Spillover Effects of U.S. Unconventional Monetary Policy on Korean Bond Markets: Evidence from High-Frequency Data

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Abstract

We empirically investigate the effects of U.S. unconventional monetary policy (UMP) on Korean bond markets. Using an high-frequency event-study approach, we find that not every UMP-related news affects the domestic bond yields and foreign net investment in Korean bond market while some of the UMP news, including tapering, do affect foreign net investment. We provide an economic explanation by examining the relationship between changes in foreign net investment and the two common factors that well capture the changes in U.S. Treasury bond yields of various maturities, identified by factor analysis. We show that these two common factors contain information on expectation of future U.S. policy rates and risk premia and they are statistically associated with foreign net investment, suggesting that market expectation on U.S. economy affects foreign bond investment in South Korea. We also examine the determinants of foreign net investment using macroeconomic variables. Based on our empirical findings, we conclude that, while push factors do not dominate pull factors, Korean bond market is not a "safe haven" from the normalization of U.S. monetary policy.

Keywords: Unconventional Monetary Policy (UMP), Foreign Portfolio Investment, Capital Flows, Korean Bond Market
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1. Introduction

What would the emerging market economies (EMEs) expect from the normalization of U.S. unconventional monetary policy (UMP)? What would be the spillovers to them? These questions are being actively asked in global and local policy circles and much research is being done to answer. Several studies show that U.S. UMP had large international effects and argue that the magnitude of spillover effect depends on macroeconomic factors such as soundness of banking system, current deficit, real GDP growth, and exchange rate regimes (Neely (2014), Chen et al. (2014)). Meanwhile, a consensus is not made because other study such as Eichengreen and Gupta (2014) argues that the size and liquidity of the country's financial market is a more important determinant of the differential impact.[1]

While it can be very informative to perform cross-country comparisons and understand the source of differential effects, using VAR and panel data for cross-country study may hinder the country-specific phenomenon and a small set of influential observations may cover up the details of an individual country. In this regard, we focus on the case of South Korea to see how the Korean bond yields and foreign net investment are affected by UMP-related announcements. Our main questions are: (1) How did Korean bond market respond to UMP shocks? More specifically, are those responses are different for different maturities? Would foreign net investment of domestic bond be affected by the release of UMP-related information? (2) Should we worry about capital outflow in response to UMP shocks?

To answer those questions, one needs to identify the shocks of UMP. Since the U.S. policy rate is stuck at zero lower bound, researchers cannot use the variations in federal funds rate as a proxy for such shocks.[2] Under the world of zero lower bound, there are several potential solutions for identifying the monetary policy shocks. Firstly, one can rely on an event-study approach using high-frequency data. This approach assumes that, on the day or in the time-window when UMP news is released, any shock comes from UMP news. This line of study identifies announcements that they argue are complete surprises, and then simply adds up the jumps in asset prices in short windows

[1] See the following literature review for more detail.
[2] One option is to use the federal funds futures price. But, an similar price does not exist in South Korea.

bracketing these announcements.[3] The second approach is to use the identification-through-heteroskedasticity approach, following Rigobon (2003) and Rigobon and Sack (2004). This approach is considered as a less strict version of the first approach since it only requires that volatility is larger on UMP announcement days relative to other days. The third approach is to use the typical SVAR approach, but with a different sign restriction that reflect stances of monetary poicy at zero lower bound. Dahlhaus and Vasishtha (2014) can be an example. They define a "policy normalization shock" that increases both the yield spread of U.S. long-term bonds and monetary policy expectations while leaving the policy rate per se unchanged.

As the environment of zero lower bound stimulates the different approaches of identifying monetary policy shocks, a rise of forward guidance, another product of zero lower bound environment, also emphasizes the multi-dimensionality of monetary policy shocks. As Gurkaynak et al. (2005) successfully shows that information on future path of policy is more important than information on the current level of policy rate in order to understand the effect of monetary policy on asset prices, recent studies emphasize (at least) two dimensions of monetary policy shocks.

In this study, we use a high-frequency event-study approach to examine the effects of UMP-related news on Korean bond market. We begin to look at the responses of U.S. Treasury yields of various maturities on the dates of UMP news released. After confirming that those new information related to UMP systematically affects U.S. Treasury yields, we turn to Korean bond market data to see the effect of UMP on domestic bond yields and foreign net investment. We find that, contrary to the U.S. case, not every UMP news affect the domestic bond market while some of them strongly do. In order to provide an economic explanation, following the approach in Gurkaynak et al. (2005) and Chen et al. (2014), we extract the two common factors that explain quite well the changes in Treasury yields of various maturities and attempt to explain the behavior of foreign net investment with those two factors. Given that those two factors contain the information on future path of policy rate and time-varying risk premia, it is equivalent to see how expectation on U.S. monetary policy and economy affects foreign net investment. Our subsequent analysis shows that the statistical association between for-

[3]Among many, see Doh (2010), Gagnon et al. (2011), Meaning and Zhu (2011), Neely (2014), Krishnamurthy and Vissing-Jorgensen (2011), Joyce and Tong (2012), and Swanson et al. (2011) to take this approach to study the effect of UMP on U.S. economy and other countries.

eign net inflow and the two common factors of U.S. Treasury yields becomes stronger during the period of Operation Twist and the period related to tapering, suggesting that any upward adjustment of expectation on future policy rate and risk premia can result in foreign net outflows. This result implies that "push" factors such as monetary and fiscal policy in advanced countries can play a role in capital flows. We also examine the effect of "pull" factors such as arbitrage opportunities including interest rate differential and exchange rate, and CDS premium as a proxy of country risk and find that CDS premium is an important determinant of foreign bond inflows even at high-frequency. We conclude that neither pull factors nor push factors dominate and Korean bond market is not a "safe haven" yet, still vulnerable to external shocks of U.S. monetary policy.

The rest of the paper is structured as follows: Section 2. reviews the literature on the effect of UMP on advanced and emerging market economies. Section 3.1. explains our empirical methodology and discusses a possible source of bias. Section 4. starts with data description and analyzes the U.S. case and Korean case. We delve into the Korean case more by looking at various yields and examining the behavior of foreign net investment. Analysis using factor analysis and macroeconomic variables follows to add an economic interpretation to our empirical finding. Section 5. discusses the related issues and section 6. concludes with summary.

2. Literature Review

Empirical studies on how UMP affects other countries has been accumulating these days. While they differ in terms of identification strategies and empirical methods, they focus on whether UMP affects other countries through the following channels: portfolio balance channel, liquidity channel, and signaling channel.[4]

Portfolio balance channel is based on imperfect substitutability between securities of different maturities or asset classes. For example, Quantitative easing (QE) or large-scale asset purchases (LSAP) involves the purchase of long-term bonds and result in the reduction of those assets to private investors. Due to imperfect substitutability between securities of different maturities or asset classes, it would increase demand for assets in EMEs and lower their yields. Liquidity channel focuses on the effect of overall

[4]Many of them do not make an explicit distinction of these channels, while Krishnamurthy and Vissing-Jorgensen (2011) is an exception.

liquidity increase in financial markets. QE increases reserves on the balance sheets of private banks. With increased funds, previously liquidity-constrained banks becomes more willing to extend credit to investors. It results in lower borrowing costs and lower bond yields. Signaling channel recognizes that central bank announcements can affect long-term interest rates by signaling a future path of policy rates. If forward guidance of low policy rates in the future is perceived as a credible commitment by the Fed, then the risk-neutral component of bond yields may decline. Then, larger interest differential will induce carry trade and capital flows into EMEs, affecting yields and trading volume of bonds in EMEs.

We can categorize the related literature into two groups: one is about the effect of UMP on advanced economies including the U.S. itself. The other is about the effect on emerging market economies. We review one by one.

Krishnamurthy and Vissing-Jorgensen (2011) analyze the effect of QEs using event-study approach. They explain the various kind of channels through which the effect of QEs are transmitted. They find evidence for a signaling channel and an inflation channel for both QE1 and QE2. They also find that the Fed's purchase of mortgage-backed securities was effective in lowering mortgage rates. In addition, their study find evidence for a unique demand for long-term safe assets, which supports the preferred habitat hypothesis of term structures. Rosa (2012) takes the similar approach and identifies the surprise component of LSAP announcements using newspaper articles and estimates the effect of LSAP. According to this study, the cumulative financial market impact of the Fed's LSAP program is equivalent to an unexpected cut in the Fed's policy rate that ranges between zero (for three-month yields) and 197 basis points (for ten-year yields).

Rogers et al. (2014) extend the scope of analysis to four major central banks and use the daily and intraday data to find that UMPs by the Fed, BOE, ECB, and BOJ are effective in easing financial conditions.[5] They also find the asymmetric effect of spillovers - the effect of US policy shocks on non-US yields are larger than the other way around.

Neely (2014) uses the traditional portfolio theory to predict the effect of UMP on long-term yields of US and other countries (Australia, Canada, Germany, Japan, U.K.). In theory, a change in the supply of an asset, accompanied by UMP, should affect its

[5]However, expansionary monetary policy shock did not raise the stock prices in UK and Japan.

price and those of assets whose returns covary with it. He finds that LSAP lowers the long-term bond yields of US, Australia, Canada, Germany, Japan, and UK.

Bauer and Neely (2014) take one step further from Neely (2014). They decompose the yield changes following UMP into changes caused by signaling effect and portfolio balance effect. Using dynamic term structure models, they find that signaling effects tend to be larger for countries that show strong yield responses to conventional US monetary policy shocks, and portfolio effects are larger for countries with higher bond yield covariances with US bond returns.[6] For example, signaling effect is more important for Canada while portfolio balance effect is more important for Germany and Australia. Portfolio balance effects were small for Japanese yields and signaling effects could not be found.

Following a "taper tantrum" in mid-2013, which raised the concern on the normalization of U.S. monetary policy, academic interest on the effect of U.S. monetary policy on emerging economies has been increasing, too.

Bowman et al. (2014) use VAR and event study to examine the determinants of EMEs' vulnerability to UMP.[7] They find that the Fed's UMP shocks that lower U.S. sovereign yields also lower sovereign yields in most EMEs. They also find that countries with high interest rates, CDS spreads, inflation rates, current-account deficits and more vulnerable banking system seem to be affected more by changes in US financial variables.

Chen et al. (2014) present a similar finding that spillovers on asset prices and capital flows are significant and the impacts are smaller for countries with better fundamentals. Using factor analysis, they extract two factors ("signal shocks" and "market shocks") from the changes in Treasury yield of 1, 2, 3, 5, 7, 10, 20, and 30 years. Signal shocks, which affect expectations of future policy rates, are highly correlated with short-term yields while market shocks, which affect long-term yields through a variety of channels, are highly correlated with long-term yields. Panel regressions with daily data show that signal factor is more important for explaining stock price, equity investment, bond yields, and exchange rates. However, this effect is not found in bond flows.

[6] They also show that the estimates of changes in short-term expectations and term premia are very sensitive to model specification.

[7] In order to identify the monetary shocks under zero lower bound, they use the identification-through-heteroskedasticity method by assuming that the volatility of monetary policy shocks is higher on the day of UMP announcements. See Rigobon (2003) and Rigobon and Sack (2004) for the exposition of this method and Wright (2012) for an application related to monetary policy under zero lower bound.

Dahlhaus and Vasishtha (2014) examine the effect of "policy normalization" on portfolio flows. They firstly extract a common factor from monthly net portfolio flows to EMEs and then include it in a seven-variable VAR system, which consists of federal funds rate, term spread between US 10-year Treasury yield and federal funds rate, federal funds futures contract at the 36-month horizon, US inflation, US industrial production growth, VIX, and the common factor of capital flows. Then, by a sign restriction, they identify a "policy normalization shock" that increases the term spread and monetary policy expectations (as measured by federal funds futures rate) while the federal funds rate is left unchanged. The impact of this shock on capital flows to EMEs is rather small. However, they emphasize the potential importance of interactions between US monetary policy and country-specific macroeconomic variables.

Fratzscher et al. (2013) use daily data on portfolio equity and bond investment flows from January 2007 to December 2010 to examine the effect of UMP on capital flows to EMEs and advanced economies. Using regression analysis with dummies for the Fed' UMP-related announcement days, they find that QE1 was highly effective in lower sovereign yields and raising equity prices. While QE2 boosted equity prices worldwide, it did not affect yields across countries. In terms of capital flows, they find that QE1 triggered a portfolio rebalancing out of EMEs to U.S. and QE2 triggered rebalancing in the opposite direction. Like other studies, they find that heterogeneity in the response to US monetary policy is related to county-specific risk, suggesting pull factors can be more important.

Lim et al. (2014) attempt to quantify the impact of UMP and its hypothetical withdrawal on capital flows. Based on monthly data, their finding is that, of the 62 percent increase in inflows to developing countries during 2009–13 related to changing global monetary conditions, QEs are responsible for at least 13 percent of this. And their simulations of tapering suggest that, relative to a status quo of no change in quantitative easing, capital inflows contract by a 0.6 percent of developing country GDP by the end of 2016. And this result is not sensitive to the pace of tapering.

While some studies emphasize the role of economic fundamentals in insulating from foreign shocks (e.g., tapering talk), not all studies reach the same conclusion. Eichengreen and Gupta (2014) analyze the effect of the Fed's tapering talk on exchange rates, foreign reserves and equity prices in EMEs between April and August 2013. They

find that better fundamentals such as budget deficit, public debt, level of reserves and growth rate did not provide the proper insulation from the foreign shock. According to their research, countries with larger financial markets experienced more pressure on exchange rate, foreign reserves, and equity prices, suggesting that investors are better able to rebalance their portfolios when the target country has a relatively large and liquid financial market.

In this study, we focus on the specific case of Korean bond market to see if there are spillovers from U.S. unconventional monetary policy shocks and if there is any possibility of foreign capital outflows in response to external shocks.

3. Empirical Strategy

In this section, we illustrate the approach of our empirical study in a more general context and highlight the advantage of event-study approach to our research questions and the sources of potential biases.

3.1. A High-Frequency Event-Study Analysis

In general, two main problems in estimating the effect of (unconventional) monetary policy on asset prices (or returns) are the endogeneity of the variables under consideration and the omitted variable problem.

These issues can be captured in the following simplified system of equations, as used in Rigobon and Sack (2004):

$$\Delta i_t = \beta \Delta y_t + \gamma_1 z_t + \epsilon_t \tag{1}$$

$$\Delta y_t = \alpha \Delta i_t + \gamma_2 z_t + \eta_t \tag{2}$$

where Δi_t is the change in policy rate (or monetary policy stance) and Δy_t is the change in asset price or trading volume. Equation (1) can be interpreted as a monetary policy reaction function, which responds to Δy_t and z_t. z_t is a common shock that simultaneously affects both Δi_t and Δy_t.[8] The variable ϵ_t is a shock related to (unconventional)

[8]We treat z_t as a scalar for simplicity of exposition, but the results can be generalized to the case where z_t is a vector of variables.

monetary policy, and η_t is a shock to asset prices or trading volumes. These shocks are assumed to have no serial correlation and to be uncorrelated with each other and with the common shock z_t.

There are two ways to interpret interpret these equations in our context. One is to interpret (1) and (2) under zero lower bound environment. For Δi_t, we cannot use the changes in the level of federal funds rate because it is close to or stuck in zero lower bound. Instead, one can interpret it as news from UMP, such as an announcement on large-scale asset purchase. Then, we replace Δi_t with UMP_t, which represents any changes in unconventional monetary policy stances. Then, equation (1) and (2) can be rewritten as:

$$\begin{aligned}\text{UMP}_t &= \beta \Delta y_t + \gamma_1 z_t + \epsilon_t \\ \Delta y_t &= \alpha \text{UMP}_t + \gamma_2 z_t + \eta_t\end{aligned}$$

The other way is to interpret ε_t as shocks to monetary policy stances including UMP, and Δi_t as changes in yields of our interest (such as Treasury yields). And α will capture the effect of changes in Treasury yields on domestic bond yields. That is, we estimate an indirect effect of unconventional monetary policy shocks through their impact on other asset prices. In the following analysis, we take the first interpretation.

Let's proceed to talk about the potential sources of bias. The reduced-form of the system (1) and (2) is given by

$$\Delta i_t = \frac{1}{1-\alpha\beta}\left[(\beta\gamma_2 + \gamma_1)z_t + \beta\eta_t + \epsilon_t\right] \tag{3}$$

$$\Delta y_t = \frac{1}{1-\alpha\beta}\left[(\alpha\gamma_1 + \gamma_2)z_t + \alpha\epsilon_t + \eta_t\right] \tag{4}$$

Our main interest is the estimate of coefficient α, which measures the responses of domestic bond yields and trading volumes on unconventional monetary policy. However, regressing Δy_t on Δi_t results in bias. The probability limit of OLS regression of Δy_t on Δi_t is given by:

$$\text{plim}\,\hat{\alpha}_{OLS} = \alpha + (1-\alpha\beta)\frac{(\beta\gamma_2+\gamma_1)\gamma_2\sigma_z^2 + \beta\sigma_\eta^2}{(\beta\gamma_2+\gamma_1)^2\sigma_z^2 + \beta^2\sigma_\eta^2 + \sigma_\epsilon^2}$$

Note that there are two sources of bias. One is simultaneity bias and the other is the omitted variable problem. Simultaneity bias arises when β is not zero. It is because any changes in η_t will be transmitted to Δi_t through non-zero β, making Δi_t correlated with the error term η_t. The other is omitted variable bias. If we fail to consider z_t in (2), correlation between Δi_t and z_t will produce a biased estimate of α.

Fortunately, in terms of econometric specification, β is equal to zero in our context because any yield changes in Korean bond markets are not likely to affect the decision of monetary policy stance in U.S.[9] In other words, the Fed in U.S. does not care about the situations in South Korea in determining its monetary policy stances.[10] $\beta = 0$ implies no simultaneity problem in estimating (2). With $\beta = 0$, the above equation becomes:

$$\operatorname{plim} \hat{\alpha}_{OLS} = \alpha + \frac{\gamma_1 \gamma_2 \sigma_z^2}{\gamma_1^2 \sigma_z^2 + \sigma_\epsilon^2} \tag{5}$$

Equation (5) is now simplified. As long as neither γ_1 nor γ_2 are zero, it still suffers from bias caused by omitted variable problem. However, if σ_ϵ^2 is far larger than σ_z^2, the bias term will be smaller. As an extreme case, if the variance of the monetary shock becomes infinitely large compared to the variance of other shocks, or $\sigma_\epsilon/\sigma_z \to \infty$, then the bias will go to zero and the OLS estimate is consistent.[11]. A high-frequency event-study analysis can be a powerful tool in this case. If an event window is sufficiently narrow so that it captures only the innovations to monetary policy and there is no time for z_t to affect Δi_t, then a consistent OLS estimate is obtained.

Another advantage of using a high-frequency event-study approach for our study is that it is easier to detect the effect of major events or announcements related to UMP, since they are publicly announced.

[9] As of June 30, 2013, in term of value shares, South Korea takes 1.08% of total U.S. securities, 0.70% of equity, 1.35% of short-term debt, and 1.28% of long-term debt. Data come from "Foreign Portfolio Holdings of U.S. Securities," available at http://www.treasury.gov/resource-center/data-chart-center/tic/Pages/fpis.aspx.

[10] At a press conference on September 18, 2013, the then Fed chairman Bernanke says "The United States is part of a globally integrated economic and financial system, and problems in emerging markets—or in any country, for that matter—can affect the United States as well. And so, again, we are watching those developments very carefully." This statement hints that the Fed might consider the counter-spillover effects from emerging economies. However, it is still natural to assume that the Fed's monetary policy is not responsive to an individual economy of a small size.

[11] This property is referred as "near identification" in Fisher (1976)

3.2. Identification through Heteroskedasticity

The event-study analysis alone cannot test if these assumptions on relative size of variances are met. And the magnitude of the bias that remains in those estimates is unclear. Under this situation, the method of Rigobon and Sack (2004), so called identification through heteroskedasticity can be effective to see if the assumptions are valid. By comparing the estimates of the two methods, we can see the validity of the assumptions. However, since our main explanatory variables are dummy variables that take a value of zero or one, it is not easy to generate instrumental variables necessary for this method. One way to circumvent this problem is to rely on the second interpretation above and to use Δi_t in equation (1) instead of UMP_t. Gilchrist and Zakrajšek (2013) use this method to examine the effect of UMP on corporate credit risk. We do not consider this approach here and leave it for future research.

4. Main Analysis

4.1. Data

4.1.1. Statistics

For our analysis, we use U.S. Treasury yields, yields of Korean government bonds (KTB) and Monetary Stabilization Bond (MSB), foreign net investment in Korean bond market, and other macroeconomic variables. For U.S. Treasury daily yields, Department of Treasury provides the data.[12] For Korean bond-related data and macroeconomic variables, we use Infomax, Bloomberg, and the Bank of Korea Economic Statistics System. For data on weekly foreign net investment, we use the EPFR Global Database, which contains weekly net portfolio investment flows by more than 14,000 equity funds and more than 7,000 mutual and ETF bond funds, with U.S. $8 trillion of capital under management. While this database is known to represent only 5-20 percent of the market capitalization in equity and in bonds for most countries, generally with a lower proportion for bonds compared to equities, related research confirms that EPFR data can be deemed as a fairly good sample of global flows, closely matching portfolio flows stem-

[12] http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield

ming from balance of payment data.[13]

It is important to consider the changes from rolling-down (changes from maturing bond) to see the changes in how foreigners buy and sell domestic bonds. For example, a 2-year bond will be categorized as 1-year bond on a day when its remaining maturity becomes one-year or shorter. If this rolling-down happens, the outstanding value of 1-year bond increase while that of 2-year bond declines. Thus, the outstanding value of bonds can change without any actual purchase or sale. In this regard, the accurate measure of how foreigners buy and sell in a given period is net investment, not net purchase because net purchase is equal to (purchase - sales) and net investment is (net purchase - changes in rolling-down).

One can ask why we are interested in bond market, even though the size of foreign investment in stocks is far larger than that of bonds and the importance of foreign fund flows through bank lending is increasing. We do not ignore their significance. However, we reckon that the relative significance of foreign bond and equity investment has been changing after the financial crisis. Figure 1 shows the cumulative sums of monthly foreign net investment of bond and equity in South Korea from 2007. It shows that foreign equity funds exited from South Korea from 2007 and it reached the level of 2007 only after 2013. Meanwhile, foreign bond investment has been steadily increasing only except the period of late 2008-mid 2009. For foreign funds flows through banks, we cannot obtain a high-frequency data and leave it for future research.

4.1.2. Dates of UMP-Related News

Table 1 displays our choice of UMP-related dates with short description of events on those dates. In order to choose the announcement dates of UMP, we start from the choices of Krishnamurthy and Vissing-Jorgensen (2011) and Gilchrist and Zakrajšek (2013), which considers the first two QEs (LSAPs in their article) and Operation Twist (Maturity Extension Program in their article). They choose 11/25/08, 12/01/08, 12/16/08, 01/28/2009, and 03/18/2009 for QE1, 08/10/10, 09/21/2010, and 10/15/2010 for QE2, and 09/21/2011 for Operation Twist. In addition to these dates, we add the dates of QE3, tapering off, and forward guidance, using Chen et al. (2014), Bowman et al. (2014), FOMC minutes, and informal talks with bond market participants. We use 2013/05/22

[13] See Fratzscher et al. (2013) for more details on the features of the dataset.

and 2013/06/19 for the dates of tapering. Since forward guidance such as "economic conditions . . . are likely to warrant exceptionally low levels . . . at least through mid-2013" is often accompanied by large-scale asset purchases, our choice of forward guidance dates is confined to the dates of forward guidance that are not accompanied by large-scale asset purchases. Those dates are 2011/08/09 and 2012/01/25, as our choice of the dates of forward guidance.

We use one-day event window, partly because intraday data is not easily available in South Korea. However, previous research justifies the use of one-day event window in our study. Fleming and Remolona (1999) find that a release of a major macroeconomic announcement induces sharp and instantaneous changes in price and bid-ask spread, followed by a change in trading volume. While fluctuations in trading volume seems persistent, it ends within in a day.[14] In addition, Krishnamurthy and Vissing-Jorgensen (2011) shows that an intrady bond yield that reacts to UMP news during the day tends to stay at the after-change level until the end of the day, which also justifies the use of one-day window.

In the event-study approach below, we compare the results of Krishnamurthy and Vissing-Jorgensen (2011) and Gilchrist and Zakrajšek (2013) to see the validity of our choice.

4.2. U.S Case

We begin by running the following event-style regression using the US data:

$$\Delta i_t = \theta_0 + \theta_1 \text{QE1}_t + \theta_2 \text{QE2}_t + \theta_2 \text{QE3}_t + \theta_3 \text{OT}_t + \theta_4 \text{Taper}_t + \theta_5 \text{FG}_t + \varepsilon_t \tag{6}$$

where Δi_t denotes the daily changes of 1-year, 3-year, 5-year, 10-year, 20-year and 30-year Treasury yields; QE1 is a dummy variable which takes a value of one on the five QE1 announcement dates; QE2 is a dummy variable for the three QE2 announcement dates; QE3 is a dummy variable for the three QE3-related dates; OT is a dummy related to Operation Twist; Taper is a dummy related to tapering off; FG is a dummy for dates of forward guidance enunciating future low rates that are not accompanied by

[14] However, one-day event window is not justifiable in every study on financial market reactions. Some finance literature report evidence of over- or under-reaction in cases for small capitalization stocks or in less liquid markets.

QEs.[15]In this specification, the coefficients θ_i's measure the average effect of each dummies (QE1, QE2, QE3, OT, Taper, FG) on the specified yield. We estimate (6) by OLS over the sample period from 02/01/08 to 12/30/2014.[16]

Table 2 shows the average effects of UMP-related announcements on Treasury yields. According to the estimates in the table, the effect of QE1 on Treasury yields are quite substantial. It affects the yields of all maturities other than 30-year Treasury bond. For example, 10-year Treasury yield declines by 20 basis points (in average) following the five announcements related to QE1. These results are consistent with the ones from Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Wright (2012), and D'Amico and King (2013), who document that large-scale asset purchase programs lowered the long-term interest rates. Compared to the effects of QE1, the effects of QE2 and QE3 are rather weak. The statistically significant effects are not found in long-term interest rates.

Operation Twist, announced on September 21, 2011, affected the yields of all maturities. Note that Operation Twist was a plan to purchase $400 billion of Treasury securities with maturities of 6 to 30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less. In principle, this plan intends to lower the long-term interest rates and raise the short-term interest rates. These patterns are evident in Table 1. On the same day, 1-year, 3-year, and 5-year yields got higher while 10-year, 20-year, and 30-year yields declined.

Tapering also affected various yields. We consider the news on May 22, 2013 and June 19, 2013. According to the expectations hypothesis, which says that the long-term interest rate is the average of short-term forward rates, market expectation of an increase in short-term rate would result in an increase in long-term rates following tapering news, since they were interpreted as the normalization of monetary policy in the near future. As shown in table 2, on the days of tapering news, yields of Treasury securities with maturities of 5 to 30 years increased, suggesting that tapering news made

[15]For example, on December 13, 2012, QE3 are announced and, at the same time, the FOMC stated that it expected to keep the funds rate extremely low until at least mid-2015. While this statement is clearly an example of forward guidance, we categorize this date into QE3.

[16]Gilchrist and Zakrajšek (2013) run the similar regression:

$$\Delta i_t = \theta_0 + \theta_1 \text{LSAP-I}_t + \theta_2 \text{LSAP-II}_t + \theta_2 \text{MEP}_t + \epsilon_t$$

where LSAP corresponds to QE and MEP refers to Operation Twist. They use the daily data from January 2, 2008 to December 30, 2011.

market participants expect future short-term rates to increase , while they left short-term interest rates (1-year and 3-year) nearly untouched.

A dummy variable FG (forward guidance) takes a value of one on the days when the Fed enunciates keeping its policy rate at very low levels for the specific time periods, not announcing large-scale asset purchase programs. On Aug 9, 2011, FOMC statement says "economic conditions . . . are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013." If these announcements of keeping future policy rates low are credibly accepted by market participants, then we expect that long-term interest rates will decline. Our estimation result shows that forward guidance by the Fed worked well because all the yields except 1-year yield declined on the days of forward guidance (Aug 9, 2011 and January 25, 2012) just by the Fed's *verbal* emphasis on future low rates without any particular *actions* such as asset purchase program and maturity extension programs. This result is consistent with Gurkaynak et al. (2005), who shows that a large majority of the effects of FOMC statements could be attributed to information concerning future policy path in FOMC statements rather than to changes in current federal funds rate themselves.

To sum up, QEs (espeically QE1) were effective in lowering long-term interest rates. OT was very successful in achieving its goal of raising short-term rates and lowering long-term rates. News on tapering off raised long-term rates while the Fed's emphasis on future low policy rate resulted in lower interest rates. Results from OT, Taper, and FG variables suggest that the Fed's intention on future path of monetary policy is well accepted in financial markets.

Based on this result, we reckon that our choice of events date are not mis-guided because our results are consistent with previous studies and hypothesis based on economic theory. In the following section, we examine the effects of UMP on Korean bond markets, using the same set of UMP event dates.

4.3. Case of South Korea

4.3.1. Effects on Bond Yields

Now we turn to the case of South Korea. Table 3 provides a summary statistics related to foreign bond investment in South Korea.[17] Several patterns emerge: Firstly, shares of foreign investment in Korean bond market is steadily increasing. Relative to total market capitalization of Korean bond market, foreign share increase from 4.2 percent in 2007 to 8.8 percent in 2014. Secondly, foreign bond investment is concentrated mostly in two categories, KTB and MSB. Foreign investors spend more than 95 percent of their bond investment on KTB and MSB in 2014 (61.5 percent for KTB and 35.4 percent for MSB in 2014), while the shares of KTB and MSB in Korean bond market take only 33.3 percent and 6.8 percent of total bond market capitalization, respectively. Figure 2, 3, and 4 also confirm these. Lastly, the share of foreign net investment in long-term bonds is increasing over time. The share of long-term bond whose maturity is 10-year or longer increase from 11.1 percent in 2008 to 15.5 percent in 2014. It seems to reflect the increased popularity of "buy and hold" strategy by foreign investors.

We run the same regression equation of (6) using MSB yields of 1-year and 2-year, and KTB yields of 3-year, 5-year, 10-year, 20-year.[18] Table 4 shows our result. Contrary to the case of U.S., which shows a very systematic responses to UMP announcements, the immediate responses of Korean bond market are rather weak. While QE1 still lowers the yields of 3-, 5-, and 10-year KTB, the effects of QE2 and QE3 are almost non-existent.[19] Just like the U.S. case, the effect of OT on 21 September, 2011 (22 September, 2011 in South Korea) is strong: it raises short-term rates and lowers long-term rates. The news of tapering off on 2013/05/22 and 2013/06/19 does not affect Korean bond yields. And the effect of forward guidance is only found in relatively short-term rates. Since OLS estimates capture the average effect of events on multiple dates, we also look into the daily changes one by one. Table 5 shows the effects of selected dates. Note that the effect of tapering on Korean bond yields drastically differs depending on the dates. On May 22, 2013, when the then Fed chairman Bernanke told Congress the Fed may cut the pace of bond purchases at the next few meetings if policy makers see indications of

[17] We do not report the yield of 30-year KTB since it is available only from 11 September, 2012.

[18] 1-year and 2-year KTB bonds are "off-the-run."

[19] Result on QE2 is consistent with Fratzscher et al. (2013). According to their study, QE1 were highly effective in lowering sovereign yields and raising equity prices worldwide and QE2 boosted equity prices worldwide, it did not affect yields across countries.

sustained economic growth, 10-year Treasury yield rose by 9.6 basis point and 20-year yield rose by 6.8 basis point. However, nothing really happened to Korean bond yields on the very next day. Contrary to this, the news on June 19, 2013 strongly affected both the yields of U.S. and South Korea. The 10-year KTB yield rose by 17 basis point. The results in table 4 and 5 suggests that not every UMP news affects Korean bond yields and a mechanism in which UMP news affects Korean bond market may be different compared to the one for U.S.[20]

4.3.2. Effects on Foreign Net Investment

In this section, we examine the effect of UMP news on foreign net inflows. Using the weekly data from EPFR, we run the same regression equation of (6), just replacing the dependent variable with foreign net investment.[21]:

$$NI_t = \theta_0 + \theta_1 \text{QE1}_t + \theta_2 \text{QE2}_t + \theta_2 \text{QE3}_t + \theta_3 \text{OT}_t + \theta_4 \text{Taper}_t + \theta_5 \text{FG}_t + \varepsilon_t \tag{7}$$

Note that each dummy of three QEs, Operation Twist (OT), tapering (Taper), forward guidance (FG) takes the value of one when the week includes the day of a specific UMP news.[22]

Table 6 shows the result. We use three kinds of dependent variable: total amount of foreign net investment of EPFR dataset (Total), ETF-related bond funds (ETF), and bond funds related mutual funds (Mutual Fund). In our sample, ETF-related fund takes 14% of total amount and mutual fund-related fund takes 86%. While QE2 and QE3 do not have a noticeable effect on yields, they do increase foreign net investment, which is consistent with portfpolio balance channel. The negative estimate for QE1 would not necessarily imply that QE1 have a negative effect on foreign net investment in Korean bond market. Figure 5 shows that, at the timing of QE1 announcement, foreign net

[20]The result in 4 may result from a bias because Korean bond market is also affected by other factors, such as news from Euro area and Japan. That is, there is a possibility that the existence of z_t in (2) may cause a bias. However, even in this case, the patterns on 22 May, 2013 and June 19, 2013 in table 5 cannot be easily explained.

[21]We also have the foreign net investment statistics from Infomax. However, we do not think that it property takes the effect of rolling-down into account. We present the result from using the weekly EPFR dataset.

[22]In case a UMP new is announced on the last day of the week, we let the next week take the value of one instead, to fully capture the effect.

investment is negative, but recovering. Both Operation Twist and tapering news have a negative effect on foreign net investment, while the effect of forward guidance is not statistically different from zero.[23]

Evidence from Korean bond yields and foreign net investment suggests that U.S. (unconventional) monetary policy shocks affect Korean bond mearket, but not all shocks do. In the following section, we examine how we can explain the behavior of foreign net investment using factor analysis.

4.4. Factor Analysis Approach

In the above section, we observe that foreign net investment is affected by UMP news. We make another step to see what components of UMP shocks affect foreign net investment. By doing so, we provide an economic interpretation of our empirical finding.

Motivated by Gurkaynak et al. (2005) and Chen et al. (2014), we attempt to extract the common components that explains the changes in Treausury yields from 2 January, 2008 to 30 December 2014. The equation (8) displays the basic structure of factor analysis:

$$\Delta y_{it} = \gamma_{1i} f_{1t} + \gamma_{2i} f_{2t} + \cdots + \gamma_{ki} f_{kt} + \epsilon_{it} \tag{8}$$

Δy_{it} is the changes in U.S. Treasury yields of 1-, 2, 3-, 5-, 7-, 10-, 20-, and 30-year.[24] f_{kt} is the k-th factor and γ_{ki} is the k-th factor loading for factor i.

We perform factor analysis and find that two factors explain more than 95 percent of changes in various Treasury yields. After formally testing if having two factors is adequate to explain the variations of Treasury yields, we use the commonly used Varimax rotation method to find a plausible interpretation for each of them. As in Chen et al. (2014), we obtain a very nice interpretation of two factors, f_1 and f_2. Figure 6 shows the correlation coefficients of Δy_{it} with two factors, f_1 and f_2. One can easily see that f_1 tends to be highly correlated with changes in yields of longer maturities. And f_2 shows just the opposite case. In this regard, Chen et al. (2014) dub f_1 as "market factor" as they view it as encompassing the portfolio rebalancing channel of monetary policy, as

[23] Considering that Opertation Twist is to sell short-term debts and buy long-term debts, its impact on foreign net investment may differ depending on maturities.

[24] The Treasury yields of various maturities are calculated following Gürkaynak et al. (2007) and can be obtained from the Federal Reserve Board website (http://www.federalreserve.gov/econresdata/researchdata/feds200628.xls.

well as any other information the Fed communicates about the supply of bonds that will be available to private investors, and information on time-varying risk premia. And they name f_2 as "signal factor" because they interpret it as containing more information on future short-term policy rates of the Fed. We agree with their interpretation in general. Piazzesi and Swanson (2008) show that risk premia for very short-term yields are small and relatively stable at daily frequency. But, for longer-term bonds, risk premia are larger on average and more volatile over time. Their finding suggests that, if there is a factor moving more closely to long-term bond yields, that factor can be more about time-varying risk premia. This result is consistent with an interpretation of "market factor" in Chen et al. (2014). For "signal factor," if the expectation hypothesis of term structures holds, short-term yields like 1-year or 2-year bond would reflect the changes in expectation about future short-term policy rates.

With this interpretation of f_1 and f_2, we attempt to explain the behavior of foreign net investment using f_1 and f_2. We perform rolling regression based on the following equation (9):

$$NI_t = \beta_0 + \beta_1 f_{1t} + \beta_2 f_{2t} + u_t \tag{9}$$

Note that a negative β_1 implies that, as market participants perceive increased risk premia or a rise in long-term yields, foreign net investment declines. Likewise, a negative β_1 implies that tapering, accompanying expectation of an increase in future short-term policy rates, causes an exit of foreign funds from Korean bond market. Figure 6 shows the results when the window size is 26 weeks (half a year).[25] Both estimates of β_1 and β_2 are relatively stable during the early part of the sample period and become volatile later. It is notable that both estimates of β_1 and β_2 becomes negative during the period of Operation Twist (mid-2011) and the period when the possibility of tapering is much discussed by the Fed and mass media (from 2013). Especially the estimates of β_2, which shows the sensitivity of foreign net investment to f_2 ("signal factor"), becomes negative throughout the year of 2013 and it is statistically negative during mid-2013 when tapering is one of the most important economic issue. Considering that f_2 contains the information on future policy rate in the near future, it strongly suggests the possibility of outflows of foreign funds (negative foreign net investment).

[25] We perform rolling regression with different rolling windows and the main implication is not affected.

4.4.1. Regressions with Macroeconomic Variables

As shown above, U.S. UMP news clearly affects Korean bond market in terms of yields and foreign net investment, but not as sytematically as it affects U.S. bond yields. It suggests that "pull" factors may be important.

We follow the empirical approach in Won and Joo (2009), who examine the determinants of foreign bond investment using the daily data from January 2005 to February 2009. Our baseline regression equation to see the effect of other macroeconomic variables is as follows:

$$NI_t = \alpha_0 + \alpha_1 \Delta i_t + \alpha_2 \Delta E_t + \alpha_3 Arbitrage_{t-1} + \alpha_4 CDS_{t-1} + u_t, \tag{10}$$

where Δi_t is the change in domestic short-term interest rate, ΔE_t is the change in won/dollar exchange rate, and $Arbitrage$ is a measure of arbitrage opportunity, defined as the interest rate differential minus CRS (Currency Swap) rate. CDS is the CDS premium for South Korea, which is a proxy for country risk and a "pull" factor. We use the difference between 3-month CD rate in South Korea and 3-month LIBOR for the interest rate differential. We run variations of equation (10), differing from sets of explanatory variables, sample periods, and frequency of data. In most specifications, only the variable CDS premium is statistically significant and so is even at daily frequency.[26]

The experiment with macroeconomic variables shows that CDS rate for South Korea, which can be a "pull" factor, also affects foreign net investment.

5. Discussion

5.1. Fequency of Data

Event-study methodology requires several assumptions to hold. Firstly, only unanticipated events matter on the announcement day. It is equivalent to have $\sigma_\epsilon/\sigma_z \to \infty$. Another is that news of the policy change is immediately incorporated into variables under consideration.

[26]This result is different from Won and Joo (2009), who shows that all the explanatory variables in equation (10) are statistically significant. There are several reasons for this difference. To name a few, firstly, they do not use the data of foreign net investment. They instead use net purchase statistics, which may produce biased estimates. Secondly, the sample periods are different.

As discussed in 3.1., the estimates and their statistical significance are valid as long as the assumptions of event-study approach holds. We conjecture that the relative size of other shock z_t would be relatively small compared to the shocks of UMP, ε_t in a one-day time window. That is, we presume that $\sigma_\varepsilon \gg \sigma_z$ on the days of announcements. As shown in Krishnamurthy and Vissing-Jorgensen (2011), yields seem to stay at the same level after the initial change in response to news, while trading volume turns back to the level before the news after a couple of hours. In this regard, it seems sensible to use daily data, especially for yields.

Note that using a high-frequency data is not always best. As the FOMC statement becomes more complicated and delicate to interpret, as documented in Hernández-murillo and Shell (2014), it might take more than a day for market participants to correctly understand the intention of the Fed. Then, there might be delayed effects because it might take time to digest news. The event window should be narrow enough to avoid contamination from other news but wide enough to capture any delayed effects. We still need to check the validity of our finding using an intraday data, which is not currently available.

5.2. Role of Expectation

If market participants anticipate a UMP-related announcement before the announcement day and move ahead accordingly, the average effects based on the event-study approach would result in downward bias in terms of magnitude. We check this possibility and find that, even though some of the yields respond before UMP announcements, the magnitude of downward bias is not significant.

6. Conclusion

Our study begins with an event-study approach for the U.S. case and shows that the responses of U.S Treasury yields to UMP news are consistent with the objectives of UMP and predictions based on economic theory. For the case of South Korea, while the responses of yields and foreign net investment are not as systematic as the U.S. case, some of UMP-related news affect Korean bond market. To provide an economic interpretation, we extract the two factors that well capture the changes in U.S. Treasury

yields of various maturities and provide evidence that one factor is more closely related to long-term risk premia and the other factor is more closely related to expectation on future short-term policy rates. Then, we show that an increase in risk premia of U.S. bond market and upward adjustment of expectation on future short-term rate, proxied by the two factors, can cause foreign capital outflows in Korean bond market. We also examine the determinants of foreign net investment and find that CDS premium for South Korea, proxy of country risk, is statistically significiant in most specifications. Based on these empirical findings, we conclude that, while "pull" factor is also important, South Korea is not a "safe haven."

References

BAUER, M. D. AND C. J. NEELY (2014): "International Channels of the Fed's Unconventional Monetary Policy," *Journal of International Money and Finance*, 44, 24–46.

BOWMAN, D., J. M. LONDONO, AND H. SPARIZA (2014): "U . S . Unconventional Monetary Policy and Transmission to Emerging Market Economies," *FRB International Finance Discussion Paper No. 1109*.

CHEN, J., T. GRIFFOLI, AND R. SAHAY (2014): "Spillovers from United States Monetary Policy on Emerging Markets: Different This Time?" *IMF Working Paper 14/240*.

DAHLHAUS, T. AND G. VASISHTHA (2014): "The Impact of U.S. Monetary Policy Normalization on Capital Flows to Emerging-Market Economies," *Bank of Canada Working Paper 2014-53*.

DOH, T. (2010): "The Efficacy of Large-Scale Asset Purchases at the Zero Lower Bound," *Federal Reserve Bank of Kansas City Economic Review*, 5–34.

D'AMICO, S. AND T. B. KING (2013): "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply," *Journal of Financial Economics*, 108, 425–448.

EICHENGREEN, B. AND P. GUPTA (2014): "Tapering Talk: The Impact of Expectations of Reduced Federal Reserve Security Purchases on Emerging Markets," *World Bank Policy Research Working Paper 6754*, 1–21.

FISHER, F. (1976): *The Identification Problem in Econometrics*, R.E. Krieger, New York.

FLEMING, M. J. AND E. M. REMOLONA (1999): "Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information," *Journal of Finance*, 54, 1901–1915.

FRATZSCHER, M., M. L. DUCA, AND R. STRAUB (2013): "On the International Spillovers of US Quantitative Easing," *European Central Bank Working Paper No. 1557*.

GAGNON, J., M. RASKIN, J. REMACHE, AND B. SACK (2011): "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases," *International Journal of Central Banking*, 3–43.

GILCHRIST, S. AND E. ZAKRAJŠEK (2013): "The Impact of the Federal Reserve's Large-Scale Asset Purchase Programs on Corporate Credit Risk," *Journal of Money, Credit and Banking*, 45, 29–57.

GÜRKAYNAK, R. S., B. SACK, AND J. H. WRIGHT (2007): "The U.S. Treasury Yield Curve: 1961 to the Present," *Journal of Monetary Economics*, 54, 2291–2304.

GURKAYNAK, R. S., B. P. SACK, AND E. T. SWANSON (2005): "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*.

HERNÁNDEZ-MURILLO, R. AND H. G. SHELL (2014): "The Rising Complexity of the FOMC Statement," *Federal Reserve Bank of St. Louis Economic Synopses*.

JOYCE, M. A. AND M. TONG (2012): "QE and the Gilt Market: a Disaggregated Analysis," *The Economic Journal*, 122, F348–F384.

KRISHNAMURTHY, A. AND A. VISSING-JORGENSEN (2011): "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy," *Brooking Papers on Economic Activity*.

LIM, J. J., S. MOHAPATRA, AND M. STOCKER (2014): "Tinker , Taper , QE , Bye ? The Effect of Quantitative Easing on Financial Flows to Developing Countries," *World Bank Working Paper*.

MEANING, J. AND F. ZHU (2011): "The impact of recent central bank asset purchase programmes," *BIS Quarterly Review*.

NEELY, C. J. (2014): "Unconventional Monetary Policy had Large International Effects," *Federal Reserve Bank of St. Louis Working Paper*.

PIAZZESI, M. AND E. T. SWANSON (2008): "Futures Prices as Risk-Adjusted Forecasts of Monetary Policy," *Journal of Monetary Economics*, 55, 677–691.

RIGOBON, R. (2003): "Identification through Heteroskedasticity," *Review of Economics and Statistics*.

RIGOBON, R. AND B. SACK (2004): "The Impact of Monetary Policy on Asset Prices," *Journal of Monetary Economics*, 51, 1553–1575.

ROGERS, J. H. J., C. SCOTTI, AND J. J. H. WRIGHT (2014): "Evaluating Asset-Market Effects of Unconventional Monetary Policy : A Cross-Country Comparison," *FRB International Finance Discussion Paper*.

ROSA, C. (2012): "How "Unconventional" are Large-Scale Asset Purchases? The Impact of Monetary Policy on Asset Prices," *FRB of New York Staff Report No. 560*.

SWANSON, E., L. REICHLIN, AND J. WRIGHT (2011): "Let's Twist Again: A High-Frequency Event-Study Analysis of Operation Twist and Its Implications for QE2," *Brookings Papers on Economic Activity*.

WON, S. Y. AND S. JOO (2009): "A Study on the Determinants of Foreigners' Domestic Bond Investment and Their Impacts on the Korean Bond Market (in Korean)," *Kyung Je Hak Yon Gu*.

WRIGHT, J. J. H. (2012): "What Does Monetary Policy Do to Longterm Interest Rates at the Zero Lower Bound?*," *The Economic Journal*, 122, 447–466.

Table 1: **Timeline of Uncoventional Monetary Policy**

This table shows the timeline of US unconventional monetary policy. We categorize it into QE1, QE2, QE3, OT (Operation Twist), FG (forward guidance emphasizing low future policy rate, not accompanied by QEs), and Taper, based on Krishnamurthy and Vissing-Jorgensen (2011), Bowman et al. (2014) and Federal Reserve Board Press Release, available at http://www.federalreserve.gov/newsevents/press/monetary/2015monetary.htm. * denotes our choice for the baseline regression.

Date	Description	Category
Nov 25, 2008	The initial announcement of QE1 that the Federal Reserve would purchase up to $100 billion of agency debt and up to $500 billion of agency MBS.	QE1*
Dec 1, 2008	Bernanke's speech ("Federal Reserve Policies in the Financial Crisis") suggests that the Federal Reserve could purchase longer-term Treasury securities in substantial quantities in order to stimulate the economy.	QE1*
Dec 16, 2008	"The Federal Reserve will continue to consider ways of using its balance sheet to further support credit markets and economic activity." "Weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time."	QE1*
Jan 28, 2009	"The Committee continues to anticipate that economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time." "It stands ready to expand the quantity of such purchases and the duration of the purchase program as conditions warrant."	QE1*
Mar 18, 2009	"Economic conditions are likely to warrant exceptionally low levels of the federal funds rate for an extended period of time." The FOMC statement, which announced purchases of Treasury securities of up to $300 billion and increased the size of purchases of agency MBS and agency debt to up to $1.2 trillion and $200 billion, respectively.	QE1*
Mar 31, 2010	Completion of QE1	
Aug 10, 2010	"To help support economic recovery in the context of price stability, the Committee will keep the Federal Reserve's holdings of securities at their current level by reinvesting principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities. The Committee will continue to roll over the Federal Reserve's holdings of Treasury securities as they mature."	QE2*

Aug 27, 2010	Bernanke's speech at Jackson Hole: "The Committee is prepared to provide additional monetary accommodation through unconventional measures if it proves necessary, especially if the outlook were to deteriorate significantly"	QE2
Sep 21, 2010	The FOMC statement that indicated the Committee will maintain its existing policy of reinvesting principal payments from its securities holdings.	QE2*
Oct 15, 2010	Bernanke's speech at Boston Fed: "there would appear–all else being equal-to be a case for further action."	
Nov 3, 2010	QE2 announced. "[T]he Committee intends to purchase a further $600 billion of longer-term Treasury securities by the end of the second quarter of 2011, a pace of about $75 billion per month."	QE2*
Jun 30, 2011	QE2 completed	
Aug 9, 2011	"Economic conditions...are likely to warrant exceptionally low levels for the federal funds rate for at least through mid-2013."	FG*
Aug 26, 2011	Bernanke's speech at Jackson Hole: refusal to pledge more QEs	
Sep 21, 2011	Operation Twist: "To support a stronger economic recovery and to help ensure that inflation, over time, is at levels consistent with the dual mandate, the Committee decided today to extend the average maturity of its holdings of securities. The Committee intends to purchase, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of 6–30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less."	OT*
Jan 25, 2012	"Economic conditions ... are likely to warrant exceptionally low levels for the federal funds rate for at least through late 2014."	FG*
Jun 20, 2012	Operation Twist extended: "The Committee also decided to continue through the end of the year its program to extend the average maturity of its holdings of securities."	OT

Aug 31, 2012	QE3 hinted: "The Federal Reserve will provide additional policy accommodation as needed to promote a stronger economic recovery and sustained improvement in labor market conditions in a context of price stability."	QE3*
Sep 13, 2012	QE3 announced: "If the outlook for the labor market does not improve substantially, the Committee will continue its purchases of agency mortgage-backed securities, undertake additional asset purchases, and employ its other policy tools as appropriate." "will continue to maintain interest rates extremely low until at least mid-2015."	QE3*
Dec 12, 2012	"this exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored."	QE3*
May 22, 2013	Bernanke's testimony to Congress (known as "taper tantrum"): "In the next few meetings, we could take a step down in our pace of purchase."	Taper*
Jun 19, 2013	Bernanke's press conference: "If we see continued improvement and we have confidence that that is going to be sustained, then in the next few meetings, we could take a step down in our pace of purchases."	Taper*
Sep 18, 2013	Tapering delayed: "decided to wait a little longer to make sure the economy is conforming to" their positive economic outlook	
Dec 18, 2013	Tapering of QE3 announced	Taper
Jun 18, 2014	"If incoming information broadly supports the Committee's expectation of ongoing improvement in labor market conditions and inflation moving back toward its longer-run objective, the Committee will likely reduce the pace of asset purchases in further measured steps at future meetings."	Taper
Oct 29, 2014	End of QE3 announced	

Table 2: **The Effect of UMP Announcements on US Treasury Yields**

	Dependent Variables (Changes in Treasury Yields)					
	1 year	3 year	5 year	10 year	20 year	30 year
QE1	-0.042**	-0.121**	-0.182**	-0.200**	-0.133*	-0.115
	(0.019)	(0.054)	(0.081)	(0.090)	(0.073)	(0.070)
QE2	-0.002	-0.033***	-0.070***	-0.046	0.007	0.024
	(0.003)	(0.007)	(0.013)	(0.037)	(0.052)	(0.058)
QE3	-0.012***	-0.019	-0.033	-0.006	0.004	0.011
	(0.003)	(0.013)	(0.022)	(0.029)	(0.033)	(0.034)
OT	0.022***	0.071***	0.030***	-0.070***	-0.129***	-0.169***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Taper	-0.005*	0.037	0.090***	0.087***	0.067***	0.054***
	(0.003)	(0.027)	(0.034)	(0.021)	(0.015)	(0.014)
FG	-0.003	-0.084***	-0.155***	-0.135***	-0.089**	-0.069*
	(0.004)	(0.025)	(0.032)	(0.046)	(0.035)	(0.035)
R^2	0.004	0.018	0.034	0.036	0.019	0.017
p-value	0.314	0.000	0.000	0.000	0.000	0.000

This table shows the regression results of equation (6). Sample period is from January 2, 2008 to December 30, 2014 and the number of observation is 1,750. Dependent variable in each regression is the one-day change in the specified yields. Entries in the table denotes the OLS estimates of the average effect (in percentage points) of UMP annoouncements: three QEs, Operation Twist (OT), tapering (Taper), forward guidance emphasizing low future policy rate (FG). See Table 1 for the specific dates. All specifications include a constant (not reported here). The numbers in parentheses are heteroskedasticity-consistent standard errors. p-value is the F-test statistics of the null hypothesis that all coefficients are jointly zero.

Table 3: **Relative Shares of Foreign Bond Investment, by Type and Maturity**

	2007	2008	2009	2010	2011	2012	2013	2014
Total (amount)	576.9	638.0	730.4	850.1	941.4	1015.9	1095.4	1135.6
	Shares relative to outstanding value of dometics bond (%)							
KTB	24.1	25.0	25.3	28.4	31.1	31.6	32.3	33.3
MSB	16.9	14.0	11.5	10.6	9.5	8.1	6.7	6.8
	Shares relative to outstanding value of dometics bond (%)							
Pension	23.3	22.8	23.7	22.1	21.7	21.3	20.2	20.3
Insurance	21.5	21.2	19.7	20.2	22.1	24.0	27.0	29.7
Foreign	4.2	8.7	6.7	8.7	8.8	8.6	8.8	8.6
	Shares relative to outstanding value of foreign bond investment (%)							
Foreign								
KTB	56.7	49.5	48.9	55.9	67.6	67.0	59.8	61.5
1y	12.0	15.4	8.0	6.8	14.7	15.9	12.3	8.2
2y	12.7	9.6	9.6	16.8	18.9	15.7	9.7	13.4
3y	6.1	6.5	13.6	12.4	10.6	8.6	9.9	10.5
5y	14.7	7.9	7.3	9.7	12.4	12.1	12.7	13.9
10y+	11.1	10.1	10.3	10.2	11.0	14.6	15.2	15.5
MSB	24.5	39.9	42.6	39.1	27.4	27.2	35.9	35.4
1y	12.1	27.8	37.7	29.1	22.0	19.5	21.8	25.2
2y	12.3	12.1	4.9	10.9	5.4	7.7	14.0	10.2

This table shows the relative shares of foreign bond investment by type (KTB and MSB) and by maturities. 'Total (amount)' is the total outstanding value of domestic bond and the unit is trillion won. Shares of pension funds (Pension), insurance companies (Insurance) and foreignors (Foreign) are relative to the total outstanding value of domestic bond (Total (amount)). All other numbers are relative to the amount outstanding held by foreigners.

Table 4: **The Effect of UMP Announcements on Korean Treasury Yields**

	Dependent Variables (Changes in Yields)					
	MSB		Korean Treasury Bond			
	1 year	2 year	3 year	5 year	10 year	20 year
QE1	-0.032	-0.038	-0.110**	-0.106**	-0.062*	-0.051
	(0.026)	(0.034)	(0.051)	(0.045)	(0.036)	(0.034)
QE2	0.027	0.002	-0.003	-0.013	0.012	0.006
	(0.032)	(0.057)	(0.053)	(0.046)	(0.035)	(0.025)
QE3	-0.005	-0.008	-0.005	-0.015***	0.002	-0.005
	(0.003)	(0.005)	(0.003)	(0.006)	(0.008)	(0.007)
OT	0.002**	0.002*	-0.008***	-0.008***	-0.038***	-0.039***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Taper	0.026	0.031	0.042	0.048	0.062	0.052
	(0.019)	(0.025)	(0.037)	(0.038)	(0.045)	(0.041)
FG	-0.038*	-0.053*	-0.068*	-0.083	-0.068	-0.069
	(0.021)	(0.032)	(0.035)	(0.053)	(0.050)	(0.043)
R^2	0.005	0.003	0.014	0.014	0.009	0.007
p-value	0.294	0.474	0.000	0.000	0.016	0.048

This table shows the regression results of equation (6) for the case of South Korea. Sample period is from January 2, 2008 to December 30, 2014 and the number of observation is 1,746. Dependent variable in each regression is the one-day change in the specified yields. Entries in the table denotes the OLS estimates of the average effect (in percentage points) of UMP annoouncements: three QEs, Operation Twist (OT), tapering (Taper), forward guidance emphasizing low future policy rate (FG). Note that dummy variables have one-day lag for time lag between U.S. and South Korea. See Table (1) for the specific dates. All specifications include a constant (not reported here). The numbers in parentheses are heteroskedasticity-consistent standard errors. p-value is the F-test statistics of the null hypothesis that all coefficients are jointly zero.

Table 5: **Forward Guidance/Tapering Effects on Market Expectations**

	Yield Maturity					
	1-year	2-year	3-year	5-year	10-year	20-year
Aug 9, 2011 ("at least through mid-2013")						
US	-3.7	-8.6	-13.0	-19.1	-20.5	-11.9
S. Korea	-7.0	-10.0	-12.0	-16.0	-14.0	-13.0
Jan 25, 2012 ("at least through late 2014")						
US	-0.2	-3.8	-6.5	-9.4	-8.0	-1.0
S. Korea	-1.0	-1.0	-2.0	-1.0	0.0	-1.0
Sep 13, 2012 ("at least through mid-2015")						
US	-0.2	-0.9	-1.9	-3.7	-2.9	4.8
S. Korea	-1.0	-1.0	-1.0	-1.0	1.0	2.0
May 22, 2013 (taper tantrum)						
US	-0.9	1.3	3.4	6.8	9.6	6.8
S. Korea	0.0	0.0	0.0	0.0	0.0	0.0
Jun 19, 2013 ("step down in our pace of purchase")						
US	0.5	4.2	10.0	17.0	13.7	8.6
S. Korea	7.0	9.0	13.0	14.0	17.0	15.0

This table displays the yield changes of various maturities before and after major announcements related to forward guidance and tapering. For example, 1-year US Treasury yield drops by 3.7 basis point on Aug 9, 2011 compared to the yield on Aug 8, 2011. Since the event of US on Aug 9, 2011 is reflected in South Korea on the next day, Aug 10, 2011, yield changes for South Korea is between Aug 9, 2011 and Aug 10, 2011. Units are basis points (bp). Source: Gürkaynak et al. (2007) and Federal Reserve Board of Governors (http://www.federalreserve.gov/econresdata/researchdata/feds200628.xls) for U.S. data.

Table 6: **The Effect of UMP Announcements on Foreign Net Investment**

	Dependent Variables (Foreign Net Investment)		
	Total	ETF	Mutual Fund
QE1	-20.909***	-1.384	-19.525***
	(3.210)	(1.281)	(2.533)
QE2	36.419***	5.621	30.798***
	(6.432)	(4.969)	(2.034)
QE3	17.946***	-0.276	18.225***
	(6.596)	(5.246)	(2.960)
OT	-166.727***	-4.542***	-162.185***
	(2.055)	(1.090)	(1.598)
Taper	-193.167***	-25.042***	-168.125***
	(2.055)	(1.090)	(1.598)
FG	-27.692	-0.117	-27.570
	(25.847)	(1.229)	(26.377)
R^2	0.126	0.005	0.166
p-value	0.000	0.000	0.000

This table shows the regression results of equation (7). The sample period is from the first week of 2008 to the last week of 2014 and sample size is 364. Each dummy of three QEs, Operation Twist (OT), tapering (Taper), forward guidance takes the value of one when the week includes the day of a specific UMP news. All specifications include a constant (not reported here). The unit of the dependent variable is million dollars. The numbers in parentheses are heteroskedasticity-consistent standard errors. p-value is the F-test statistics of the null hypothesis that all coefficients are jointly zero.

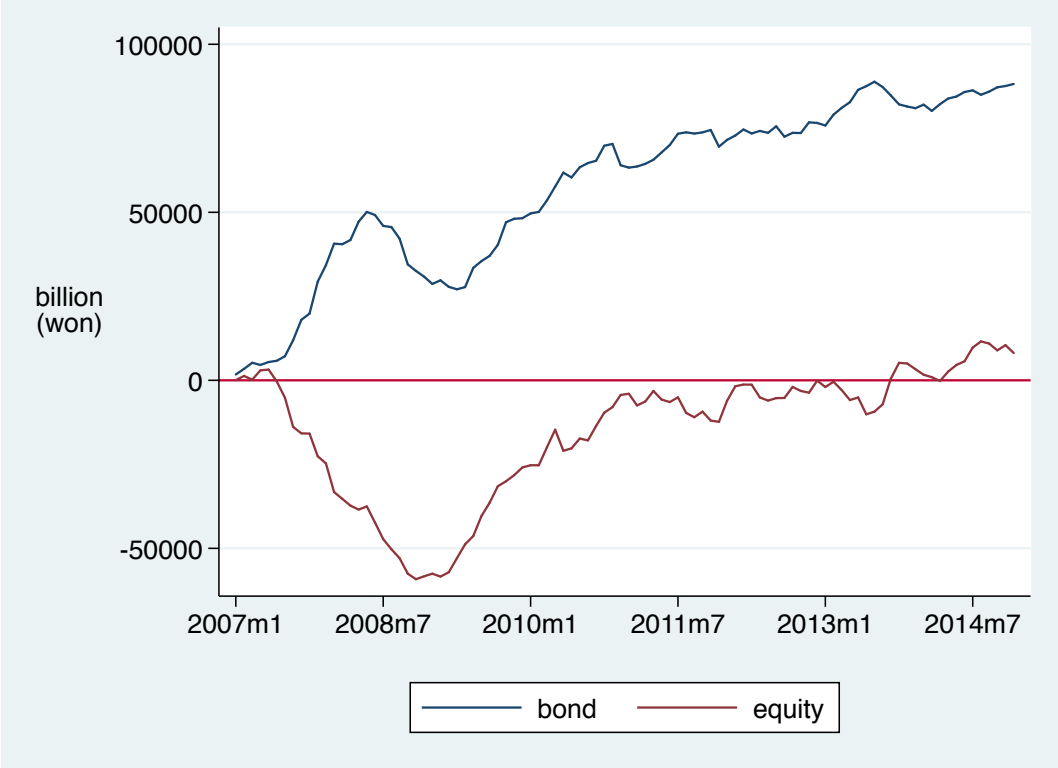

Figure 1: **Time-Series of Foreign Net Investment, Cumulative Sum**

This figure shows the cumulative sums of foreigners' net investment in bond and equity in South Korea from 2007 to 2014. Source: Infomax and ECOS (ecos.bok.or.kr)

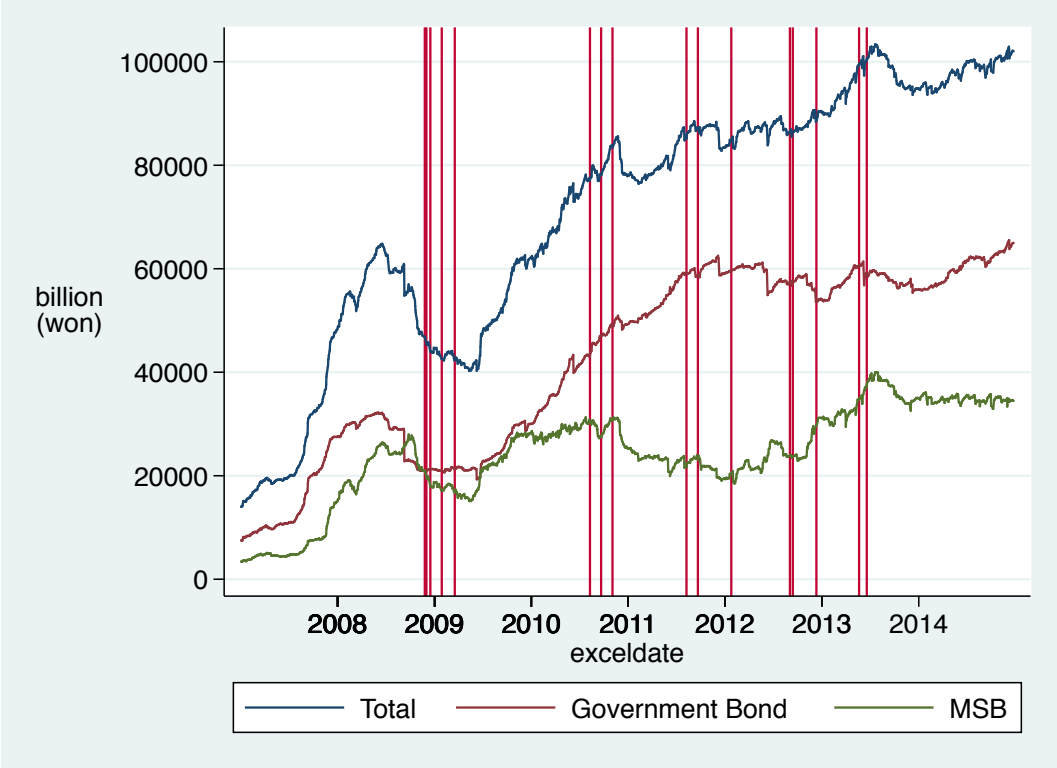

Figure 2: **Time-Series of Foreign Bond Investment, by Type**

This figure shows the daily time-series of foreigners' bond investment in South Korea from 2007 to 2014 by three categories: total amount (Total), Korean government bond (KTB), and Monetary Stabilization Bond (MSB).

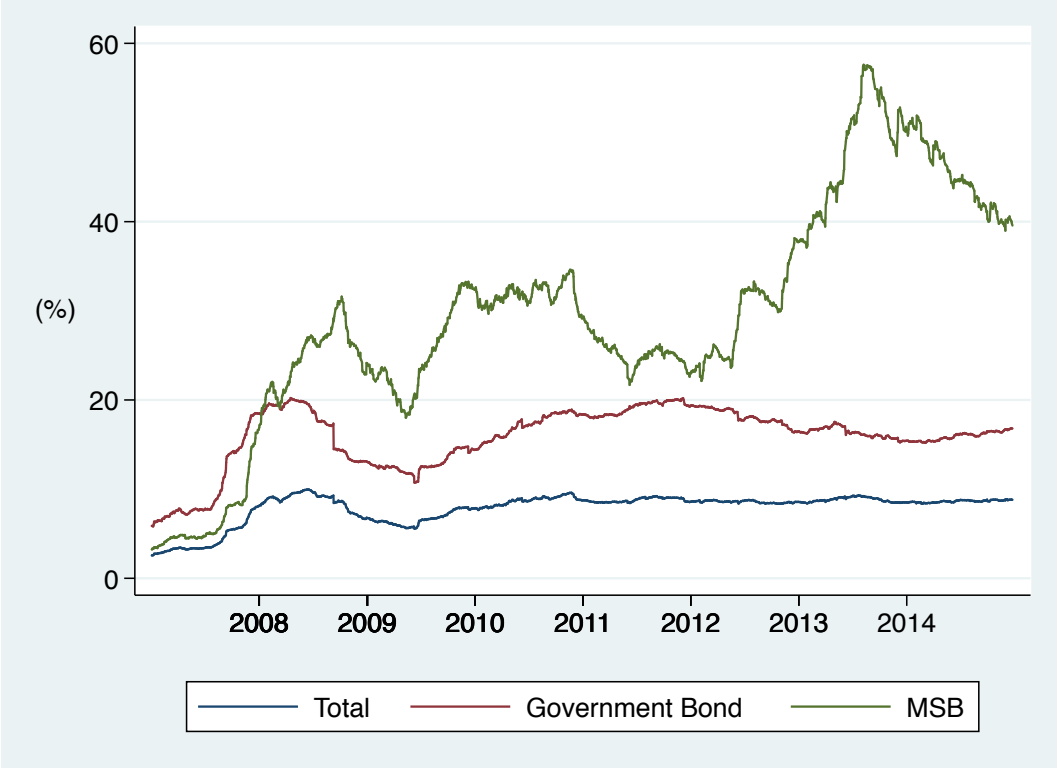

Figure 3: **Time-Series of Foreign Bond Investment (Ratio)**

This figure shows the daily time-series of foreigners' bond investment relative to market capitalization of each category in South Korea from 2007 to 2014.

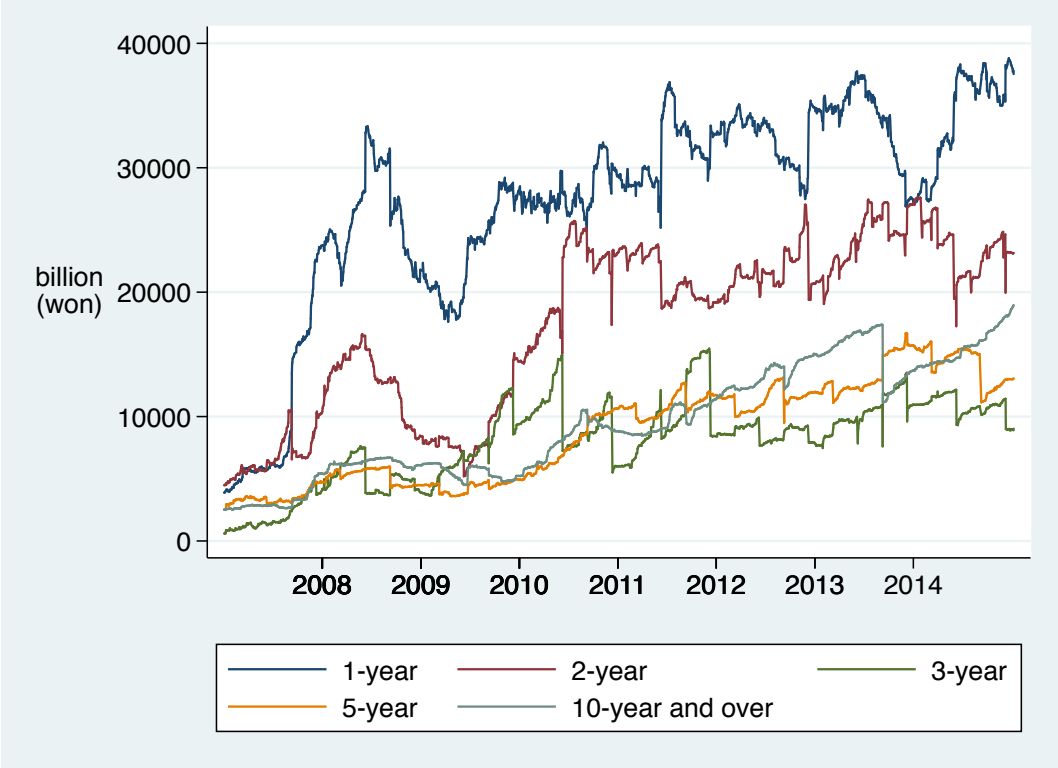

Figure 4: **Time-Series of Foreign Bond Investment, by Maturity**

This figure shows the time-series of foreigners' bond investment by maturities from 2007 to 2014.

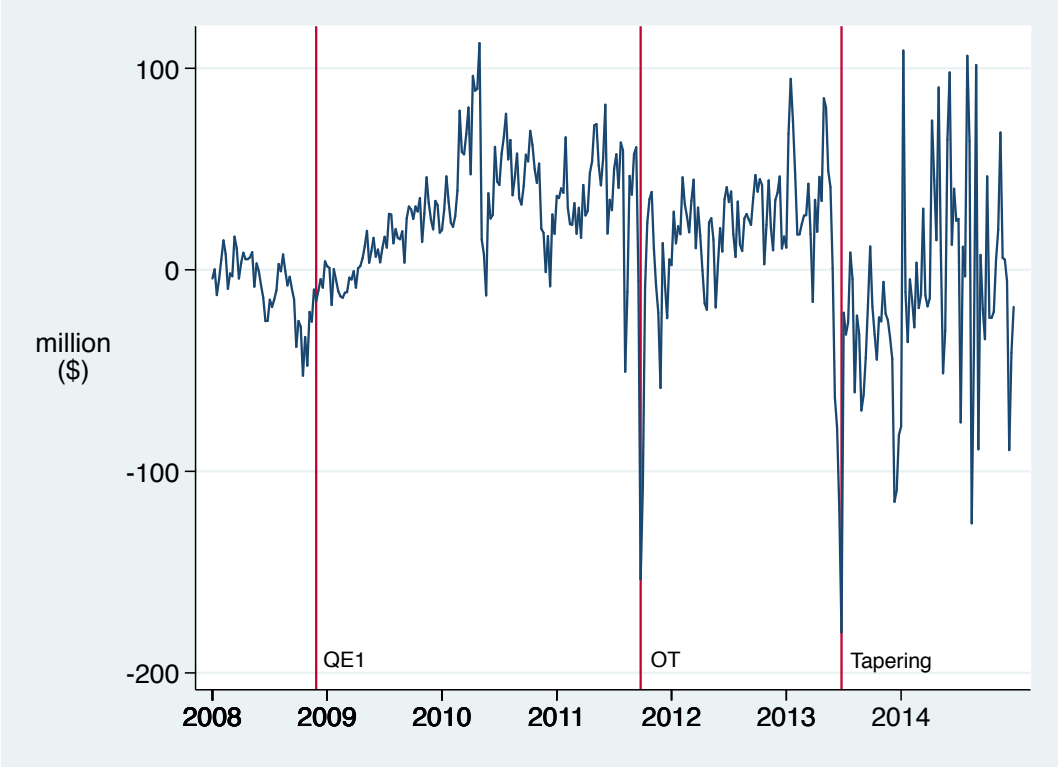

Figure 5: **Time-Series of Foreign Bond Net Investment**

This figure shows the weekly time-series of foreign net investment in Korean bond market from 2007 to 2014. The vertical lines denotes the selected dates of UMP news: 'QE1' denotes the week of the day QE1 announced (Nov 25, 2008). 'OT' denotes the week of the day Operation Twist announced (Sep 21, 2011). 'Taper' means the week of the day tapering news announced (June 19, 2013).

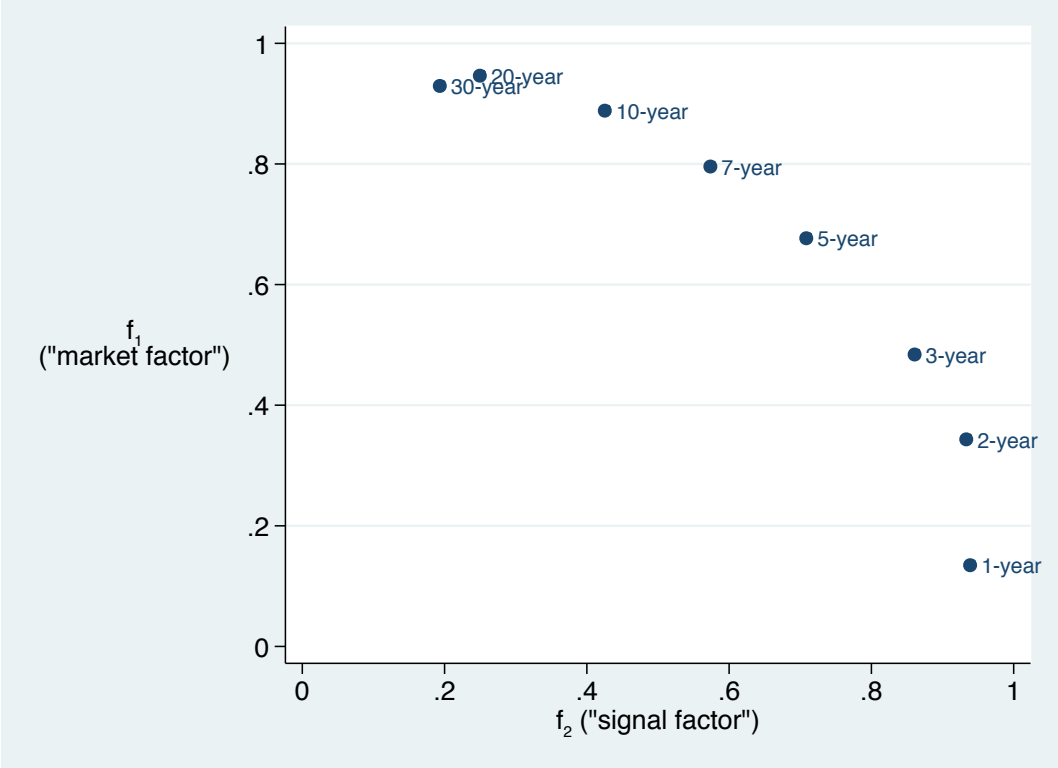

Figure 6: **Correlation between Yields of Different Maturities and Factor Loadings**

This figure shows the correlation between Treasury yields of different maturities and factor loadings: $Corr(\Delta y_{it}, f_{2t})$ for x-axis and $Corr(\Delta y_{it}, f_{1t})$ for y-axis.

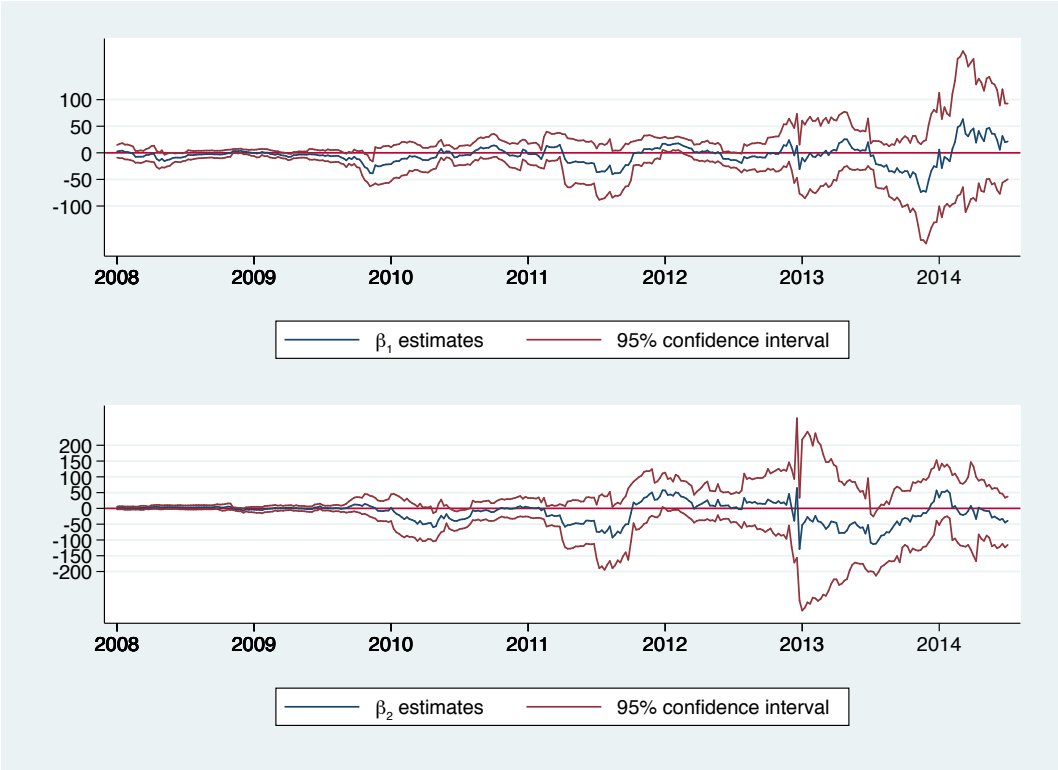

Figure 7: **Estimates from Rolling Regression**

This figure shows the OLS esimates from rolling regression of equation (9) from the first week of 2008 to the last week of 2014. The window is 26 weeks (half a year). 339 replication. Robust standard errors are used to construct the 95% confidence interval.