# Central Bank Balance Sheets and Long-term Forward Rates

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There is considerable debate with respect to the effectiveness of initiatives recently introduced by central banks in response to the global financial and economic crisis, and in particular, the impact of quantitative easing on long-term interest rates. Moreover, the impact of unconventional monetary policy may not be solely related to specific interventions per se – rather, the impact may also be related to the overall size and composition of the central bank's balance sheet. Central bank balance sheets have expanded considerably since fall 2008 in numerous countries, not just those undertaking quantitative easing. The objective of this paper is to examine the impact of the size of central bank balance sheets on long-term forward rates for a sample of developed countries. We find that, controlling for expected inflation, projected deficits and other macro variables, an increase in central bank claims on the central government or central bank assets is associated with a decline in long-term forward rates.

*Key Words:* Quantitative Easing, Central Bank Assets, Long Term Interest Rates
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## 1. INTRODUCTION

The global financial crisis has led to dramatic actions by central banks. Initially, many central banks responded to the crisis by rapidly cutting interest rates and undertaking measures to address liquidity issues in interbank funding markets. But the failure of Lehman, the bailout of AIG, and other related events, led to a deepening of the crisis. Credit markets that had been previously relatively unaffected by the crisis subsequently froze. At the same time, the real economy collapsed. Central banks responded by lowering interest rates aggressively. Moreover, some central banks responded with additional initiatives, first via credit easing, and then more

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dramatically, by introducing quantitative easing. These latter measures sought to affect longer-term interest rates, and thus, ultimately, the macro economy.

There is considerable debate with respect to the effectiveness of these interventions by central banks, and in particular, the effect of impact of quantitative easing on long-term interest rates.[2] [3] For instance, in the United States, long-term interest rates initially responded dramatically to the announcement of quantitative easing, falling nearly 50bps, but then moved higher (Chart 1). While some have interpreted these movements as evidence that quantitative easing is not particularly effective, there are many factors that could also explain contemporaneous movements in long-term interest rates, including changes in inflation expectations, the supply of government debt, future expected changes in short-term rates, investors' views on risk premia, and the overall state of the macroeconomy.

The impact of unconventional monetary policy may not be solely related to specific interventions per se – rather, the impact may also be related to the overall size and composition of the central bank's balance sheet. Central bank balance sheets have expanded considerably since fall 2008 in numerous countries, not just those undertaking quantitative easing. Moreover, both the asset and the liability side of the balance sheet has evolved; central banks have taken on riskier assets, and, depending on the degree of sterilization and the status of the banking system, government deposits and/or excess bank reserves have increased.

The objective of this paper is to examine the impact of the size of central bank balance sheets on long-term forward rates for a sample of developed countries. By focusing on estimating the historical relationship between central bank assets or claims, and forward rates, we hope to better understand the implications of the recent expansion of central bank balance sheets on interest rates. Following Laubach (2009), we estimate an empirical model of long-term forward rates. We find that, controlling for inflation expectations, projected deficits and other macro variables, an increase in central bank claims on the central government or central bank assets is associated with a decline in long-term forward rates.[4]

The paper proceeds as follows. Section 2 examines the actions taken by central banks, and the implications for the balance sheet. Section 3 presents the empirical model, and section 4 describes the data. Section 5 presents the results, and section 6 examines the implications for monetary policy and avenues for future research.

## 2. CENTRAL BANK BALANCE SHEETS AND UNCONVENTIONAL MEASURES

The size of the central bank (CB) balance sheet is directly related to the implementation of monetary policy. The implementation of monetary policy depends on the operational target, which is typically a short-term interest rate, or a quantitative target for money supply, such as bank reserves or settlement balance. Ultimately, the operational target is linked to the nominal objective, such as an inflation target, exchange rate, or a monetary aggregate target. For the sample of countries

[2] Borio and Disyatat (2009)

[3] The term "quantitative easing" is not well defined. We refer to quantitative easing as the unsterilized outright purchase of government debt - but acknowledge that the Fed does not refer to its Treasury purchase program as quantitative easing.

[4] Data is from the IMF IFS. Central Bank variables are expressed in percent to potential nominal GDP.

considered in this paper, the operational target of the respective CBs is typically a short-term interest rate. Consequently, the evolution of the balance sheet reflects the endogenous outcome of meeting this target (IMF 2001). For instance, historically speaking, in order to achieve the target for the Federal Funds Rate, the Federal Reserve (Fed) simply acts to meet the expected demand for funds. In doing so, the Fed alters the composition and size of the balance sheet accordingly. Consequently, the balance sheet of the Fed has evolved with a cyclical component, while also growing as share of GDP from 4.8% to 6.5% (Chart 2). The experience of the U.S., however, differs significantly from other CBs (Chart 3). Canada, for example, experienced a very stable ratio of CB assets to GDP, with little cycle variation and apparent trend, while Italy showed a strong secular decline from the early 1980s onwards. On the other hand, the CB assets of Japan increased rapidly in the early part of this decade, reflecting its earlier experience with quantitative easing.

In the more recent period balance sheets have exploded, as CBs have undertaken numerous unprecedented initiatives in order to resolve the ongoing financial crisis. These measures can be loosely grouped as liquidity, credit easing (or qualitative easing), and quantitative easing (asset purchases) facilities. In some instances, CBs have also on-boarded toxic assets in the process of bank or insurer bailouts.

1. *Liquidity facilities*: In reaction to the freezing up of interbank markets, CBs undertook numerous initiatives to ease funding conditions for banks, and in some cases, dealers. For instance, the Fed introduced the Term Auction Facility (TAF) and the Primary Dealer Credit Facility (PDCF) and entered into foreign exchange swap programs with other CBs. Likewise, the ECB extended the timing and maturity of liquidity provision, introduced supplementary refinancing operations, and conducted open market operations (OMO) at fixed rates with full allotment.

2. *Credit facilities*: CBs intervened in a targeted manner to improve conditions in credit markets, in order to avoid further economic disruption, through purchases of commercial paper (e.g. the Commercial Paper Funding Facility, or CPFF, in the U.S.), asset-backed commercial paper (ABCP), corporate bonds and covered bonds, not to mention supporting money market mutual funds.

3. *Purchase programs (quantitative easing)*: CBs in the U.S. and U.K. began purchasing government-issued securities in order further ease overall financing conditions. These efforts in the U.S. included purchases of agency debt, and agency mortgage-backed securities (MBS) (given the nationalization of Freddie Mac and Fannie Mae).

4. *Facilities to deal with insolvency of systemically important financial institutions:* Actions taken to aid the functioning of financial markets in the face of potential insolvency of institutions deemed too-big-to-fail were taken by the government in some countries, but by CBs in others (in particular the U.S.).

The implementation of the respective measures has had profound, but differential impacts on CB balance sheets. Chart 3 plots the respective impact of liquidity, credit easing and purchase facilities on the balance sheet of the U.S. Fed from the beginning of the crisis till the present. Several observations should be noted. First, the initial implementation of liquidity measures did not radically affect the balance sheet – on the asset side, the Fed's holding of Treasuries fell, replaced by the assets that were exchanged as part of the TAF and for swap lines. After the collapse of Lehman, the balance sheet expanded rapidly as liquidity measures were expanded, and the Fed acted to bailout AIG. Further balance sheet expansion occurred as the Fed introduced credit easing measures, such as the CPFF. Lastly, the announce-

ment and implementation of the decision to buy MBS and GSE debt, Treasuries, and then assets under the TALF, led to another expansion of the balance sheet. At the same time, the liability side of the balance sheet began to evolve, as it was no longer clear that the expansion of liquidity was being sterilized with Treasury deposits. On the liability side, bank excess reserves expanded rapidly, encouraged by the paying of interest on such reserves.

While the implementation of unconventional measures by the Fed led to dramatic changes to its balance sheets, other CBs have also experienced substantial changes. Charts 4-6 depict the balance sheets of the European Central Bank (ECB), the Swiss National Bank (SNB), and the Bank of England (BoE). While the Fed's and the BoE's balance tripled to \$2.3 trillion and nearly £300 bn, respectively, the ECB's balance sheet increased by 60% to temporarily €2.1 tillion. The Bank of Japan's and SNB's balance expanded by 8.7% and 54%, respectively.[5] In the case of the U.K., these interventions were explicitly formulated as quantitative easing. In the next section, we describe the empirical model that will be employed to examine how these innovations, both in terms of the facilities themselves, and the effect on the balance, could affect long-term forward rates.

## 3. EMPIRICAL FRAMEWORK

A small literature has sought to examine the determinants of long-term interest rates, (more specifically long-term forward rates), and has typically focused on the impact of government debts and deficits. The channels through which government debts and deficits can affect long-term interest rates is threefold. First, larger debts and deficits may imply that at a future time the debt may be monetized, leading to higher inflation and thus higher long-term interest rates. Second, large debts/deficits may increase the supply of government debt relative to demand, thus causing bond prices to fall and thus raising rates, and lastly, if debts/deficits are higher, investors may fear that the government may default (even partially) leading to higher risk premiums. Also, long-term forward rates may be affected by investor risk appetite. The empirical challenge in this literature is that interest rates may be jointly determined with other variables that are contemporaneous with fiscal variables and the business cycle. Thus, use of current deficits and debt will lead to biased results. To account for these issues of endogeneity, Laubach (2009) suggests using future expected interest rates (forward rates) and expected fiscal variables. Specifically, he estimates the following reduced form regression:

$$E_t i_{t+k} = \beta_0 + \beta_1 E_t \pi_{t+k} + \beta_2 E_t f_{t+k} + \beta_3 u_{t+k} + \varepsilon_t \tag{1}$$

where the dependent variable is expectation of the long-term interest rate at time $t+k$, $E_t \pi_{t+k}$ is a measure inflation expectations, $E_t f_{t+k}$ is a measure of future expected debt or deficits, and $u_{t+k}$ are other possible regressors that could account for movements in long-term forward rates. The intuition behind Laubach's regression framework is that by regressing expected future rates on future expected deficits (or debt), while controlling for other macro developments and investor risk appetite, one avoids the endogeneity issues raised above. Another advantage of this framework is that by using future expected rates, such as the 5-year forward 10 year

[5] In some jurisdictions, the central bank holdings of government securities are subject to an explicit limit, or some approval process. See Alfredo Leone (1991).

rate, one can assume that the transitory shocks that might drive long rates from their equilibrium will dissipate over time, and thus would be less likely to affect the estimation results. For instance, if movements in policy interest rates affect long-term interest rates through arbitrage, it may be difficult to identify the impact of fiscal or other variables on forward rates. But by using forward rates, such as the 5-year forward 10 year rate, it would not be unreasonable to assume that any impact coming from movements in short-term policy rates (related to the cycle) would dissipate reasonably quickly, as policy rates would be expected to eventually return to "normal". Thus, in principle, the 5-year forward 10 year rates should not be affected by short-run policy interest rate movements, or other contemporaneous effects coming from the business cycle. Consequently, the Laubach framework, and the use of forward rates, may be useful for assessing the impact of CB balance sheets on long-term forward rates.

In order to assess the impact of changes in CB balance sheets on long-term interest rates, we simply extend the Laubach regression framework as follows:

$$E_t i_{t+k} = \beta_0 + \beta_1 E_t \pi_{t+k} + \beta_2 E_t f_{t+k} + \beta_3 u_{t+k} + \beta_4 cb_t + \varepsilon_t \tag{2}$$

where the dependent variable $E_t i_{t+k}$ is a future expected interest rate (such as the 5-year-ahead 10-year-forward rate), $E_t \pi_{t+k}$ is a measure inflation expectations, $E_t f_{t+k}$ is a measure of future expected debt or deficits, $u_{t+k}$ are macrovariables that could affect long-term interest rates, and $cb_t$ is a measure of CB assets or claims on the treasury.

As in Laubach, we expect the coefficient for inflation expectations to be positive (and be greater than one), as should the projected deficits and debt. The impact of CB balance sheets can occur through several channels, and thus could be ambiguous. On the one hand, a relative expansion of the balance sheet (all else equal) should reflect an easing of the monetary policy – a lower target for the operational interest rate, and an increase in the holding of government securities by the CB. This implies (in the absence of an effect running from movements in short-term policy interest rates to long-term forward rates) that, controlling for other variables, an increase in the balance sheet through a purchase of treasuries should lead to lower long-term forward rates. On the other hand, if the expansion of the balance sheet is not deemed to be consistent with the overall objective of monetary policy, this could lead to an increase in inflation expectations and subsequently, higher long-term interest rates. However, the inclusion of long-term inflation expectations should control for this effect. Overall, we expect the effect of an increase in the CB's balance sheet to lead to lower long-term forward rates.

## 4. DATA AND DESCRIPTIVE STATISTICS

In this section, we describe the data we use to estimate (2) for the U.S. and a panel of developed countries. For the U.S., we closely follow Laubach (2009). The dependent variables considered are the 5-year-ahead 10-year forward rate, the 5-year ahead 5-year forward rates, and the 10-year constant maturity government bond yield.[6] Inflation expectations are proxied using long-horizon inflation expectations

[6] Note that the forward rates includes term premia in addition to expectations of the 10-year or 5-year Treasury yield, and can thus not be interpreted as that expectation only. However, Laubach (2009) argues that an increase in term premia affects real allocations similarly to an increase in expected future short-term interest rates, and that distinguishing between the effects on these two components of the forward rate is therefore not essential.

by market participants and professional forecasters for the U.S. from 1981-2009.[7] For expected future debt and deficit levels, we use 5-year ahead projected debt and deficit levels based on data from the CBO, which is available at an annual frequency from 1980 to 1984, and at a semiannual frequency from 1985 until August 2009. Last, we follow Laubach (2009), and include a proxy for expected trend consumption growth (CBO's 5-year-ahead projections of the growth rate of real GNP or GDP).[8]

To capture the effect of CB balance sheets, we use two different measures: total CB assets[9], and CB claims on central government. Both variables are expressed as a ratio to potential nominal GDP. Data is available from 1980 to 2009, monthly. We use potential nominal GDP as estimated by the CBO rather than nominal GDP so that variation in the latter is not the source of cyclicality in the scaled CB balance sheet variable.[10]

The data series described above are shown in charts 7 to 9. Chart 7 shows the three dependent variables considered in the regression analysis: the 5-year forward 10-year yield, the 5-year forward 5-year yield, and the ten year constant maturity yield. Two observations are noted: first, there has been a secular decline in the respective rates since the beginning of the sample, and there is substantial shorter-term variation. Charts 8 and 9 depict the projected 5-year debt and deficits for the U.S.. Unlike the long-term interest and forward rates, there does not appear to be any long-term trend. Chart 10 shows the evolution of the Fed's balance sheet. Over time, the ratio of CB assets to GDP has been slowly increasing, with some cyclicality. The graph also clearly shows that the massive expansion of the Fed's balance sheet during the current global financial crisis is unprecedented in history, both in absolute terms as well as relative to GDP. CB assets tripled from around $800 billion pre-crisis to over $2.3 trillion in March 2009. Moreover, past purchases of government bonds, and continuing purchases of agency debt are likely to keep the balance sheet large for some time. Even as the need for many of the Fed's liquidity facilities declines, the size of the balance sheet is expected to diminish only slowly over the coming years because of sizeable outright purchases of securities of permanent nature.

To capture the historical relationship between long-term forward rates and CB variables, we restrict the sample to the pre-crisis period (1980S1-2007S2).[11] This allows us to deduct implications of the current expansion of balance sheets from a historical perspective, without distorting regression results by large movements in the data in 2008 and after.

[7] Following Laubach (2009), we use a series based on the Hoey survey of bond market participants from 1981:Q2-1991:Q1 (expectation of CPI inflation over the second 5 years of a 10-year horizon) and the Survey of Professional Forecasters conducted quarterly by the Federal Reserve Bank of Philadelphia (expectation of the average CPI inflation rate over the next 10 years) from 1991:Q3 to 2009:Q2.

[8] Regressions also include a measure of relative risk aversion (the dividend yield, defined as the dividend component of national income divided by the market value of corporate equity held (directly or indirectly) by households as reported in the Federal Reserve Board's Flow of Funds data). Coefficients are not reported, however, coefficients do not change significantly when omitting the variable.

[9] Data is from the IMF IFS. Central Bank assets are calculated as series 11+12a+12e+12s. 12s is not available pre-2001, but can be calculated by adding 12g, b, c, and d. Claims on the central government are given by line 12a.

[10] However, dividing central bank variables by actual GDP versus potential GDP does not significantly change the series, and only marginally changes the regression results.

[11] Including observations until 2009S1 results in somewhat weaker coefficients, which remain statistically significantly.

*Data for other developed countries*

In order to expand the analysis beyond that of the U.S., we consider data for other developed countries, including Australia, Canada, Switzerland, Japan, UK, and US.[12] Unfortunately, the data is much more limited, and in practice, we can only use current interest rates and actual fiscal variables. For the dependent variable, we use 10-year constant maturity government bond yields, available at a monthly frequency. For inflation expectations, we use semi-annual Economic Consensus 5-10 Year Forecast from 1990-2009. CB assets and claims on the central government are obtained from the IMF IFS, at monthly frequency (see footnote 4), scaled by potential GDP. For the fiscal variables, we use actual deficit data, available at a quarterly frequency for Australia, Canada, Japan, U.K., and U.S. (and interpolated from annual data for Switzerland ), and actual debt available at quarterly frequency for Australia, Canada, Japan, and the US (and interpolated from annual data for Switzerland and the UK). Instead of GDP growth forecasts, we use actual quarterly growth rates.

**Stationarity Properties**

Before proceeding to the regression results, we first consider the time-series properties of the data. Table 1 in the appendix reports augmented Dickey–Fuller (ADF) t-test statistics and their p-values for government bond yields, inflation expectations, fiscal variables, and CB variables for the U.S. The null hypothesis of a unit root is not rejected for all variables.[13] Tables 2, 3, and 4 in the appendix reports ADF and panel unit root tests for government bond yields, inflation expectations, fiscal variables, GDP growth, and CB variables for the panel of developed countries. The null hypothesis of a unit root is not rejected for all variables, except government deficits, for which results are ambiguous: panel tests seem to reject the null hypothesis of a unit root, whereas individual ADF tests do not reject the null hypothesis in most cases. While these results suggest that non-stationarity may be an issue with respect to the estimation, we follow Laubach, who suggests that non-stationarity is not a major issue for this particular regression framework. That said, further analysis is needed to assess the robustness of the results.

## 5. REGRESSION RESULTS

### 5.1. U.S. regression results

Table 5, Panels A and B, report results for regressions of the 5-year forward 10 year rate on CB claims, controlling for other macro variables, and deficits and debts, respectively. The coefficients on expected inflation are positive and highly statistically significant in all regressions. The finding that the coefficients are larger than 1 is consistent with the view that investors demand higher risk premia on nominal assets when inflation expectations rise to compensate for greater uncertainty about

[12] We also expand the sample to European countries, including Germany, Spain, France, Italy, Netherlands, Norway, and Sweden. However, data on central bank assets for the Eurozone countries are sometimes incoclusive (break in series at time of Euro adoption), or incomplete for others. Including these countries in the panel yields similar signed coefficients - however, few are statistically significant.

[13] Note that several variables should be, theoretically, stationary, including the debt and deficit variables, as well as central bank variables. Moreover, given the small sample size, the test for stationarity has low power. Nevertheless, we acknowledge the fact that non-stationarity may be an issue.

future inflation (see, e.g., Okun 1971 and Ball and Cecchetti 1990). In addition, Feldstein (1976) points out that, because taxes are levied on nominal returns, nominal interest rates have to increase more than one-for-one with expected inflation.[14]

Regarding the additional controls, the trend growth rate enters with the expected sign predicted by the neoclassical growth model, and is statistically significant in all specifications. In theory, and abstracting from business cycle effects, higher debt and deficit levels should be associated with higher long term interest rates. The coefficients on projected deficits are somewhat weaker than in Laubach (2009) (in the range of 6 to 15 basis points per percentage point of the ratio), but are positive and are statistically significant in all but the first specification. Coefficient estimates on projected debt are also weaker than in Laubach (2009) (in the range of 0.2 to 2 basis points), positive, and are statistically significant in only one specification.

The coefficient for CB claims has the expected sign: coefficients on claims range from -.67 to -1.12 and are statistically significant in all three regressions. The exercise is repeated with central assets on the right-hand side (Table 6 Panels A and B). The coefficients on CB assets range from -.77 to -1.23 and are statistically significant in all regressions. This suggests that higher CB assets or claims (more government bonds held by the CB) imply lower long-term forward interest rates.

For robustness, we estimate the regression using IV GMM regression (third column in Table 5 and Table 6). Coefficients do not change significantly, and remain statistically significant.

Table 7 examine alternative specifications using current 10-year Treasury yields, and 5-year-ahead 5-year forward rates, and current fiscal variables instead of 5-year-ahead projections, and CB claims. Table 8 repeats the regressions for CB assets. Following Laubach (2009), we use CBO projections for the current fiscal year instead of the latest realized deficit/GDP ratio, which is available only at annual (fiscal-year) frequency. Current-year fiscal projections are fairly close to actual outcomes.

As shown in Tables 7 and 8, it does not seem to matter which combination of dependent variable and fiscal variable is used – both CB variables remain statistically significant and are relatively robust to alternative specifications. However, deficit variables are no longer significant and change signs, presumably reflecting the endogeneity problem due to cyclical responses of fiscal variables and interest rates (see Laubach, 2009). Inflation expectations are again robust to alternative specifications, entering with a positive and statistically significant sign.

The estimated coefficient for central bank assets and claims on the government appear large. However, the estimated historical relationship between central bank balance sheets and long-term forward rates is mostly related to changes in the holdings of treasuries, as they relate to hitting the central banks operational target. Recent initiative undertaken to address liquidity issues (such as the TAF) are inherently short-term, and most likely do not represent a permanent (or even cyclical shift) in the CB's balance sheet. Consequently, any inference on the impact of current expansion of CB balance sheets on long term forward rates using estimated coefficients should be seen as an upper bound. The Federal Reserve's holdings of Treasuries (claims on the Government) increased from 3.2% of potential GDP to

[14] The dividend yield enters with the expected sign, but is not always statistically significant. Laubach (2009) argues that higher dividend yield may be interpreted as a sign of elevated risk aversion, as investors demand higher than usual compensation for bearing risk may coincide with greater demand for safe Treasury securities, reducing their (current and expected) yields.

4.4% in 09Q2. The estimated coefficient of about -0.9 would suggest that the recent increase in Treasury holdings was associated with a 1.08 percentage point decrease in long term forward rates. This is about twice the size of the initial impact of the announcemnet of Treasury purchases on 10 year Treasury yields.

Given these sizeable historical relationship, it is surprising that the Fed's purchase program of Treasuries and its other facilities that led to a rapid expansion of its balance sheet did not result in a larger drop in long term interest rates. However, it is important to keep in mind the context and factors that are likely to have impacted long term interest rates simultaneously. We name a few factors that could have coutered the negative impact of the Fed's balance sheet expansion: most importantly, the supply of debt has increased massively as the U.S. is financing two large fiscal stimulus programs. The increased supply of debt should, in theory, lead to a rise in yields. Second, inflation expectations started to increase in the second half of 2009, as concerns about the inflationary impact of the Fed's sizeable balance sheet emerged. Third, the economic outlook started to improve in 2009, contributing to the rise in long term interest rates.

On the other hand, a strong historical relationship suggests that an exit from sizeable balance sheets is likely to positively impact long term rates. This might explain why, up to now, the Fed has been reluctant to consider the sale of assets held outright in its exit strategy - the Fed's approach focuses on raising interest rates (inspite of a large balance sheet and substantial excess reserves, by paying interest on reserves), and changing the composition of its balance sheet (i.e. reducing reserves using reverse repos or other instruments). Markets expect Treasury yields to increase by about 0.5 percentage points as the Fed's purchase program of mortgage related securities ends in March.

One might argue that it is not the overall size of the balance sheet or of government debt holdings that matters for long term forward rates, but rather the CB holdings of government debt that is long term. We use historical data on maturity distribution of US Treasury securities held by the Fed to proxy holdings of long term government securities.[15] Holdings of long term US Treasury securities (over 10 years, 5-10 years, and 1-5 years) carry negative coefficients, which are however not significant. The average maturity does not yield significant results. Very short term holdings (within 15 days and 15-90 days) yield large, statistically significant and negative coefficients - which suggests that monetary policy operations at the very short end do have an impact on long term forward rates.

Another interesting question is how foreign demand for U.S. Treasuries has impacted long term forward rates. We use data from the Treasury International Capital (TIC) System on net purchases of U.S. treasuries for the largest holders of U.S. Treasury securities (China, Japan, UK, Oil exporters, Russia, and Brazil).[16] Increased demand from China appears to be associated with a fall in long term forward rates, but purchases of the group do not yield significant results.

Last, our results might be biased because of an indirect impact of CB asset expansion on inflation expectations, which in turn could lead to higher interest rates. In the current context, it has been argued that the expansion of the Fed's

[15] The data available is the distribution of US Treasury holdings by remaining maturity rather than by original maturity of the asset held.

[16] Net holdings refer to net purchases U.S. long term Treasuries (Purchases by Foreigners-Sales by Foreigners). Ideally, we would like to include the stock, i.e. holdings of U.S. Treasuries, in the regression. However, the data is not a smooth series because it is constructed by adding up purchases and gets updated once a year using surveys.

balance sheet has led to a rise in inflation expectations. If this is true, the positive correlation of CB assets and long term interest rates could be primarily a result of higher inflation expectations. To verify this point, we regress *real long term rates* on central bank assets. We simply regress the 5-year-ahead 10-year forward rate, minus long term inflation expectations, on CB assets. The results (not shown) yields nealy the same coefficients. We also use the "real" 5-year ahead 5-year forward rate, and the "real" 10-year Treasury yield as dependent variables, with similar results.

### 5.2. Panel regression results

Table 9 reports regression results for panel regressions including Australia, Canada, Switzerland, the UK, the US, and Japan, using a GMM instrumental varibles estimator. Again, inflation is a positive and statistically significant determinant of long term interest rates in all regressions. Debt and deficit enter with a positive coefficient, consistent with expectations. The coefficient is statistically significant in all four cases. The first two columns refer to regressions using CB assets on the central government as an explanatory variable. As expected, the variable enters with a negative coefficient, which is statistically significant in all cases. The third and fourth column repeats the regression for CB claims, and finds similar results: the coefficient on CB claims carries the expected sign, and is statistically significant in both regressions. The results confirm that central bank assets are an important determinant for long term interest rates, not only for those countries engaging in quantitative easing.

For robustness, we also use alternative regression techniques (not shown). Using either fixed or random effects panel OLS, both CB assets and claims carry a negative sign. CB assets are statistically significant, but not claims. All other variables keep their signs and are significant. Using GLS, we find again that coefficients on CB assets are statistically significant, but not for claims. Both variables carry a negative sign. Last, we use the dynamic panel estimator proposed by Arellano and Bond. Results are somewhat weaker: when CB assets are specified as predetermined or endogenous, the coefficient is negative and smaller than in previous regressions, but not statistically significant. Overall, we consider the results to be relatively robust to various regression methods.

## 6. CONCERNS, POLICY IMPLICATIONS AND AVENUES FOR FUTURE RESEARCH

The preliminary regression results presented above suggest that there is a link between the size of the CB balance sheet and long-term forward rates. But one major concern of the empirical framework is that the innovations in the balance sheet are simply proxies for the short-term policy rate, and as such, the effect of changes of the CB sheet are over-stated. However, if one assumes that forward rates, being sufficiently in the future, are immune to changes in short-term policy rates associated with the business cycle, then this concern is mitigated.

The policy implications from these results would suggest that the recent expansion of CB balance sheets could have sizeable effects on long-term forward interest rates, all else equal. However, it is important to note that the estimated historical relationship between CB balance sheets and long-term forward rates is mostly related to changes in the holdings of treasuries, as they relate to hitting the CBs

operational target. Many of the recent initiatives undertaken to address liquidity issues (such as the TAF) are inherently short-term, and most likely do not represent a permanent (or even cyclical shift) in the CB's balance sheet. Consequently, any inference on the impact of current expansion of CB balance sheets on long term forward rates using estimated coefficients should be seen as an upper bound.

Certainly, there are questions whether central bank intervention in the form of balance sheet expansion, if it is found to have an impact, is desirable. Monetary policy can be seen as a "distortion", where low interest rates may lead to poor resource allocation and overinvestment, such as it is sometimes claimed to have happened in Japan. However, central banks might not always have the choice, such as in the current crisis, where action appeared necessary to support confidence fight the fear of deflation.

Going forward, further robustness tests of our results using alternative specifications is warranted. In fact, some of the negative correlation between CB variables and long-term forward rates might be driven by the positive trend in the former and the negative trend in the latter variable over the sample period. Preliminary regression results using detrended variables suggests that coefficients are robust to detrending, however, some of the coefficients on CB variables are no longer statistically significant. Second, it might be insightful to complement our analysis with case studies, examining the U.S., U.K., and Japan experience of quantitative easing in greater detail.

## REFERENCES


[1] Ball, Laurence, and Stephen G. Cecchetti. 1990. "Inflation and Uncertainty at Long and Short Horizons." Brookings Papers on Economic Activity, 1, 215–245.

[2] Borio, Claudio and Piti Disyatat. 2009. "Unconventional monetary policies: an appraisal" BIS Working Papers No 292

[3] Feldstein, Martin S. 1976. "Inflation, Income Taxes, and the Rate of Interest: A Theoretical Analysis." American Economic Review, 66, 809–820.

[4] International Monetary Fund. 2001.

[5] Laubach, Thomas. 2009. "New evidence on the interest rate effects of budget deficits and debt". Journal of the European Economic Association June 2009, Vol. 7, No. 4, p. 858-885.

[6] Leone. Alfred.1991. "Effectiveness and Implication of Limits on Central Bank Credit to Government". In *The evolving role of central banks* By Patrick Downes, Reza Vaez-Zadeh

[7] Okun, Arthur. 1971. "The Mirage of Steady Inflation." BrookingsPapers on Economic Activity, 2, 485–498.


## 7. APPENDIX

### 7.1. Charts

**FIG. 1** U.S. 10 Year Treasury Yields and Treasury Purchases

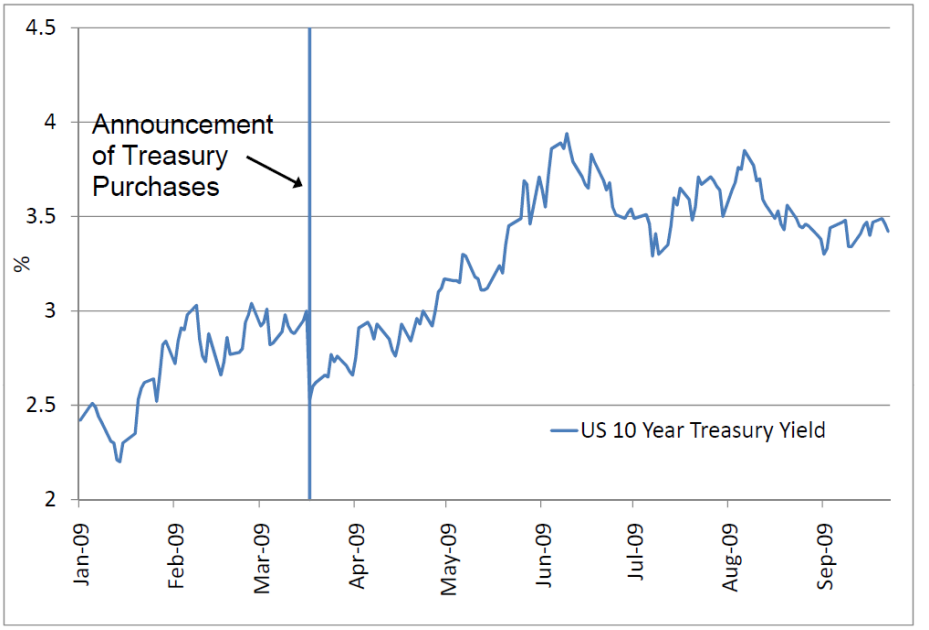


**FIG. 2** Central Bank Balance Sheets (in percent of potential GDP)

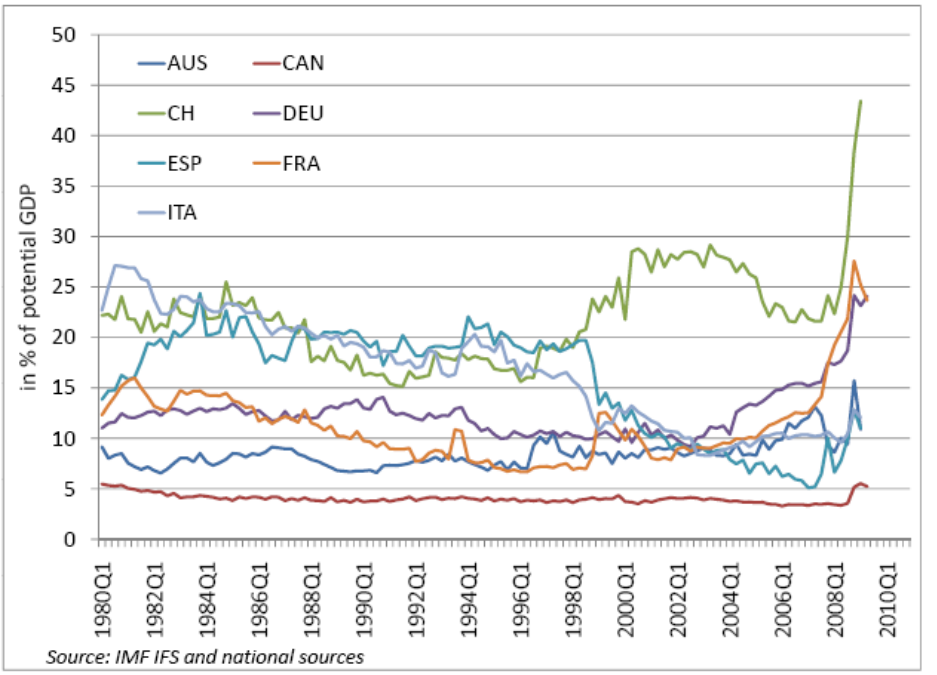

**FIG. 3** Central Bank Balance Sheets (2) (in percent of potential GDP)

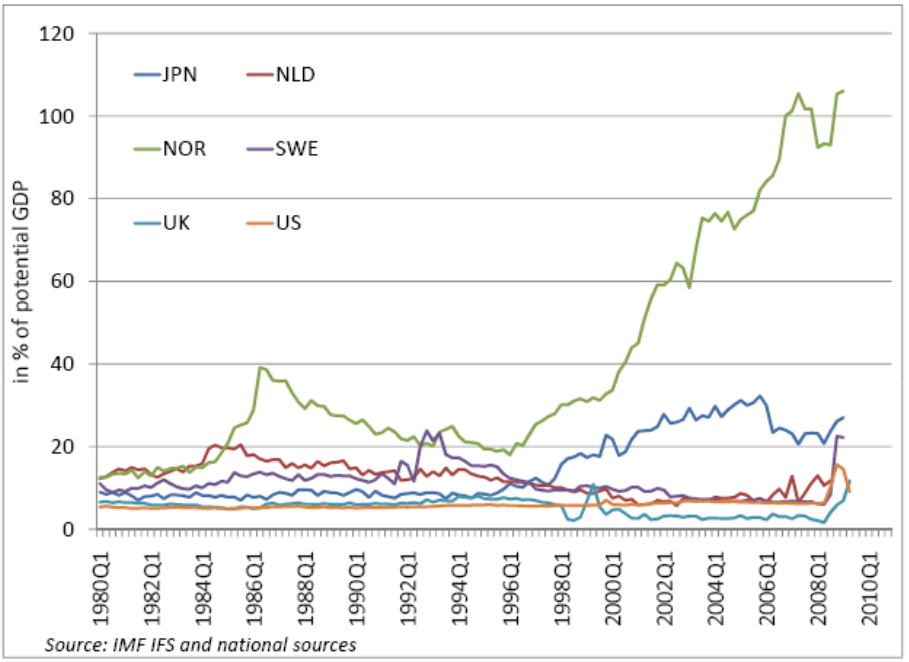


**FIG. 4** Composition of the Federal Reserve's Balance Sheet

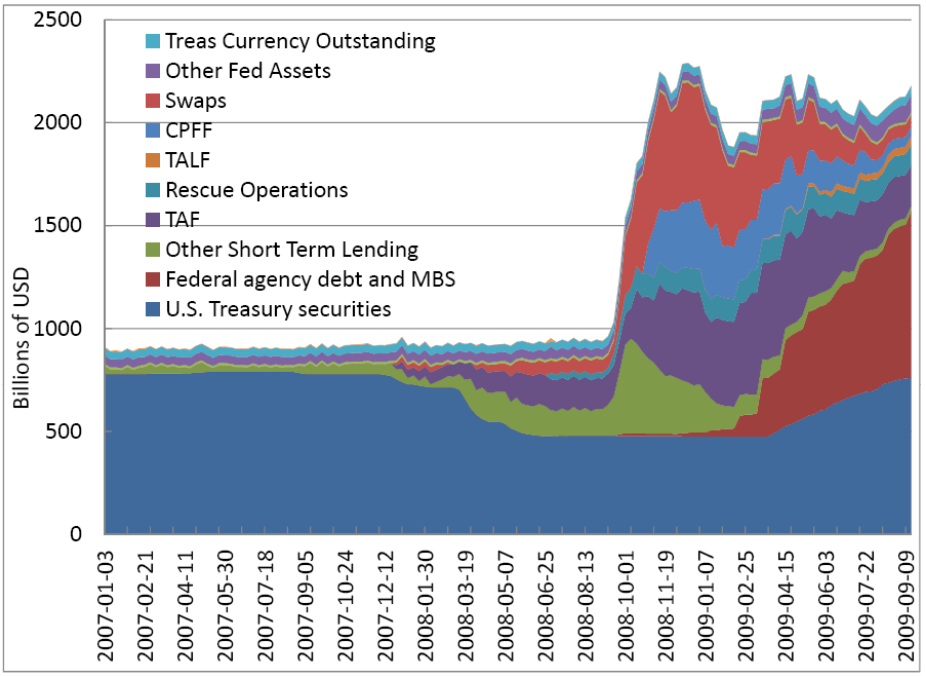

**FIG. 5** 5-year-ahead 10-year forward rate, 5-year-ahead 5-year forward rate, and 10 year constant maturity government bond yield

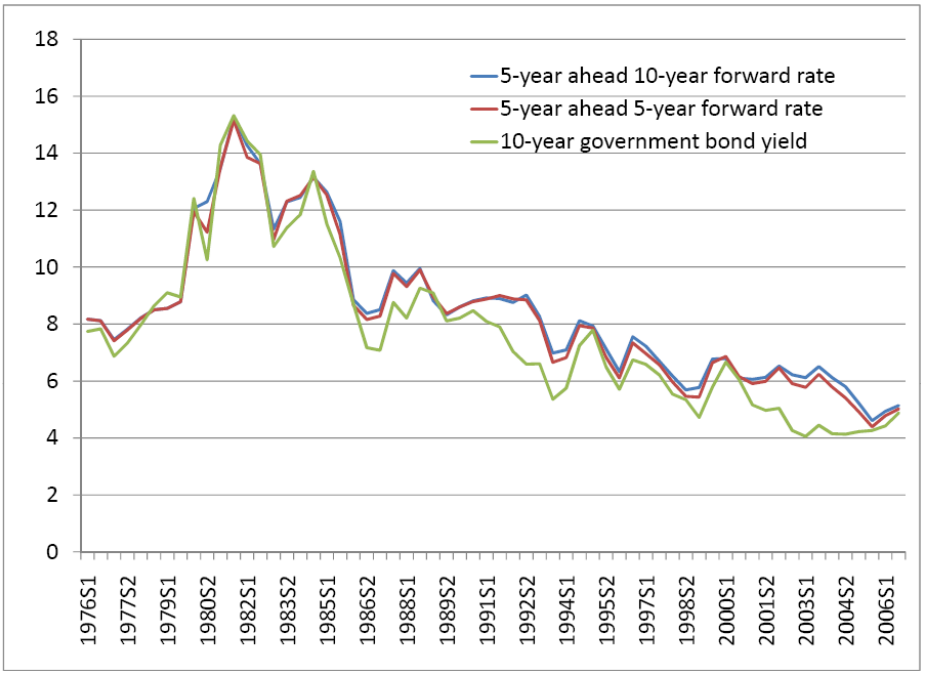


**FIG. 6** Actual and 5-year ahead projected deficit

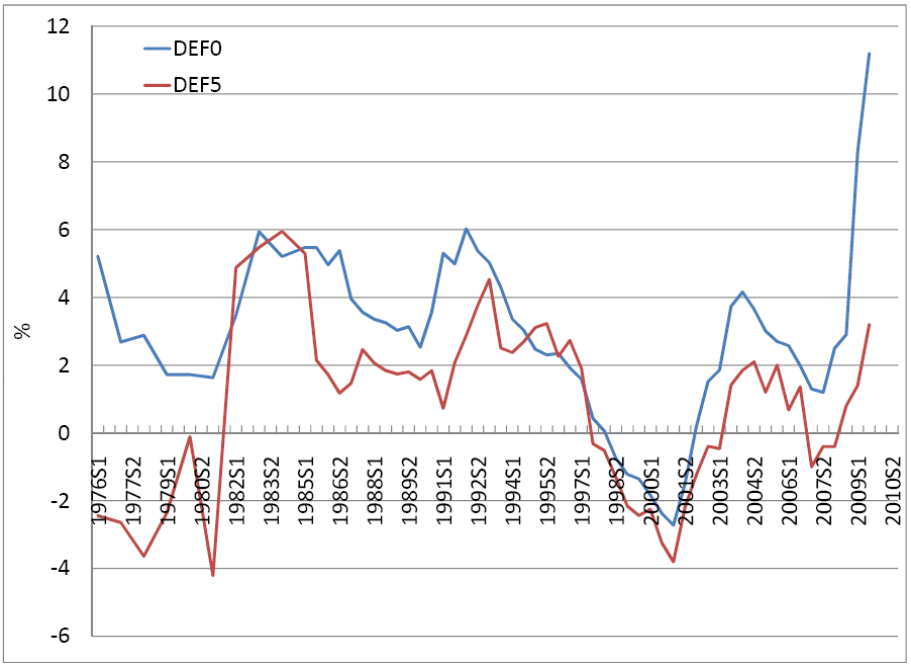

**FIG. 7** Actual and 5-year ahead projected debt

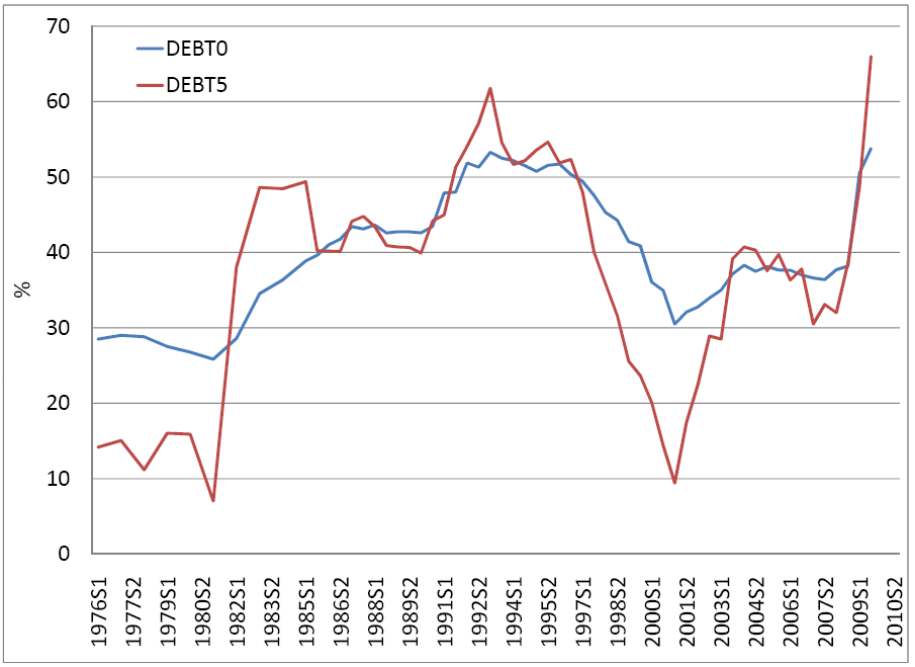


**FIG. 8** U.S. Central bank assets and claims to potential GDP

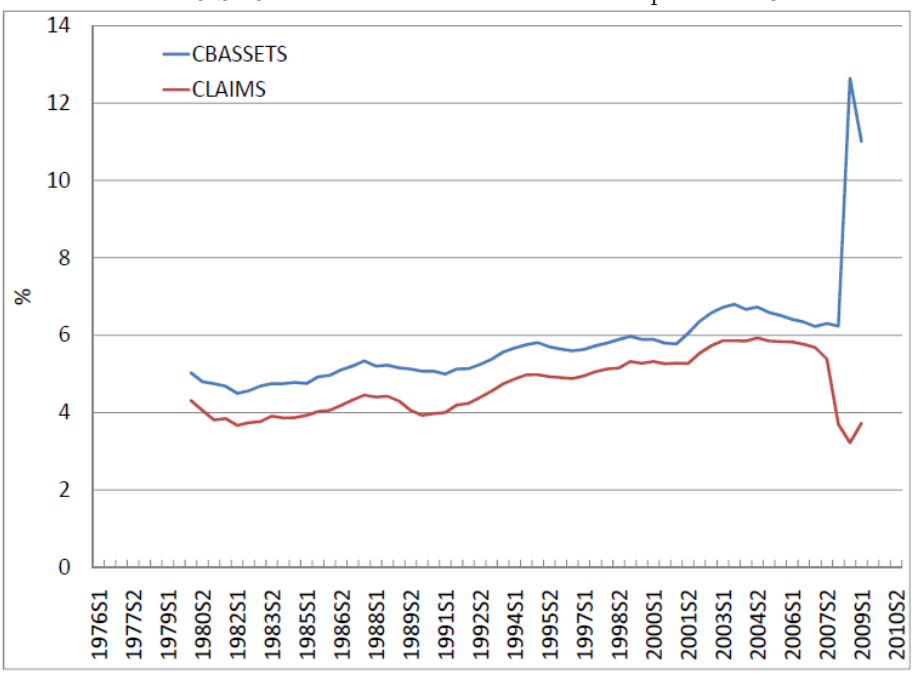

TABLE 1
Augmented Dickey-Fuller Tests (US: Semi-annual Data, Updated from Laubach, 2009)

| **Variable** | **t-stat** | **p-value** | **N** |
|---|---|---|---|
| Ten-year treasury constant yield | -1.257 | 0.644 | 66 |
| 5-year forward 10 year rate | -1.046 | 0.732 | 66 |
| Inflation expectations | -0.552 | 0.873 | 67 |
| Current deficit / GDP | -1.211 | 0.662 | 48 |
| Current debt / GDP | -2.065 | 0.259 | 47 |
| Projected 5-year deficit / GDP | -2.436 | 0.138 | 49 |
| Projected 5-year debt / GDP | -1.907 | 0.326 | 47 |
| Central bank assets / GDP | -1.103 | 0.709 | 58 |
| Central bank claims / GDP | -2.144 | 0.229 | 57 |

### 7.2. Tables

TABLE 2
Augmented Dickey-Fuller Tests (Panel: Quarterly Data 1980Q1-2009Q2)

| | **10 year** | | | **Inflation expectations** | | |
|---|---|---|---|---|---|---|
| | **t-stat** | **p-value** | **N** | **t-stat** | **p-value** | **N** |
| AUS | -0.781 | 0.821 | 118 | -2.294 | 0.187 | 13 |
| CAN | -3.067 | 0.032 | 109 | -3.126 | 0.029 | 69 |
| CH | -1.772 | 0.393 | 117 | -2.749 | 0.075 | 38 |
| DEU | -1.480 | 0.540 | 117 | -0.949 | 0.767 | 72 |
| ESP | -1.445 | 0.556 | 87 | -3.493 | 0.012 | 54 |
| FRA | -1.296 | 0.629 | 98 | -2.722 | 0.076 | 69 |
| ITA | -1.897 | 0.332 | 69 | -3.128 | 0.029 | 72 |
| JPN | -1.111 | 0.710 | 118 | -2.671 | 0.086 | 52 |
| NLD | -1.964 | 0.302 | 114 | -1.200 | 0.667 | 49 |
| NOR | -1.415 | 0.572 | 96 | -2.128 | 0.235 | 36 |
| SWE | -0.838 | 0.804 | 116 | -3.584 | 0.010 | 49 |
| UK | -1.157 | 0.688 | 66 | -1.565 | 0.495 | 71 |
| UK | -1.200 | 0.673 | 117 | -1.911 | 0.325 | 69 |
| Panel Unit root tests (assumes individual unit root process) | | | | | | |
| | **t-stat** | **p-value** | **N** | **t-stat** | **p-value** | **N** |
| Im, Pesaran and Shin W-stat | 0.170 | 0.568 | 1338 | -4.5082 | 0.000 | 761 |
| ADF - Fisher Chi-square | 17.393 | 0.897 | 1338 | 71.0354 | 0.000 | 761 |
| PP - Fisher Chi-square | 17.825 | 0.882 | 1351 | 98.4708 | 0.000 | 776 |

TABLE 3
Augmented Dickey-Fuller Tests 2(Panel: Quarterly Data 1980Q1-2009Q2)

| | **Debt** | | | **Deficit** | | |
|---|---|---|---|---|---|---|
| | **t-stat** | **p-value** | **N** | **t-stat** | **p-value** | **N** |
| AUS | -2.113 | 0.240 | 92 | -1.538 | 0.511 | 122 |
| CAN | -2.551 | 0.106 | 119 | -1.274 | 0.640 | 123 |
| CH | -2.499 | 0.120 | 75 | -3.370 | 0.015 | 79 |
| DEU | -0.365 | 0.910 | 111 | -3.933 | 0.003 | 115 |
| ESP | -2.200 | 0.208 | 79 | -2.782 | 0.064 | 119 |
| FRA | -0.156 | 0.940 | 119 | -2.163 | 0.221 | 119 |
| ITA | -1.317 | 0.620 | 119 | -1.450 | 0.555 | 115 |
| JPN | 0.801 | 0.994 | 121 | -1.200 | 0.673 | 120 |
| NLD | -1.975 | 0.298 | 119 | -2.424 | 0.138 | 111 |
| NOR | 0.378 | 0.981 | 111 | -2.531 | 0.111 | 119 |
| SWE | -3.126 | 0.027 | 119 | -3.292 | 0.017 | 119 |
| UK | -0.863 | 0.797 | 119 | -0.678 | 0.847 | 123 |
| US | -0.917 | 0.780 | 118 | -2.303 | 0.173 | 120 |
| Panel Unit root tests (assumes individual unit root process) | | | | | | |
| | **t-stat** | **p-value** | **N** | **t-stat** | **p-value** | **N** |
| Im, Pesaran and Shin W-stat | 1.007 | 0.843 | 1449 | -2.904 | 0.002 | 1522 |
| ADF - Fisher Chi-square | 27.178 | 0.400 | 1449 | 57.883 | 0.000 | 1522 |
| PP - Fisher Chi-square | 16.394 | 0.926 | 1462 | 22.633 | 0.654 | 1535 |

TABLE 4
Augmented Dickey-Fuller Tests 3(Panel: Quarterly Data 1980Q1-2009Q2)

| | **Cbassets** | | | **Claims** | | |
|---|---|---|---|---|---|---|
| | **t-stat** | **p-value** | **N** | **t-stat** | **p-value** | **N** |
| AUS | -1.876 | 0.343 | 115 | -2.121 | 0.237 | 115 |
| CAN | -3.400 | 0.013 | 113 | -3.138 | 0.027 | 116 |
| CH | -0.064 | 0.950 | 109 | -1.753 | 0.402 | 110 |
| DEU | 2.699 | 1.000 | 72 | -1.350 | 0.602 | 73 |
| ESP | -0.821 | 0.809 | 112 | -1.139 | 0.698 | 108 |
| FRA | 0.161 | 0.969 | 117 | -0.642 | 0.856 | 116 |
| ITA | -1.045 | 0.735 | 116 | -0.736 | 0.833 | 116 |
| JPN | -0.585 | 0.868 | 112 | -1.051 | 0.733 | 116 |
| NLD | -1.428 | 0.566 | 113 | -0.902 | 0.785 | 114 |
| NOR | 0.611 | 0.990 | 112 | -2.338 | 0.162 | 116 |
| SWE | -2.158 | 0.223 | 116 | -0.562 | 0.873 | 113 |
| UK | -2.443 | 0.132 | 117 | -1.777 | 0.390 | 117 |
| US | 1.132 | 0.998 | 114 | -1.330 | 0.614 | 112 |
| Panel Unit root tests (assumes individual unit root process) | | | | | | |
| | **t-stat** | **p-value** | **N** | **t-stat** | **p-value** | **N** |
| Im, Pesaran and Shin W-stat | 1.332 | 0.909 | 1448 | -0.504 | 0.307 | 1448 |
| ADF - Fisher Chi-square | 60.029 | 0.000 | 1448 | 29.330 | 0.296 | 1448 |
| PP - Fisher Chi-square | 37.807 | 0.063 | 1461 | 30.953 | 0.230 | 1461 |

TABLE 5
Baseline results - Central Bank Claims

This table presents results of OLS and IV GMM regressions of forward interest rates on central bank claims. The data is semi-annual from 1980 to 2007. The dependent variable is the 5-year forward 10-year interest rate. Inflation expectations are 5-10 years ahead inflation expectations. Projected deficit is the 5 year-ahead CBO forecast of the deficit-to-GDP, and the projected debt is the 5-year ahead CBO forecast of the debt-to-GDP. Projected growth is the 5-year ahead projection of the growth rate of real GDP. Central bank claims are the ratio of central bank holdings of government securities to potential GDP. The second column also includes the dividend yield, which is defined as the dividend component of national income divided by the market value of corporate equity held (directly or indirectly) by households as reported in the Federal Reserve Board's Flow of Funds data. The coefficients are not reported, however, exluding the dividend yield from regressions does not change results significantly. Standard errors in parentheses. For the IV GMM specification, lagged claims are used as instruments and SEs are heteroskedasticity- and autocorrelation-robust. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

| **Panel A: Projected deficits and central bank claims** | | | |
|---|---|---|---|
| | **OLS** | **OLS** | **IV GMM** |
| **Inflation Expectations** | 1.180*** | 0.994*** | 0.968*** |
| | (0.110) | (0.211) | (0.200) |
| **Projected Deficit** | 0.06 | 0.139** | 0.081 |
| | (0.048) | (0.061) | (0.059) |
| **Projected Growth** | | 0.704* | 0.519* |
| | | (0.417) | (0.286) |
| **Central Bank Claims** | -0.644** | -1.089*** | -0.941** |
| | (0.241) | (0.369) | (0.340) |
| **R2** | 0.749 | 0.728 | 0.901 |
| **DW** | 0.681 | 0.879 | |
| **Hansen-J** | | | 0.62 |
| **Panel B: Projected debt and central bank claims** | | | |
| | **OLS** | **OLS** | **IV GMM** |
| **Inflation Expectations** | 1.191*** | 1.045*** | 1.034*** |
| | (0.116) | (0.193) | (0.187) |
| **Projected Debt** | 0.002 | 0.015 | 0.008 |
| | (0.006) | (0.012) | (0.009) |
| **Projected Growth** | | 0.664 | 0.493 |
| | | (0.493) | (0.347) |
| **Central Bank Claims** | -0.697** | -0.989** | -0.898** |
| | (0.263) | (0.374) | (-0.387) |
| **R2** | 0.900 | 0.905 | 0.897 |
| **DW** | 0.709 | 0.848 | |
| **Hansen-J** | | | 0.471 |

TABLE 6
Baseline results - Central Bank Assets

This table presents results of OLS and IV GMM regressions of forward interest rates on central bank assets. The data is semiannual from 1980 to 2007. The dependent variable is the 5-year forward 10-year interest rate. Inflation expectations are 5-10 years ahead inflation expectations. Projected deficit is the 5 year-ahead CBO forecast of the deficit-to-GDP, and the projected debt is the 5-year ahead CBO forecast of the debt-to-GDP. Projected growth is the 5-year ahead projection of the growth rate of real GDP. Central bank assets are the ratio of central bank holdings of government securities to potential GDP. The second column also includes the dividend yield, which is defined as the dividend component of national income divided by the market value of corporate equity held (directly or indirectly) by households as reported in the Federal Reserve Board's Flow of Funds data. The coefficients are not reported, however, exluding the dividend yield from regressions does not change results significantly. Standard errors in parentheses. For the IV GMM specification, lagged CB assets are used as instruments and SEs are heteroskedasticity- and autocorrelation-robust. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

| **Panel A: Projected deficits and central bank assets** | | | |
|---|---|---|---|
| | **OLS** | **OLS** | **IV GMM** |
| **Inflation Expectations** | 1.171*** | 0.950*** | 0.905*** |
| | (0.111) | (0.211) | (0.196) |
| **Projected Deficit** | 0.068 | 0.139** | 0.098* |
| | (0.047) | (0.061) | (0.055) |
| **Projected Growth** | | 0.717* | 0.632** |
| | | (0.417) | (0.286) |
| **Central Bank Assets** | -0.736** | -1.200*** | -1.167*** |
| | (0.278) | (0.431) | (0.419) |
| **R2** | 0.904 | 0.913 | 0.993 |
| **DW** | 0.682 | 0.857 | |
| **Hansen J** | | | 0.865 |
| **Panel B: Projected debts and central bank assets** | | | |
| | **OLS** | **OLS** | **IV GMM** |
| **Inflation Expectations** | 1.203*** | 0.995*** | 0.989*** |
| | (0.107) | (-0.212) | (0.183) |
| **Projected Debt** | 0.004 | 0.017 | 0.011 |
| | (0.006) | (0.011) | (0.009) |
| **Projected Growth** | | 0.724 | 0.627* |
| | | (0.506) | (0.343) |
| **Central Bank Assets** | -0.748** | -1.200** | -1.076** |
| | (0.295) | (0.446) | (-0.423) |
| **R2** | 0.900 | 0.907 | 0.710 |
| **DW** | 0.706 | 0.856 | |
| **Hansen J** | | | 0.829 |

TABLE 7
Alternative Specifications - Central Bank Claims

This table presents results of OLS regressions of forward interest rates on central bank claims. The data is semi-annual from 1976 to 2007. The dependent variables are the 5-year forward 10-year interest rate. Inflation expectations are 5-10 years ahead inflation expectations. Projected deficit is the 5 year-ahead CBO forecast of the deficit-to-GDP, and the projected debt is the 5-year ahead CBO forecast of the debt-to-GDP. Projected growth is the 5-year ahead projection of the growth rate of real GDP. Central bank claims are the ratio of central bank claims to GDP. Regressions include the dividend yield, which is defined as the dividend component of national income divided by the market value of corporate equity held (directly or indirectly) by households as reported in the Federal Reserve Board's Flow of Funds data. The coefficients are not reported, however, exluding the dividend yield from regressions does not change results significantly. Newey-West standard errors in parentheses, *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

| | **10-year yield** | **5-year forward 5 year yield** | **10-year yield** | **5-year forward 5 year yield** |
|---|---|---|---|---|
| **Inflation Expectations** | 1.429*** | 1.185*** | 1.358*** | 1.180*** |
| | (0.122) | (0.112) | (0.140) | (-0.109) |
| **Deficit** | -0.203*** | -0.006 | | |
| | (0.046) | (0.045) | | |
| **Projected Deficit** | | | -0.056 | 0.060 |
| | | | (-0.057) | (-0.052) |
| **Central Bank Claims** | -0.939*** | -0.765** | -0.801*** | -0.644** |
| | (0.169) | (-0.34) | (-0.189) | (-0.241 |
| **R2** | 0.914 | 0.899 | 0.893 | 0.902 |
| **DW** | 0.777 | 0.715 | 0.671 | 0.681 |

TABLE 8
Alternative Specifications - Central Bank Assets

This table presents results of OLS regressions of forward interest rates on central bank assets. The data is semi-annual from 1976 to 2007. The dependent variables are the 5-year forward 10-year interest rate. Inflation expectations are 5-10 years ahead inflation expectations. Projected deficit is the 5 year-ahead CBO forecast of the deficit-to-GDP, and the projected debt is the 5-year ahead CBO forecast of the debt-to-GDP. Projected growth is the 5-year ahead projection of the growth rate of real GDP. Central bank assets are the ratio of central bank assets to GDP. Regressions include the dividend yield, which is defined as the dividend component of national income divided by the market value of corporate equity held (directly or indirectly) by households as reported in the Federal Reserve Board's Flow of Funds data. The coefficients are not reported, however, exluding the dividend yield from regressions does not change results significantly. Newey-West standard errors in parentheses, *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

| | **10-year yield** | **5-year forward 5 year yield** | **10-year yield** | **5-year forward 5 year yield** |
|---|---|---|---|---|
| **Inflation Expectations** | 1.399** | 1.177*** | 1.285*** | 1.171*** |
| | (0.127) | (0.113) | (0.140) | (0.111) |
| **Deficit** | -0.172*** | 0.016 | | |
| | (0.048) | (0.045) | | |
| **Projected Deficit** | | | -0.049 | 0.068 |
| | | | (0.057) | (0.047) |
| **Central Bank Assets** | -1.078*** | -0.792** | -1.103*** | -0.736** |
| | (0.212) | (0.288) | (0.200) | (0.278) |
| **R2** | 0.917 | 0.900 | 0.901 | 0.904 |
| **DW** | 0.801 | 0.713 | 0.719 | 0.682 |

TABLE 9
Panel Regressions

This table presents results of IV GMM regressions on a panel of 6 developed countries, including Australia, Canada, Switzerland, Japan, UK, and US. The data is quarterly from 1996 to 2007. The dependent variable is the 10-year government bond yield. Inflation expectations are 5-10 years ahead inflation expectations. Deficit and debt are in percent of GDP. Growth is the annual growth rate of real GDP. Central bank assets are the ratio of central bank assets to GDP. Standard errors in parentheses, *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

| **Debt/Deficit and central bank claims** | | | **Debt/Deficit and central bank assets** | |
|---|---|---|---|---|
| | **IV** | **IV** | **IV** | **IV** |
| Inflation exp. | 2.356*** | 1.819*** | 1.841*** | 1.712*** |
| | (0.027) | (0.095) | (0.104) | (0.096) |
| Debt | 0.042*** | | .005*** | |
| | (0.004) | | (0.005) | |
| Deficit | | 0.094*** | | 0.039* |
| | | (0.025) | | (0.021) |
| Growth | 0.022 | 0.088** | 0.011 | 0.038** |
| | (0.034) | (0.035) | (0.038) | (0.042) |
| Claims | -0.336*** | -0.120*** | | |
| | (0.027) | (0.020) | | |
| CB assets | | | -0.073** | -0.074*** |
| | | | (0.009) | (0.010) |

Instrumented: claims or cbassets
Instruments: inflation, debt (or deficit)
GDP, claims(-1) or cbassets(-1), Inflation(-1)