS, and KPSS tests point to non-stationarity for the exchange rate in levels and stationarity in the first differences, an I(1) process for JPY/USD.[9] The net purchases series (NetUST and NetUSC) should already be stationary in levels, since they are defined as buying minus selling of assets by Japanese investors. Unit root tests indeed reject - by ADF (k) and DF-GLS tests - the null hypothesis that there is a unit root in the net purchases and interest rate series when expressed in levels. These are most likely I (0) series, although there is always uncertainty on the true data generating process. ADF and KPSS tests suggest stationarity for i10 in both sample periods.

The lag-length for the VARs is chosen by a combination of minimization of the Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike (AIC), Schwarz-Bayes (SBIC) and Hannan Quinn (HQ) information criteria. We assume maximum lag-length of 12. We also conduct Breusch-Pagan serial correlation Lagrange Multiplier (LM) tests. The VARs do not suffer from serial correlation problems according to LM serial correlation results for various lags. The residual correlation matrices do not suggest misspecification problems either.

Pairwise Granger Causality tests detect bidirectional effects between changes in the spot rate and NetUST, as well as unidirectional effects from the long bond yield to changes in the spot rate. Block exogeneity Wald tests suggest, for the VARs with NetUST removed as regressors during 1995-2006 that the significance of the other regressors weakens when the U.S. long bond or variations in the JPY/USD are the dependent variables and the variable of net purchases of U.S. assets is dropped from the VAR model. Under changes in the nominal exchange rate as the dependent variable, the p-values reject the null that

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[9] We also conduct two of the M-tests developed by Ng and Perron (2001) with modified Akaike Information Criterion (MAIC) used for lag-length selection. The modified MZ_α and MZ_t tests have less severe size distortions when the errors have a negative moving average (MA) root. These tests are less supportive of the I (0) decision for U.S. interest rates and net purchases of U.S. securities and of I (1) for exchange rates for the subsample from 1995 to 2006. They tend to confirm, however, the basic findings of the other tests for the longer period 1986 to 2006. The divergence in results may be due to the low power of tests when the sample size is relatively small.

Table 1. Unit Root Tests on Monthly Data.

Series	Trend?	ADF (k)	DF-GLS (k)	KPSS(4)	MZ$_\alpha$ (k)	MZ$_t$ (k)
1995:01 – 2006:12						
NetUST	Yes	-3.22 (10)*	-3.37 (2)**	0.14*	-9.44 (4)	-2.16 (4)
Δ(NetUST)	No	-3.44 (9)**	-10.61 (2)***	0.03	-60.54 (0)***	-5.47 (0)***
NetUSC	Yes	-3.89 (4)**	-9.95 (0)***	0.09	-8.52 (12)	-2.06 (12)
Δ(NetUSC)	No	-7.23 (6)***	-13.35 (1)***	0.02	-0.54 (13)	-0.51 (13)
i10	Yes	-3.11 (3)	-2.25 (1)	0.17**	-6.53 (5)	-1.71 (5)
Δ(i10)	No	-4.14 (11)***	-3.11 (2)***	0.12	-1.21 (10)	-0.72 (10)
s	Yes	-2.84 (8)	-2.38 (1)	0.26***	-5.32 (5)	-1.62 (5)
Δ(s)	No	-3.78 (7)**	-7.85 (0)***	0.07	-0.93 (13)	-0.67 (13)
1986:01 – 2006:12						
NetUST	Yes	-4.26 (10)***	-4.70 (2)***	0.09	-15.11 (5)*	-2.74 (5)*
Δ(NetUST)	No	-4.84 (9)***	-0.99 (9)	0.02	-11.41 (9)**	-2.36 (9)**
NetUSC	Yes	-3.67 (7)**	-3.87 (4)***	0.42***	-3.96 (12)	-1.33 (12)
Δ(NetUSC)	No	-7.76 (11)***	-5.24 (5)***	0.02	-0.29 (13)	-0.36 (13)
i10	Yes	-4.08 (7)***	-3.80 (13)***	0.11	-18.41 (2)**	-3.00 (2)**
Δ(i10)	No	-6.03 (13)***	-1.05 (13)	0.04	-1.13 (10)	-0.66 (10)
s	Yes	-2.99 (11)	-1.10 (1)	0.57***	-3.56 (11)	-1.24 (11)
Δ(s)	No	-3.46 (13)***	-0.06 (10)	0.34	0.34 (13)	0.61 (13)

Notes: Data are of monthly frequency. **NetUST** refers to the net (gross purchases minus sales) Japanese purchases of 10-Year U.S. Treasury Bonds, **NetUSC** refers to the net Japanese purchases of U.S. Corporate Bonds, **i10** measures the U.S. 10-year constant maturity yield rate, and **s** is the spot dollar/yen. The symbol Δ stands for first-differences. Deterministic trend is included in levels based on graph inspection. ADF(k) refers to the Augmented Dickey-Fuller t-tests for unit roots, under the unit root null. The lag length (k) is chosen by the Campbell-Perron data dependent procedure, whose method is usually superior to k chosen by the information criterion; see Ng and Perron (1995). The method starts with an upper bound, k$_{max}$=13, on k. If the last included lag is significant, choose k = k$_{max}$. If not, reduce k by one until the last lag becomes significant (we use the 5% value of the asymptotic normal to assess significance of the last lag). If no lags are significant, then set k = 0. In parenthesis is the selected lag length. DF-GLS (k) refers to the modified ADF test proposed by Elliott et al. (1996), with the Schwarz Bayesian Information Criterion (BIC) used for lag-length selection. The KPSS test follows Kwiatkowski et al. (1992), in which the null is that the series is stationary and k=4 is the lag truncation parameter. The Ng and Perron (2001) MZ$_\alpha$ and MZ$_t$ tests employ MAIC for lag-length selection. The symbols * [**] (***) indicate rejection of the null at the 10%, 5%, and 1% levels, respectively.

all other lagged endogenous variables in the equation are not statistically significant. Overall, these results are consistent with the view that the U.S. long-run bond and Japanese net purchases of U.S. assets seem to disseminate important information to the foreign exchange market.

The main results of this paper for the sub-sample 1995 to 2006 are summarized in Figure 4. For each VAR, we report GIRFs, whose diagnostic tests include the LM Breusch-Pagan tests discussed above and the residual correlation matrix. After some experimentation, the VAR was estimated with 5 lags. The 5 percent confidence bands generated by 1,000 Monte Carlo replications rule out zero responses when specifically noted.

In Figure 4, we show the plots of impulse responses in the three-variable **VAR = [NetUST, i10, Δs]**. At the top right chart of Figure 4, the shock to NetUST affects 10-year bond yields negatively in the short-run. This negative impact (-0.045 with standard deviation of 0.019 at one month) is consistent with an increase in purchases from the Treasury market causing prices to rise and yields to fall. The negative impact is also present at the second month: -0.062 with standard deviation of 0.031. This supports the notion that a rally to the U.S. fixed income market (more inflows than outflows) is responsible for the price movements.

The middle chart of Figure 4 displays that the innovation in NetUST implies a positive response at the 3-month period on variations of the JPY/USD exchange rate: an appreciation of the dollar against the JPY. The estimated response, at month 3, is 0.721 with standard deviation of 0.284. Between month 3 of the maximal impact just reported and month 1 (at the time of the shock), there is a two-month delay period. The delayed effect appears to be persistent across different specifications and probably reflects forward purchases when exchanging Japanese Yen into U.S. dollars to purchase U.S. securities in the upcoming months. Further, as a net measure of the volume of U.S. bonds transacted, there is no reason for the effect of a volume variable to have instantaneous effects on the nominal exchange rate.

Moreover, one would conjecture that the immediate response of the i10 to NetUST is only natural since both are direct indicators from the U.S. Treasury. The same argument can be made for the immediate response of the exchange rate to i10, based on economic theories (uncovered and covered interest parity conditions) that directly link i10 and the exchange rate. However, to our knowledge, it would be difficult to make an argument that justifies the direct instantaneous relationship between exchange rate and net purchases of U.S. Treasuries.

One closely linked approach is Branson's (1979) portfolio balance approach with three distinct assets, money, domestic bonds and foreign bonds. Open market purchases result in an initial depreciation followed by a delayed

appreciation of the domestic currency. Unlike the Dornbusch (1976) overshooting model, Branson's approach illustrates that in the long-run covered interest parity need not hold even in the presence of monetary shocks. This result follows from the existence of "coupon effect" from holding foreign bonds on the part of domestic agents. Branson's model assumes a monetary shock whereas in our paper an externally generated demand shock creates a delayed appreciating response of the U.S. dollar.

Moreover, traders may not in practice resort to the foreign exchange rate market every time they make purchases of U.S. treasuries. They may instead draw funds from their existing dollar reserves to make a series of purchases. Only when reserves reach a certain lower limit, they may decide to resort to the foreign exchange market to buy more U.S. dollars. This in itself may create non-synchronous trading. Perhaps this behavior might be reflected in the delayed VAR response of the exchange rate to NetUST in our study. Other issues such as "carry-trade" might be relevant as well. For example, investors might short the yen to buy Australian dollars where interest rates are higher. A similar type of transaction might occur for the U.S. treasuries, where interest rates also relatively higher. Such trades might bring back the non-synchronous trading argument as a possible explanation of the delayed response. Last, but certainly not least, issues with data availability and frequency might distort lead-lag effects. In *Datastream*, i10 and exchange rates are available on a daily basis whereas NetUST and NetUSC (from the TIC dataset) are only available on a monthly basis. Deriving monthly values from daily figures as well as averaging of NetUST and NetUSC may result in non-simultaneous reporting of data.

At the bottom chart of Figure 4, a shock to the 10-year Treasury yields brings about statistically significant positive impacts on the U.S. dollar, especially at the time of the shock and after two months of the shock. As yields increase, the attractiveness of the USD based assets increase relative to JPY denominated assets. The USD thus tends to appreciate against the yen. The maximum response occurs at the second month (0.493 with standard deviation of 0.297 at one month) following the shock to the U.S. Treasury bond market, and then converges to zero afterwards. This short-lived response of the exchange rate is consistent with the very short-term response of the exchange rate at the moment of the shock (t = 0) for shocks in the short-term interest rate differential in Kitamura and Akiba (2006).[10] For financial variables such as interest rates and exchange rates, it is natural to expect instantaneous responses. Similarly, the GIRFs in Nagayasu (2003) for the quarterly 1974-1999 period suggest that JPY depreciates with innovations in (short-term) the U.S. interest rates. More generally, Eichenbaum and Evans (1995) show that tight monetary policies indicated by the federal funds

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[10] Their short-lived finding for short-term differentials contrasts with the lack of statistical significance for the JPY/USD to shocks in long-term bond differentials.

target have persistent effects of around 3 years on the USD appreciation against JPY, DEM, and other major currencies.

Figure 4. Impulse Responses of U.S. Treasuries by Japanese Investors:

VAR [NetUST, i10, Δs], 1995-2006.

Response to Generalized One S.D. Innovations ± 2 S.E.

Response of I10 to NETUST

Response of D(S) to NETUST

Response of D(S) to I10
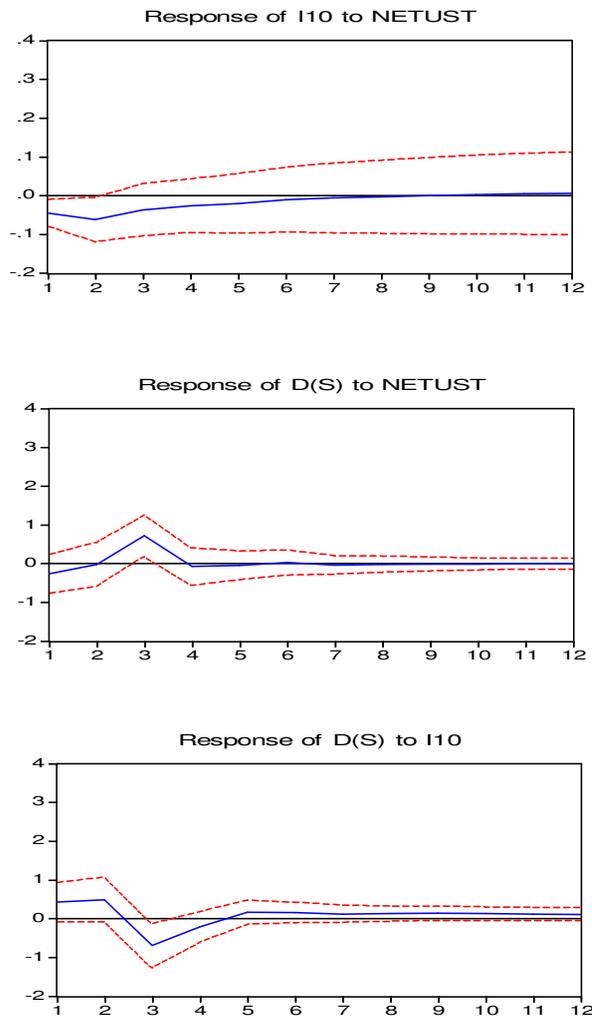
Variance decompositions, not reported but available upon request, indicate that shocks to net purchases of Treasuries explain about 6% of the changes in the spot exchange rate and that shocks to the long-bond yield explain about 8% of the changes in the spot exchange rate after 6 months. For the full sample analysis,

from 1986 to 2006, the impulse responses are qualitatively the same, although the magnitudes are smaller, reflecting the greater integration across international financial markets in the relatively more recent period.

An important extension would be to know if the responses of our VAR models change with the institutional setting. There is, for example, a rapid growing literature on Japan's zero interest rate policy and its implications.[11] In response to the sluggish economy and the problems in its financial system, the BOJ has been following a policy of very low interest rates for several years. The zero interest rate policy (ZIRP) was implemented in the period between April of 1999 and August of 2000. It was announced in April of 1999 that the BOJ would continue the zero rate policy until deflationary concerns were dispelled. In August 2000, the overnight call rate was increased to 0.25 percent but the rate had to be lowered to 0.15 percent later and the quantitative monetary easing policy (QMEP) was adopted in March of 2001.

One possibility is to see whether the ZIRP changes the results of our VAR systems. We define a dummy variable (DUM99) as 1 for the period from April of 1999 to August of 2000 and zero otherwise.[12] The statistical significance of DUM99 in our system is not substantial: The t-statistics for the null hypothesis of zero coefficients on DUM99 for 1995-2006 are small for each of the three equations. Impulse responses and variance decompositions do not suggest any visible change from the patterns reported earlier.

5. Concluding Remarks

We show that the information content of net purchases of U.S. Treasuries and the level of the 10-year bond yield help explain yen/dollar movements. For the more recent period of 1995 to 2006, the one time shock to the NetUST affects the 10-year U.S. Treasury bond yields negatively within one month of the shock and at the third month on variations of the JPY/USD exchange rate (an

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[11] Oda and Ueda (2005) discuss the policies taken since 1999 and conclude that they have led to declines in medium to long term interest rates. Yamaguchi (2004) examines BOJ's change in the main operating target from overnight call rates to the outstanding balance of current accounts. Bernanke et al. (2004) show that the Japanese yield curve shifted upwards with close to zero interest rates. Using simulations, Okina and Shiratsuka (2004) emphasize that market expectations for the path of short-term interest rates have been stabilized, reducing the longer-term yields and flattening the yield curve. The policy duration effect, however, failed to reverse expectations in financial markets. Auerbach and Obstfeld (2005) discuss welfare implications of recent Japanese monetary policies.

[12] Other definitions of the dummy variable to capture the more general QMEP instead of the ZIRP period were attempted and led to the same results. The introduction of a dummy variable appears when studying innovational and additive outliers in cointegrated vector autoregressions: Nielsen (2004) shows that the basic model without dummies can always be the benchmark specification.

appreciation of the U.S. dollar). Several reasons that explain the lagged responses between markets (yen/dollar and U.S. Treasury) are provided. Also, the one-time increase in the 10-year Treasury yields brings about a yen depreciation within one month of the shock and after two months of the shock. As U.S. yields increase, the attractiveness of the USD-based assets increase relative to JPY denominated assets, causing a depreciation of the U.S. dollar. As for policy implications, if currency volatility arises, the "carry-trade" mechanism of borrowing in yen and investing abroad could be in check as movements in exchange rates could offset any gains from the difference in interest rates. If the current level of volatility continues, however, our results suggest the appreciation of the U.S. dollar will likely continue backed by flows of funds into U.S. Treasury and Corporate assets.

Our study differs from Eichenbaum and Evans (1995), Nagayasu (2003), or Kitamura and Akiba (2006) in that the critical demand variable stems from the purchase of the U.S. securities by Japanese investors, who are the major U.S. debt holders and who have also been facing incredibly low interest rates domestically. The U.S. fixed income and FX markets are therefore intertwined in this paper in an attempt to explain the recent "conundrum" referred to by former U.S. FRB Chairman Greenspan. While leaving other possible explanations open (supply side, discipline hypothesis), our approach supports the proposition that Japanese investors influence the U.S. long bond yield and then the exchange rate.

For further research, an interesting follow-up would be to combine our model with central bank intervention in the foreign exchange market. See Lewis (1995). It is quite possible that BOJ's behind-the-scenes interventions (to avoid abrupt changes) in the exchange market help explain the observed delayed effect.

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