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# The Microstructure of China's Government Bond Market

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## Abstract

Although China now has one of the largest government bond markets in the world, the market has received relatively little attention and analysis. We describe the history and structure of the market and assess its functioning. We find that trading in individual bonds was historically sparse but has increased markedly in recent years. We find also that certain announcements of macroeconomic news, such as China's producer price index (PPI) and manufacturing purchasing managers' index (PMI), have significant effects on yields, even when such yields are measured at a daily level. Despite the increased activity in the market, we are able to reject the null hypothesis of market efficiency under two different tests for four of the most actively traded bonds.

Key words: trading activity, market efficiency, announcements, interest rates

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# I. Introduction

An efficient and well-functioning government bond market is often considered important to the smooth functioning of financial markets more generally. High liquidity in a government bond market can smooth the use of the market for hedging positions in other markets, facilitating issuance and secondary market trading in such markets. The creditworthiness of a government bond market, combined with liquidity, can make the market a benchmark for risk-free rates and for pricing instruments in other markets. Such characteristics also make government bonds a key store of value, especially during times of market turmoil.

While the importance of government bond markets has resulted in countless studies of such markets in the U.S. and other developed countries, there are relatively few studies of emerging government bond markets. In particular, only a small number of studies have examined the Chinese government bond market. For example, Cassola and Porter (2011) study Chinese bond yields and their role in monetary policy. Fan, Li, and Zhou (2012) use monthly data during 2001 – 2010 to test the preferred-habitat hypothesis in the Chinese bond market. Ye, Wang, and Yang (2010) assess Chinese bonds traded on the exchange market during 2003 – 2006 and study the common factors in Chinese bond returns. Fan, Tian, and Zhang (2012) examine the predictability of quarterly excess returns on Chinese government bonds from 1997 to 2009.

The Chinese government bond market is worthy of further study for several reasons. First, the market is large in an absolute sense with 7.38 trillion renminbi (RMB) outstanding as of December 31, 2011 ($1.17 trillion US dollars). Aside from the U.S. and Japanese government bond markets, the size of the Chinese market is on par with the largest government bond markets in the world. Moreover, given that the Chinese economy is now the second largest in the world and growing quickly, the importance of the Chinese government bond market to global financial markets is only likely to grow.

In this paper, we examine the Chinese government bond market with the goal of better understanding the market's liquidity and informational efficiency. While the amount of Chinese government debt outstanding is large, secondary market trading is modest, albeit growing quickly. Indicative of the lack of trading in many instruments is that prices are not available on a daily basis for many securities. Our initial analysis considers the determinants of trading for a given security – based on Bloomberg data availability – and finds that having a coupon, higher coupon rate, larger issue size, longer maturity, and more recent issuance are all associated with increased trading activity.

The market's efficiency at processing information is also an open question because of the limited trading that occurs. We conduct standard market efficiency tests and reject the null hypothesis that the market is efficient. We also examine the extent to which market prices are affected by macroeconomic news. We find that yields across the curve are significantly affected by producer price index (PPI) and manufacturing purchasing managers' index (PMI) surprises, but not other surprises. The lack of significance for most announcements may reflect the relative unimportance of the releases at determining prices, the manner in which the information is released, and/or the noisiness of the bond price data.

Lastly, we assess whether issuance supply shocks temporarily depress prices as has been found for the U.S. government bond market (Fleming and Rosenberg (2007) and Lou, Yan, and Zhang (2011)). While the short sample for which we have reasonably thorough data makes it difficult to identify such effects, the magnitude of any such effects might be larger for a less liquid market. In practice, we identify weak evidence in favor of such a price pressure effect for the Chinese government bond market.

Our paper contributes to the growing literature on China's financial markets, most of which has focused on equity markets. For example, Chan, Menkveld, and Yang (2008) examine the effects of information asymmetry on equity prices in the local A- and foreign B-share market in China. Fernald and Rogers (2002) propose that the A-B share premium may be caused by differences in discount factors for the A and B shares, since Chinese local investors and foreign investors face different investment opportunity sets and have different risk exposures. Xiong and Yu (2011) study the warrants bubble in China and test short-sales constraints and heterogeneous beliefs in driving bubbles. Mei, Scheinkman and Xiong (2009) further analyze the joint effects of short-sales constraints and heterogenous beliefs using data on A-B share premia, given that China's stock market has stringent short-sales constraints and perfectly segmented dual-class shares. Our paper also recognizes the distinctive features of China's financial markets, but focusses on implications for the government bond market as opposed to equity markets.

The paper proceeds as follows. In the next section, we discuss the history and structure of the Chinese government bond market. The data we analyze are reviewed in Section III. In Section IV, we present our empirical results, including those for what securities trade, the market efficiency tests, announcement effects, and the effects of supply shocks. Section V concludes.

## II. The Chinese Government Bond Market

*A. Market History and Structure*

Chinese government bonds were first issued in 1950 by the Ministry of Finance. Issuance was terminated in 1958, but resumed in 1981, primarily to address a shortfall in funding for national construction projects. The market remained quite small for many years, but has rapidly grown into one of the world's largest government bond markets in recent years, as shown in Figure 1.

[Figure 1 about here]

At first, China only had a primary market. Issuance was done through administrative allotment and government bonds could not be traded or transferred after issuance. Secondary market trading was introduced in select cities in 1988 and then allowed nationwide in 1990 when stock exchanges were opened in both Shanghai and Shenzhen.

China experimented with an underwriting system for government bond issuance in 1991, and then created a primary dealer system in 1993. Since 1996, all tradable government bonds have been issued through an auction system. A national unified bond custody and settlement system was established in December 1996 with the newly founded centralized securities depository, China Government Securities Depository Trust & Clearing Co., Ltd (CDC).

The secondary bond market includes three submarkets: the exchange market, the inter-bank market, and the over-the-counter (OTC) market. Until 1997, the exchange market was most active, and individual investors and commercial banks were the main participants. Banks were pulled out of the exchange market in 1997 and began conducting their trading in the inter-bank market. Since then, secondary trading for Chinese government bonds has been highly segmented, with activity split among stock exchanges, the inter-bank market, and the OTC market. The OTC market has consistently accounted for only a small share of market activity.

Between 1998 and 2001, the government instituted a number of changes authorizing inter-bank market participation for insurance companies, agricultural credit institutions, fund management (mutual fund) companies, securities firms, finance companies, and leasing companies. A market maker system was established in April 2001 to increase liquidity in the market. Since then, investors have been allowed to participate in multiple markets. Since 2005, all book-entry government bonds have been issued simultaneously in either two markets (stock exchanges and the interbank market) or all three (Jingu (2008)).

The distribution of depository holdings in China's government bond market has evolved with the changing market structure.[1] As of December 31, 1997, shortly after inter-bank trading was introduced, the inter-bank depository accounted for 29.6% of outstanding government bonds, with the exchange market accounting for 51.0% and the OTC market and other 19.4% (Source: Chinabond). As of December 31, 2011, after rapid growth of the inter-bank market, the inter-bank depository accounted for 92.8% of outstanding government bonds, the exchange market 2.7%, and the OTC market and other 4.5% (Source: Chinabond).

Commercial banks are the single largest investors in Chinese government bonds, accounting for 67.5% of bonds outstanding as of December 31, 2011. Insurance institutions (9.7%), special members (8.0%), funds institutions (7.9%), and other investors (6.9%) make up the balance. Special members include the People's Bank of China, the Ministry of Finance, policy banks, CDC, and the China Securities Depository & Clearing Corporation Limited.

*B. Issuance History and Patterns*

The rapid growth of China's government bond market has necessarily been led by increased issuance volume, as shown in Figure 2A. The increased issuance volume, in turn, is primarily attributable to an increase in issuance frequency, as shown in Figure 2B. Issuance sizes have varied somewhat over the years, as shown in Figure 2C, but have not shown an upward trend.

[Figure 2 about here]

The maturity profile of Chinese government bond issuance ranges from 3 months to 50 years. At the early stages of the market, issuance focused on 3-, 7-, and 10-year bonds. Through the auction system initiated in 1996, the Ministry of Finance diversified the maturity profile by also issuing short-term bills and long-term bonds. In November 2009, China auctioned its first 50-year super-term government bond to meet demand from pension funds and insurance companies (Financial Times, Nov 27, 2009).

Table 1 provides a timeline for the introduction of different maturities. As of 1996, only 3-, 7-, and 10-year bonds were issued. The 2-year was introduced in 1997,

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[1] In the Chinese bond market, each sector of the market is also the trustee of a portion of the total volume of bonds outstanding, known as its depository balance.

followed by the 5- and 30-year bonds in 1998. Over time, the term structure filled out; the most recent additions were the 9-month and 50-year bonds in 2009. Some bonds, however, were discontinued during the period. The 15-year bond was only issued from 2001 to 2009, and the 8-year Chinese government bond was issued only once, in 1999.

[Table 1 about here]

In contrast with some other government bond markets, Chinese bond issuance does not follow a standard calendar pattern. In the first half of 2011, for example, new 1-year notes were issued on Thursday, January 13, Thursday, March 24, Friday, April 15, Thursday, May 5, and Tuesday, May 10. In the U.S. in contrast, new 1-year bills are issued every four weeks, on a Thursday.

## III. Data

*A. Issue Characteristics and Prices*

The detailed bond issuance data in the paper comes from Bloomberg. Such data include the bond identification number, term, coupon rate, coupon type, issue size, issuance date, maturity date, and issuance price. Bloomberg has 629 unique identification numbers for RMB-denominated bonds issued between January 1996 and December 2011.[2] However, a bond issued on both the Shanghai and Shenzhen stock exchanges receives a different identification number for each exchange, so we find many pairs of bonds with the same issuance date, maturity date, term, issuance amount, issuance price, and coupon rate. We mark each pair as one bond and, after accounting for these duplications, identify 384 unique bonds issued between 1996 and 2011.

The secondary market data is also from Bloomberg and runs from October 15, 1999 through December 31, 2011. Bloomberg receives pricing data from a variety of sources, including exchanges and dealers, such as the Berlin Stock Exchange, Bank of China, Citibank, and HSBC. Bloomberg then uses a proprietary method called BVAL to compile and sometimes extrapolate the prices using all of the sources. The final data contain the bond identification number, closing price, and the associated yield to maturity. All data are at the daily frequency. There are 422 unique bond identification numbers in the secondary market dataset, or 276 after accounting for duplication

[2] As mentioned earlier, CDC, the central securities depository was established in 1996, facilitating the dissemination of Chinese government bond data since that time.

across exchanges. We therefore have no secondary market data for 108 of the 384 bonds issued between 1996 and 2011 (108 = 384-276).[3]

Even among the bonds for which there is pricing data, the data is sometimes sparse, reflecting the relatively low liquidity of the Chinese government bond market. Figure 3 shows the percent of secondary market data available by month. Data availability is calculated as the number of price or yield observations across all securities and trading days within a month divided by the number of observations there would be if none were missing.[4]

[Figure 3 about here]

Data availability has improved significantly in recent years across all securities. This improvement is most noticeable in 2009. In April 2009, in particular, the data availability jumps to 56.3% from 23.6% the preceding month. This sharp increase in data availability drives our decision to solely utilize data from April 1, 2009 to December 31, 2011 for most of our analyses.

[Table 2 about here]

Table 2 reports summary statistics for the bonds in our sample. Zero coupon bonds account for 19.5% of issued bonds, but only 0.7% of bonds for which we have secondary market prices, suggesting that pricing availability is much less prevalent for zero-coupon securities. The average coupon rate of all coupon-bearing bonds is 3.48%, close to the 3.47% average of coupon-bearing bonds for which we have secondary market prices, suggesting that data availability is comparable for higher- and lower-coupon securities (excluding securities with no coupon at all). The average issuance size is 31.4 billion RMB across all bonds, but 37.9 billion RMB for those with secondary market prices, suggesting that bonds with larger issuance sizes are more likely to be traded. The average maturity at issuance over all bonds is 6.76 years, whereas the average is 10.19 years for bonds with secondary market prices, suggesting that bonds

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[3] Three of the 384 bonds matured before the October 15, 1996 start of our secondary market sample period.

[4] In these calculations, we assume that the first day a bond can trade is the earlier of its issuance day and the first day for which we have data (thereby allowing for the inclusion of data for days when a security trades when-issued) and that the last day a bond can trade is the day before maturity. We define trading days to be synonymous with weekdays. In practice, despite holidays, we have price observations on every weekday of the year in recent years. We also observe prices on some weekend days, which emanates from the Chinese practice of extending some holidays while requiring work on a nearby weekend. Nonetheless, the frequency of price observations on weekends (when there are price observations) is much lower than on adjacent weekdays, so we exclude all weekend days from our analysis.

with longer maturities tend to be more actively traded. Finally, the average issuance year is just short of 2007 (2006.9) for all bonds, but 2007.3 for bonds with secondary market prices, suggesting that prices are more common for more recently issued securities, which is consistent with the evidence on the increased availability of secondary market prices over time (Figure 3).

*B. Yields*

For much of our analysis, we are interested in how market behavior differs across the yield curve. We therefore generate yield and yield change series for the four most frequently traded sectors, covering the 3-, 5-, 7-, and 10-year maturities. The 3-year sector is defined to include all bonds with a remaining time to maturity between 2.5 and 3.5 years; the 5-year sector includes bonds with a time to maturity between 4.5 and 5.5 years; the 7-year sector includes bonds with a time to maturity between 6.5 and 7.5 years; and the 10-year sector includes bonds with a time to maturity between 9.5 and 10.5 years. Because our sample period covers a number of years, the same bond can show up in different sectors at different times.

Since a certain number of yield observations appear inconsistent with their surrounding data, we use an algorithm to screen out potential outliers. In this algorithm, we first calculate the standard deviation of daily yield changes for each bond in our sample. We then flag all yield changes greater than five standard deviations in absolute value. For any such flagged changes followed by a flagged change in the opposite direction within 30 calendar days, we drop all observations between the two flags, including the first flagged observation but excluding the second. If the flag is within the first 15 or last 15 days of the sample period (for that security), then we drop all observations between the flag and the beginning or end (respectively) of the data series (for that security). In total, we drop 58 observations out of the 38,377 observations that fall into one of our four maturity buckets between April 1, 2009 and December 31, 2011.[5]

[Figure 4 about here]

Figure 4 plots average bond yields for each of the four sectors from April 1, 2009 through December 31, 2011. Yields are generally trending higher over the sample period, and show a sharp increase in October 2010 when the People's Bank of China tightened policy. As expected, yields tend to move together across the curve.

[5] While our filter is based on yield changes, we also drop the prices associated with the screened out yields.

Table 3 shows the relationships among the yields more formally. Panel A shows that the yields are highly correlated across the curve with the highest correlations, not surprisingly, being between securities adjacent on the curve. Panel B shows that daily yield changes are positively correlated, albeit less so than levels, with the highest correlations again those between adjacent securities. Panel C shows that weekly yield changes are consistently higher than daily yield changes, suggesting that yields may be affected by short-term technical factors, such as temporary order imbalances.

[Table 3 about here]

As a comparison, and to benchmark our results, we also calculate the correlations of yields and yield changes for the same four sectors in the U.S. Treasury securities market. Because of the high liquidity of the U.S. market, we consider the yields of the on-the-run 3-, 5-, 7-, and 10-year notes as being representative of the sectors (and do not average across all securities within the sectors). The yields are plotted in Appendix Figure A1 and the correlations are plotted in Appendix Table A1. The same general correlation patterns hold for the U.S. market, although the coefficients are generally higher. Also, the daily and weekly yield change coefficients are similar to one another for the U.S. market, suggesting that short-term technical factors may be less important to that market.

*C. Auction Dates*

For our analysis of supply effects, we collect auction dates from Bloomberg's World Economic Calendar (WECO) database.[6] In particular, for the period between April 1, 2009 and December 31, 2011, we identify auction dates for 59 of the 90 securities issued with original maturities of 3, 5, 7, and 10 years (12 of 26 for 3-year notes, 15 of 25 for 5-year notes, 16 of 18 for 7-year notes, and 16 of 21 for 10-year notes). We match up the auction dates with our broader dataset based on the proximity of auction dates to issuance dates for securities with the same original maturity.[7]

*D. Announcements*

To study the government bond market's response to China's macroeconomic news announcements, we also collect announcement data from Bloomberg. Data collected include the monthly announcements of the producer price index (PPI), consumer price index (CPI), real gross domestic product (GDP), money supply - M2, value added of

[6] Auction dates are not a field in the Bloomberg issuance dataset discussed earlier.
[7] All but one of the matched securities has an auction date one to two days before issue date. The exception has an auction date 12 days before issue date.

industry, retail sales, manufacturing purchasing managers' index (PMI), trade balance, and investment in fixed assets. These macroeconomic variables are released by the National Bureau of Statistics of China and are widely monitored by market participants as barometers of the Chinese economy.

Table 4 reports details of the macroeconomic announcements for the April 1, 2009 to December 31, 2011 period, including summary statistics of the announcement surprises (calculated as the actual number minus the expected number).[8] All announcements are measured as year-over-year percentage changes except for manufacturing PMI, which is measured as the percentage level, and trade balance, which is measured in billions of U.S. dollars. For each release date, we also observe the release times. Since the Shenzhen and Shanghai stock exchanges close at 3 pm, Chinese Standard Time, we assume that the initial market reaction to any announcements made after 3 pm Chinese Standard Time occurs the following trading day.

[Table 4 about here]

## IV. Results

*A. What Trades?*

As discussed, we do not observe secondary market prices or yields for many outstanding Chinese government bonds. For those for which we do observe prices or yields, the frequency of such observations varies substantially between securities, from as low as 0.1% to as high as 100%. Moreover, as shown in Table 2, the characteristics of bonds for which we do and do not observe secondary market prices differ appreciably. We proceed to examine more formally the relationship between security characteristics and the prevalence of secondary market prices in an effort to better understand how trading activity, and hence liquidity, varies across securities.

A key assumption underlying our analysis is that the prevalence of a security's pricing observations is a reasonable proxy for the security's trading activity. That is, we assume that a security with few or no secondary market prices trades less frequently than a security with many secondary market prices. While the assumption seems reasonable, it is possible that other factors independent of trading activity, and perhaps related to our explanatory variables, also explain the prevalence of pricing

[8] Note that the number of releases is less than the number of months in our sample for value added of industry, retail sales, and investment in fixed assets because these announcements were not released in February 2010 or February 2011.

observations, thereby biasing our results. In future work, we hope to obtain transactions data to verify our assumption.

We conduct our analysis by relating the prevalence of secondary market prices and yields to various security characteristics. Our dependent variable, $p_i$, equals the percent of trading days over a security's life, within our sample period, for which we observe a secondary market price or yield. The dependent variable is therefore almost continuous, but censored at zero and one. We therefore employ a two-sided Tobit model:

$$p_i^* = \alpha + \beta' \boldsymbol{X}_i + \varepsilon_i \ ,$$

$$where\ p_i = \begin{cases} p_i^* \ if \ p_i^* > 0 \ and < 1 \\ 0 \ if \ p_i^* \leq 0 \\ 1 \ if \ p_i^* \geq 1 \end{cases} \tag{1}$$

and $\boldsymbol{X}_i$ represents our vector of independent variables. The independent variables include an indicator variable equal to 1 if the bond has a coupon, coupon rate, issuance size, maturity at issuance, and issuance year (measured as the number of years since 1995). Issuance size and maturity at issuance have long right tails, so we include the natural logarithms of these variables in our models.

Table 5 displays the results for our full October 15, 1999 to December 31, 2011 sample period. In the univariate regressions, we find that whether a bond pays a coupon or not is the single most important determinant of trading, accounting for 17% of the variation in our data prevalence measure. Since securities with coupons are more likely to trade, it is not surprising to find coupon rate – defined here to be zero for zero coupon securities – also significantly related to trading activity. Trading activity is also found to be positively related to issuance size and maturity, so that larger and longer-term securities are more likely to trade. Lastly, trading activity is positively related to issuance year, so that more recently issued securities are more likely to trade.

[Table 5 about here]

The univariate findings hold up qualitatively in the multivariate model. Having a coupon, coupon rate, issuance size, and time to maturity are all positively correlated, so it is not surprising to see coefficients on all four variables become less significant in the multivariate model. The effect of issuance year, which is presumably picking up the increased level of trading activity over time, is actually somewhat greater in the multivariate model.

Because of the importance of issuance year in explaining trading activity, and because of the sharp increase in data availability in April 2009 (Figure 3), we repeat our analysis on the shorter April 1, 2009 to December 31, 2011 sample period. Qualitative results are almost the same as for the longer sample. All but one of the explanatory variable coefficients is of the same and statistically significant. The exception is the coefficient for coupon rate, which is negative and insignificant in the multivariate model.

*B. Market Efficiency*

We test the market efficiency of the Chinese government bond market using the Kendall Tau test and the variance ratio test.

The Kendall Tau test assesses whether two variables are statistically dependent. It is a measure of rank correlation. Consider two random variables X and Y each of size $n$, such that there is a set of $n$ joint observations $(x_1, y_1), (x_2, y_2),..., (x_n, y_n)$. If $x_j$-$x_i$ and $y_j$-$y_i$ have the same sign, then $(x_i, y_i)$ and $(x_j, y_j)$ are concordant. If $x_j$-$x_i$ and $y_j$-$y_i$ have opposite signs, then $(x_i, y_i)$ and $(x_j, y_j)$ are discordant. Let $n_c$ be the number of concordant pairs and $n_d$ be the number of discordant pairs. The Kendall score, $S$, is $n_c - n_d$. The Kendall $\tau$ coefficient standardizes $S$ by the number of pairs in the sample, $n$, and is given by:

$$\tau \equiv \frac{n_c - n_d}{\frac{1}{2}n(n-1)} \qquad (2)$$

The Kendall $\tau$ coefficient ranges from -1 to 1, where 1 means the two variables are perfectly positively correlated and -1 means the two variables X and Y are perfectly negatively correlated.

In our analysis, we assess whether bond prices follow a random walk by testing whether the series have independent increments as measured by their daily returns $\{r_t\}$. The null hypothesis is that the Kendall $\tau$ coefficient for $r_t$ and $r_{t-1}$ is equal to zero (Campbell, Lo, and MacKinlay, p. 34).

The variance ratio test is a test of uncorrelated increments across a variety of lag orders—traditionally 2, 4, 8, and 16 (Campbell, Lo, and MacKinlay, p. 49). Under the hypothesis that log prices follow a random walk, the variance of price increments should be distributed linearly as a function of the interval length. More specifically, for a test of lag order $Q$, the variance ratio VR(Q) is given by:

$$VR(Q) \equiv \frac{Var[r_t(Q)]}{Q*Var[r_t]} = 1 + 2\sum_{k=1}^{Q-1}\left(1 - \frac{k}{Q}\right)\rho(k) \qquad (3)$$

where $r_t(k) = r_t + r_{t-1} + \ldots + r_{t-k+1}$, and $\rho(k)$ is the k-order autocorrelation coefficient for the series of returns $\{r_t\}$. The null hypothesis is that in an efficient market where the random walk hypothesis holds, $\rho(k)$=0 and, thus, VR(Q)=1 for all values of Q. In particular, we test whether VR(Q) follows the following asymptotic distribution:

$$\sqrt{nq}(VR(Q) - 1) \sim N(0, \frac{2(2Q-1)(Q-1)}{3Q}) \quad (4)$$

We conduct the market efficiency tests on the most frequently traded bonds in our sample with maturity at issuance of 3, 5, 7, and 10 years. Frequency is measured as the number of trading days in our sample period from April 1, 2009 to December 31, 2011 in which we observe the price or yield. We conduct each test using the daily bond prices over this same period.[9]

The results are shown in Table 6. For the Kendall Tau test, the null hypothesis that the daily price follows a random walk is rejected at the 5% significance level for all bonds, suggesting that the market is not efficient. The lack of efficiency seems to be coming from negative autocorrelation in returns, as indicated by the negative value of the Kendall $\tau$ coefficient. The correlation between the daily return and its one day lag ranges from -0.09 in the case of the 7-year to -0.31 in the case of the 10-year bond.

Similarly, for the variance ratio test, the null hypothesis is rejected at the 5% statistical level for all bonds across lag orders of 2, 4, and 8. We fail to reject the null hypothesis at the 5% level for the 3-, 5-, and 7-year bonds for the test with lag order 16, which suggests that the returns exhibit less negative serial correlation over longer time intervals. This is consistent with our earlier conjecture that the lower correlation of daily vs. weekly yield changes might emanate from yields being affected by short-term technical factors.

[Table 6 about here]

As a comparison and to again benchmark our results, we conduct these same market efficiency tests on the U.S. market. The results, reported in Appendix Table A2, suggest that the U.S. market is efficient. For the Kendall Tau test, we fail to reject at the 10% significance level for all four securities the null hypothesis that the price follows a random walk. For the variance ratio test, we fail to reject at the 5% significance level

[9] The tests are done using "clean" prices (that is, prices that exclude accrued interest). Results are the same qualitatively if we look at yield changes instead of returns.

for all four securities and for all examined lag orders the null hypothesis that the price follows a random walk.

*C. Announcement Effects*

We assess announcement effects by regressing daily yield changes on announcement surprises, as in past studies. In particular, we regress the daily yield change, $\Delta y$, in each maturity sector, $m$, on the set of standardized announcement surprises, $\Delta Z$

$$\Delta y_m = a_m + \beta_m \Delta Z + \varepsilon_m \tag{5}$$

The daily yield change for a given sector is calculated as the average daily yield change (in basis points) for all securities within that sector. We take the average to reduce instances of missing data and to mitigate the effects of noisy price data. We also limit the analysis to the April 1, 2009 to December 31, 2011 period due to data availability.

Each announcement surprise is calculated as the difference between the actual release value on the announcement date and the Bloomberg survey value. The Bloomberg survey value is the average forecast taken from a survey of economists' forecasts. To standardize these shocks, we divide them by their sample standard deviation, as in Balduzzi, Elton, and Green (2001).

[Table 7 about here]

Table 7 displays the results. In univariate regressions, the PPI coefficient is consistently positive and statistically significant (at the 10% level or better) for all four maturities. The manufacturing PMI coefficient is also positive and significant at the 10% level for the 5-year sector, but positive and insignificant for the other sectors. Finally, the money supply (M2) coefficient is positive and significant at the 10% level for the 10-year sector, but not significant for any other sector. No other announcement surprise coefficients are statistically significant at the 10% level or better for any of the four maturity sectors.

In multivariate regressions, the PPI coefficient remains positive and statistically significant across all four sectors. The manufacturing PMI coefficient is positive and statistically significant for both the 3-year and 5-year sectors. No other announcement surprise coefficients are statistically significant at the 10% level or better for any of the four maturity sectors.

Because the announcement surprises are standardized, the regression coefficients are easy to interpret as the yield change (in basis points) per one standard deviation surprise shock. The PPI coefficient of 1.3 for the 3-year sector, for example, thus implies that the 3-year yield increases by 1.3 basis points for every one standard deviation positive PPI surprise.

Again, for comparison purposes, we conduct an announcements analysis for the U.S. market using a similar approach. In particular, for the same four sectors and same sample period, we regress yield changes on standardized announcement surprises. We differ somewhat in approach in only looking at yields for the on-the-run notes given the high liquidity of these securities. For macroeconomic announcements important in the U.S., we choose the eight monthly announcement surprises identified by Balduzzi, Elton, and Green (2001) as having significant effects on both intraday 2- and 10-year Treasury prices at the 1% level: consumer confidence, consumer price index, durable goods orders, new home sales, NAPM Index, producer price index, nonfarm payrolls, and retail sales.

The U.S. announcement effects are shown in Appendix Table A3. We identify positive and statistically significant (at the 1% level) coefficients for nonfarm payrolls and retail sales.[10] No other announcement surprise coefficients are statistically significant at the 10% level or better for any of the four maturity sectors.

The low number of significant announcements in the U.S. market is similar to that for the Chinese market, despite the large number of studies that have identified a high number of significant announcements in the U.S. market using intraday data, suggesting that the use of daily data may be partially responsible. However, the magnitudes of the significant coefficients are also much smaller for the Chinese market than the U.S. market, suggesting that there may also be differences between the two markets in the importance of the macroeconomic announcements, in how the information in the announcements is released, and/or in the quality of the market data.

*D. Supply Effects*

We test the effects of issuance supply shocks on the Chinese government bond market by examining secondary market yields over the days surrounding auctions. In the U.S. Treasury market, Fleming and Rosenberg (2007) show that prices tend to be depressed by new supply in auction weeks and recover in subsequent weeks. Lou, Yan, and Zhang (2011) document this pattern more thoroughly and attribute it to dealers' limited risk-bearing capacity and to the imperfect capital mobility of end investors.

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[10] Nonfarm payrolls has long been considered the most important scheduled macroeconomic announcement in the U.S. and retail sales is often found important (Fleming and Remolona (1997)).

Our particular methodology for assessing supply effects closely follows that of Lou, Yan, and Zhang (2011). In particular, we assess yields of the most recently issued securities around subsequent auctions of securities with the same maturity. While we identify 59 auctions over the April 1, 2009 to December 31, 2011 sample period in the more actively traded 3-, 5-, 7-, and 10-year sectors, we lose some observations for lack of yield data and exclude the 3-year sector from the analysis altogether due to sparse data.[11]

Our short sample period and data availability limits our ability to identify supply effects. While our sample period covers just over three years, Lou, Yan, and Zhang (2011) examine over 28 years of data for the U.S. market. Moreover, the quality of our data may be inferior to that available for the U.S. market, as illustrated by our need to filter the data for errors. That said, the lower liquidity of the Chinese market and its lower apparent efficiency suggest that the magnitude of any supply effects could be greater in this market, motivating our decision to look for evidence of supply effects despite limited data.

To examine the behavior of yields on the days surrounding an auction, we calculate the yield difference on day $t$, $\Delta Y_t$, where:

$$\Delta Y_t = yield(t) - yield(0) \tag{6}$$

and $t$ ranges from -10 to 10, and is equal to 0 on the day of the auction. We then average the yield changes across auctions for a given day and sector.

The average yield differences are reported in Table 8. The differences are generally negative in the 10 days preceding as well as 10 days following a subsequent auction, but most are statistically insignificant. However, the 5-year note has significant differences 6, 7, and 9 days before an auction, the 7-year note has a significant difference 5 days after an auction, and the 10-year note has a significant difference 4 days before and 5 days after an auction. All of the significant differences are of the expected sign (negative).

[Table 8 about here]

Figure 5 plots the average yield differences for the three securities for days -5 to 5 along with the 95% confidence interval. The figure provides some visual evidence of

[11] In particular, we only observe yields around auction day for 53 securities (9 for 3-year notes, 12 for 5-year notes, 15 for 7-year notes, and 17 for 10-year notes).

an inverted-V pattern for the three securities whereby yields tend to rise in the days preceding an auction and decline in the subsequent days.

[Figure 5 about here]

In sum, our evidence provides modest support for the hypothesis that issuance supply shocks pressure prices lower in the Chinese government bond market. Unsurprisingly given our small sample size, the statistical significance of our findings is weaker than that found for the U.S. market by Lou, Yan, and Zhang (2011). The general pattern of yield changes, with yields peaking on auction day, appears roughly similar in the two studies, as does the order of magnitude of the yield changes.

## V. Conclusion

We describe the history and structure of the Chinese government bond market and assess its liquidity and informational efficiency. We find that the rapid growth of the market has been accompanied by an increased incidence of trading across securities so that nearly all securities are now quoted on a given day. We find that coupon-bearing securities, higher coupon rates, larger issue sizes, longer maturities, and more recent issuance are all associated with increased trading activity.

We also find that certain announcements, such as the producer price index and manufacturing PMI, have significant effects on yields, even when such yields are measured at a daily level. The lack of significance for other announcements may reflect the relative unimportance of the releases at determining prices, the manner in which the information is released and/or the noisiness of the bond price data.

Despite the increased activity in the market, we are able to reject the null hypothesis of market efficiency under two different tests for four of the most actively traded bonds. These results suggest that while there may now be some activity in most bonds on a given day, the level of activity is likely still modest, perhaps impeding the ability of posted prices to accurately reflect the latest information.

Lastly, despite having a relatively short sample of reasonably thorough data, we uncover some evidence of prices declining in the days preceding an auction and recovering in the days after an auction. Such evidence is consistent with the idea that market frictions impede the ability of dealers to smooth yields around government bond issuance supply shocks.

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## Table 1: Issuance History by Sector

| | Maturity (Years) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0.25 | 0.5 | 0.75 | 1 | 2 | 3 | 5 | 7 | 8 | 10 | 15 | 20 | 30 | 50 |
| 1996 | | | | | | 3/10/1996 | | 11/1/1996 | | 6/14/1996 | | | | |
| 1997 | | | | | 1/22/1997 | | | | | | | | | |
| 1998 | | | | | | | 2/20/1998 | | | | | | 8/20/1998 | |
| 1999 | | | | | | | | | 8/20/1999 | | | | | |
| 2000 | | | | 11/24/2000 | | | | | | | | | | |
| 2001 | | | | | | | | | | | 6/6/2001 | 7/31/2001 | | |
| 2002 | | | | | | | | | | | | | | |
| 2003 | 12/29/2003 | | | | | 53 | | 58 | | 56 | | | | |
| 2004 | | | | | 16 | | 48 | | | | | | 15 | |
| 2005 | | | | 41 | | | | | | | 12 | | | |
| 2006 | | 7/25/2006 | | | | | | | | | | 12 | | |
| 2007 | 33 | | | | | | | | | | | | | |
| 2008 | | 21 | | | | | | | | | | | | |
| 2009 | | | 4/13/2009 | | | | | | | | 6/11/2009 | | | 11/30/2009 |
| 2010 | | | 13 | | | | | | | | | | | 5 |
| 2011 | 4/18/2011 | 9/19/2011 | 8/8/2011 | 9/15/2011 | 9/6/2011 | 12/8/2011 | 10/20/2011 | 10/13/2011 | | 11/17/2011 | | 4/28/2011 | 6/23/2011 | 11/10/2011 |

Notes: The table illustrates the issuance history for the different maturities of Chinese government bonds. For each maturity, the first issuance date is in green. The last issuance date as of December 31, 2011 is in red. The number next to each arrow is the total number of issuance dates for the given maturity. The 8-year bond was only issued once, on August 20, 1999, and is listed in black.
Source: Authors' calculations, based on data from Bloomberg.

Table 2: Bond Summary Statistics

| | Primary Market | | Secondary Market | |
|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Zero coupon (percent) | 19.53 | 39.70 | 0.70 | 8.31 |
| Coupon rate (percent) | 3.48 | 1.51 | 3.47 | 1.07 |
| Issuance size (billion RMB) | 31.44 | 56.18 | 37.91 | 67.78 |
| Maturity at issuance (years) | 6.76 | 8.28 | 10.19 | 8.67 |
| Issuance year (years) | 2006.88 | 3.90 | 2007.34 | 2.88 |
| Number of bonds | 384 | | 276 | |

Notes: The table reports summary statistics for the primary and secondary market data. The sample period for the primary market is January 1, 1996 to December 31, 2011 and the sample period for the secondary market is October 15, 1999 to December 31, 2011. Mean and standard deviation for coupon rate are only calculated over bonds with a coupon.
Source: Authors' calculations, based on data from Bloomberg.

Table 3: Correlations across Maturity Sectors

Panel A: Yield Correlations

| Sector | 3 Year | 5 Year | 7 Year | 10 Year |
|---|---|---|---|---|
| 3 year | 1.00 | | | |
| 5 year | 0.96 | 1.00 | | |
| 7 year | 0.90 | 0.97 | 1.00 | |
| 10 year | 0.80 | 0.89 | 0.94 | 1.00 |

Panel B: Daily Yield Change Correlations

| Sector | 3 Year | 5 Year | 7 Year | 10 Year |
|---|---|---|---|---|
| 3 year | 1.00 | | | |
| 5 year | 0.74 | 1.00 | | |
| 7 year | 0.47 | 0.60 | 1.00 | |
| 10 year | 0.39 | 0.47 | 0.70 | 1.00 |

Panel C: Weekly Yield Change Correlations

| Sector | 3 Year | 5 Year | 7 Year | 10 Year |
|---|---|---|---|---|
| 3 year | 1.00 | | | |
| 5 year | 0.78 | 1.00 | | |
| 7 year | 0.57 | 0.80 | 1.00 | |
| 10 year | 0.53 | 0.70 | 0.87 | 1.00 |

Notes: The table reports correlation coefficients for bond yields (Panel A), daily yield changes (Panel B), and weekly yield changes (Panel C) in the secondary market between April 1, 2009 and December 31, 2011. All correlations are calculated using a series of bonds and their corresponding average daily yields, grouped by maturity bucket. The 3-year maturity bucket includes all bonds with a time-to-maturity between 2.5 and 3.5 years; the 5-year sector includes bonds with a time-to-maturity between 4.5 and 5.5 years; the 7-year sector includes bonds with a time-to-maturity between 6.5 and 7.5 years; and the 10-year sector includes bonds with a time-to-maturity between 9.5 and 10.5 years.
Source: Authors' calculations, based on data from Bloomberg.

Table 4: Macroeconomic Announcement Summary Statistics

| Announcement | No. of Releases | Release Frequency | Mean Surprise | Min. Surprise | Max. Surprise | Std. of Surprises |
|---|---|---|---|---|---|---|
| Consumer Price Index | 33 | monthly | 0.00 | -0.60 | 0.50 | 0.25 |
| Producer Price Index | 33 | monthly | 0.01 | -1.20 | 1.00 | 0.49 |
| Real GDP | 11 | quarterly | 0.09 | -0.20 | 0.40 | 0.20 |
| Money Supply - M2 | 33 | monthly | 0.11 | -1.80 | 4.00 | 1.08 |
| Value Added of Industry | 31 | monthly | -0.07 | -6.10 | 2.10 | 1.48 |
| Retail Sales | 31 | monthly | -0.01 | -7.40 | 4.00 | 1.60 |
| Manufacturing PMI | 33 | monthly | -0.29 | -3.20 | 1.30 | 0.91 |
| Trade Balance | 33 | monthly | -0.81 | -12.20 | 11.33 | 5.94 |
| Investment in Fixed Assets | 31 | monthly | 0.22 | -1.10 | 2.20 | 0.80 |

Notes: The table summarizes characteristics of select macroeconomic announcements between April 1, 2009 and December 31, 2011. Note that no announcements were made in February 2010 or February 2011 for value added of industry, retail sales, or investment in fixed assets. All of the announcements are measured as year-over-year percentage changes except for manufacturing PMI, which is measured as a percentage level, and trade balance, which is measured in billions of U.S. dollars.
Source: Authors' calculations, based on data from Bloomberg.

Table 5: What Trades in the Secondary Market?

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Zero coupon | -1.07*** | | | | | -0.49*** |
| | (0.10) | | | | | (0.09) |
| Coupon rate | | 0.17*** | | | | 0.04** |
| | | (0.02) | | | | (0.02) |
| Ln(issuance size) | | | 0.16*** | | | 0.08*** |
| | | | (0.05) | | | (0.03) |
| Ln(maturity) | | | | 0.27*** | | 0.13*** |
| | | | | (0.03) | | (0.02) |
| Issuance year | | | | | 0.08*** | 0.10*** |
| | | | | | (0.01) | (0.01) |
| Constant | 0.56*** | -0.08 | 0.97*** | 0.04 | -0.60*** | -0.70*** |
| | (0.03) | (0.07) | (0.19) | (0.05) | (0.10) | (0.14) |
| Pseudo R-squared | 381 | 381 | 380 | 381 | 381 | 380 |
| Observations | 0.172 | 0.0979 | 0.0123 | 0.140 | 0.125 | 0.525 |

Notes: The table reports the results of two-sided-censored Tobit regressions explaining which bonds trade in the secondary market. The dependent variable is the percentage of days a bond has secondary market pricing data in the form of either price or yield. The sample period runs from October 15, 1999 to December 31, 2011. Zero coupon is an indicator variable equal to 1 if the bond has no coupon, coupon rate is in percent, ln(issuance size) is the natural log of issuance in trillions of RMB, ln(maturity) is the natural log of time to maturity at issuance, in years, and issuance year is defined as the issuance year minus 1995. Standard errors are in parentheses. One-, two-, and three- asterisks indicate statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.
Source: Authors' calculations, based on data from Bloomberg.

Table 6: Market Efficiency Tests

Panel A: Kendall Tau Test

| Bond | Term | Maturity Date | N | $\tau$ Coefficient | Standard Error | P-value |
|---|---|---|---|---|---|---|
| EH828153 | 3 | 5/21/2012 | 681 | -0.058 | 5917 | 0.023 |
| EH652950 | 5 | 2/15/2019 | 717 | -0.077 | 6393 | 0.002 |
| EF292522 | 7 | 2/27/2013 | 717 | -0.078 | 6393 | 0.002 |
| EG571997 | 10 | 6/25/2017 | 717 | -0.136 | 6393 | 0.000 |

Panel B: Variance Ratio Test

| Bond | Term | Maturity Date | N | Number of Lags (Q) | VR(Q) | P-value |
|---|---|---|---|---|---|---|
| EH828153 | 3 | 5/21/2012 | 666 | 2 | 0.834 | 0.000 |
| | | | | 4 | 0.741 | 0.000 |
| | | | | 8 | 0.753 | 0.032 |
| | | | | 16 | 0.841 | 0.356 |
| EH652950 | 5 | 2/15/2019 | 702 | 2 | 0.860 | 0.000 |
| | | | | 4 | 0.737 | 0.000 |
| | | | | 8 | 0.657 | 0.002 |
| | | | | 16 | 0.676 | 0.053 |
| EF292522 | 7 | 2/27/2013 | 702 | 2 | 0.918 | 0.029 |
| | | | | 4 | 0.799 | 0.005 |
| | | | | 8 | 0.748 | 0.024 |
| | | | | 16 | 0.754 | 0.142 |
| EG571997 | 10 | 6/25/2017 | 702 | 2 | 0.680 | 0.000 |
| | | | | 4 | 0.508 | 0.000 |
| | | | | 8 | 0.412 | 0.000 |
| | | | | 16 | 0.364 | 0.000 |

Notes: The table reports results of efficiency tests for the Chinese government bond market for the April 1, 2009 to December 31, 2011 sample period. For the analysis, we select the four most frequently traded bonds within the sample period with maturity at issuance of 3, 5, 7, and 10 years. We test for market efficiency using each of these four bonds using the Kendall Tau test and the variance ratio test. The Kendall Tau test assesses whether prices follow a random walk through the hypothesis of uncorrelated returns. For each bond and trading date, the return $r_t$ is calculated as the proportional change in price from the previous trading day. The variance ratio test assesses whether prices follow a random walk by testing whether variances of the series $r_t$ and $r_{t-k}$ (where k is the number of lagged observations) are distributed as a linear function of k. As is standard in the literature, we test for lags of 2, 4, 8, as well as 16.
Source: Authors' calculations, based on data from Bloomberg.

Table 7: Macroeconomic Announcement Effects

Panel A: 3 Year

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| Consumer Price Index | -0.41 | | | | | | | | | -0.50 |
| | (0.85) | | | | | | | | | (0.90) |
| Real GDP | | 0.17 | | | | | | | | -0.55 |
| | | (1.19) | | | | | | | | (1.26) |
| Producer Price Index | | | 1.34* | | | | | | | 1.79** |
| | | | (0.75) | | | | | | | (0.79) |
| Money Supply- M2 | | | | -0.67 | | | | | | -0.85 |
| | | | | (0.75) | | | | | | (0.76) |
| Value Added of Industry | | | | | 1.14 | | | | | 1.54 |
| | | | | | (0.78) | | | | | (0.96) |
| Retail Sales | | | | | | -0.39 | | | | 0.16 |
| | | | | | | (0.82) | | | | (1.02) |
| Manufacturing PMI | | | | | | | 1.41 | | | 1.42* |
| | | | | | | | (0.86) | | | (0.86) |
| Trade Balance | | | | | | | | 0.63 | | 0.79 |
| | | | | | | | | (0.80) | | (0.80) |
| Investment in Fixed Assets | | | | | | | | | -0.83 | -0.79 |
| | | | | | | | | | (0.76) | (0.80) |
| Constant | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.05 | 0.04 | 0.05 | 0.08 |
| | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) |
| Observations | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 |
| Adjusted R-squared | -0.001 | -0.001 | 0.003 | -0.000 | 0.002 | -0.001 | 0.002 | -0.001 | 0.000 | 0.005 |

Panel B: 5 Year

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| Consumer Price Index | -0.36 | | | | | | | | | -0.73 |
| | (0.85) | | | | | | | | | (0.90) |
| Real GDP | | 0.77 | | | | | | | | 0.38 |
| | | (1.18) | | | | | | | | (1.26) |
| Producer Price Index | | | 1.37* | | | | | | | 1.65** |
| | | | (0.75) | | | | | | | (0.79) |
| Money Supply- M2 | | | | 0.26 | | | | | | 0.18 |
| | | | | (0.74) | | | | | | (0.76) |
| Value Added of Industry | | | | | 0.95 | | | | | 0.95 |
| | | | | | (0.78) | | | | | (0.95) |
| Retail Sales | | | | | | -0.57 | | | | -0.40 |
| | | | | | | (0.81) | | | | (1.01) |
| Manufacturing PMI | | | | | | | 1.44* | | | 1.44* |
| | | | | | | | (0.86) | | | (0.86) |
| Trade balance | | | | | | | | 0.42 | | 0.45 |
| | | | | | | | | (0.79) | | (0.80) |
| Investment in Fixed Assets | | | | | | | | | -0.65 | -0.67 |
| | | | | | | | | | (0.75) | (0.80) |
| Constant | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.05 | 0.06 |
| | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) | (0.15) |
| Observations | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 |
| Adjusted R-squared | -0.001 | -0.001 | 0.003 | -0.001 | 0.001 | -0.001 | 0.003 | -0.001 | -0.000 | 0.002 |

Panel C: 7 year

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| Consumer Price Index | 0.11 | | | | | | | | | -0.33 |
| | (1.10) | | | | | | | | | (1.17) |
| Real GDP | | 1.06 | | | | | | | | 0.46 |
| | | (1.54) | | | | | | | | (1.64) |
| Producer Price Index | | | 1.94** | | | | | | | 2.10** |
| | | | (0.98) | | | | | | | (1.03) |
| Money Supply- M2 | | | | 0.36 | | | | | | 0.38 |
| | | | | (0.97) | | | | | | (0.99) |
| Value Added of Industry | | | | | 1.26 | | | | | 0.93 |
| | | | | | (1.01) | | | | | (1.24) |
| Retail Sales | | | | | | -1.15 | | | | -1.31 |
| | | | | | | (1.06) | | | | (1.32) |
| Manufacturing PMI | | | | | | | 1.32 | | | 1.32 |
| | | | | | | | (1.12) | | | (1.11) |
| Trade Balance | | | | | | | | -0.69 | | -0.64 |
| | | | | | | | | (1.03) | | (1.04) |
| Investment in Fixed Assets | | | | | | | | | -1.31 | -1.58 |
| | | | | | | | | | (0.98) | (1.04) |
| Constant | 0.06 | 0.06 | 0.07 | 0.06 | 0.07 | 0.06 | 0.07 | 0.06 | 0.08 | 0.09 |
| | (0.19) | (0.19) | (0.19) | (0.19) | (0.19) | (0.19) | (0.19) | (0.19) | (0.19) | (0.19) |
| Observations | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 |
| Adjusted R-squared | -0.001 | -0.001 | 0.004 | -0.001 | 0.001 | 0.000 | 0.001 | -0.001 | 0.001 | 0.003 |

Panel D: 10 Year

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| Consumer Price Index | 0.84 | | | | | | | | | 0.19 |
| | (1.26) | | | | | | | | | (1.34) |
| Real GDP | | -0.36 | | | | | | | | -1.16 |
| | | (1.77) | | | | | | | | (1.88) |
| Producer Price Index | | | 2.21** | | | | | | | 2.11* |
| | | | (1.12) | | | | | | | (1.18) |
| Money Supply- M2 | | | | 1.94* | | | | | | 1.86 |
| | | | | (1.11) | | | | | | (1.14) |
| Value Added of Industry | | | | | 0.18 | | | | | 0.73 |
| | | | | | (1.16) | | | | | (1.43) |
| Retail Sales | | | | | | 0.15 | | | | 0.13 |
| | | | | | | (1.21) | | | | (1.52) |
| Manufacturing PMI | | | | | | | 0.93 | | | 0.93 |
| | | | | | | | (1.28) | | | (1.28) |
| Trade Balance | | | | | | | | -0.97 | | -1.15 |
| | | | | | | | | (1.19) | | (1.20) |
| Investment in Fixed Assets | | | | | | | | | -0.79 | -0.90 |
| | | | | | | | | | (1.12) | (1.19) |
| Constant | 0.00 | 0.00 | 0.00 | -0.01 | 0.00 | -0.00 | 0.01 | -0.00 | 0.01 | 0.02 |
| | (0.22) | (0.22) | (0.22) | (0.22) | (0.22) | (0.22) | (0.22) | (0.22) | (0.22) | (0.22) |
| Observations | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 | 726 |
| Adjusted R-squared | -0.001 | -0.001 | 0.004 | 0.003 | -0.001 | -0.001 | -0.001 | -0.000 | -0.001 | -0.000 |

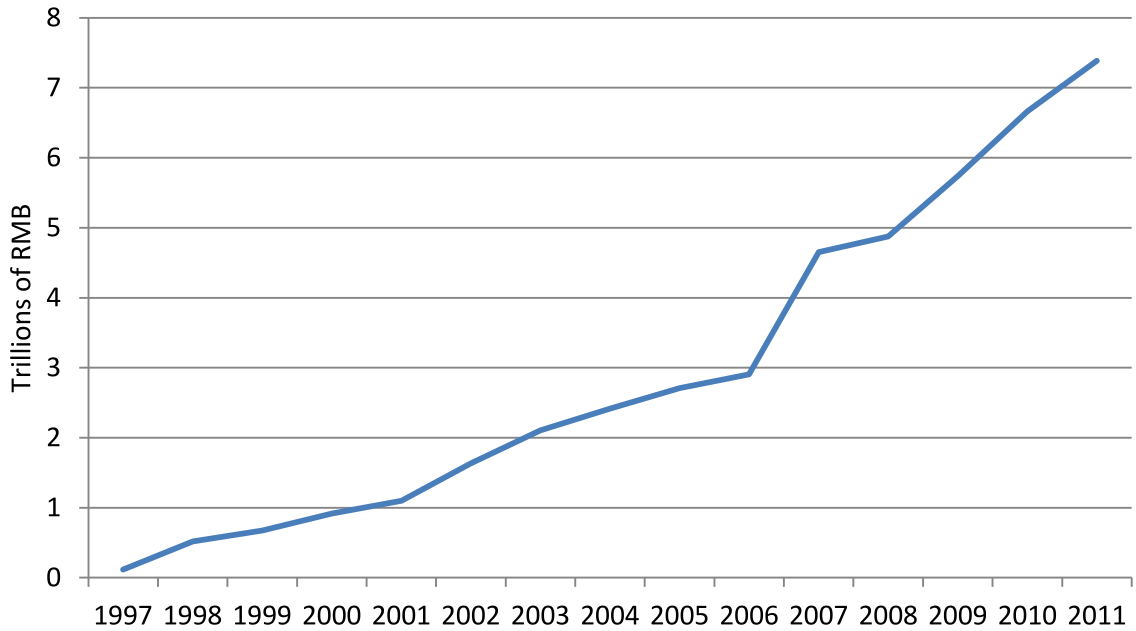
Notes: The table reports the results of linear regressions of daily yield changes on announcement surprises for each of the four most frequently traded sectors in the Chinese government bond market for the April 1, 2009 to December 31, 2011 sample period. For a given day, the 3-year sector includes all bonds with a time-to-maturity between 2.5 and 3.5 years; the 5-year sector includes bonds with a time-to-maturity between 4.5 and 5.5 years; the 7-year sector includes bonds with a time-to-maturity between 6.5 and 7.5 years; and the 10-year sector includes bonds with a time-to-maturity between 9.5 and 10.5 years. Standardized macroeconomic announcement surprises, calculated as the actual minus expected announcement value divided by the standard deviation of the surprises over our sample period, are the independent variables. Standard errors are in parentheses. One-, two-, and three- asterisks indicate statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.
Source: Authors' calculations, based on data from Bloomberg.

Table 8: Yield Changes around Subsequent Auctions

| t | 5-year notes | | 7-year notes | | 10-year notes | |
|---|---|---|---|---|---|---|
| | Mean | t-value | Mean | t-value | Mean | t-value |
| -10 | -6.05 | -1.38 | 0.18 | 0.05 | 2.58 | 0.84 |
| -9 | -8.04* | -2.06 | -0.47 | -0.15 | 1.81 | 0.58 |
| -8 | -5.60 | -1.68 | -0.32 | -0.12 | 1.65 | 0.59 |
| -7 | -5.23* | -1.99 | 1.31 | 0.51 | 1.46 | 0.45 |
| -6 | -5.24* | -1.84 | -0.03 | -0.01 | -0.46 | -0.16 |
| -5 | -4.47 | -1.48 | -1.89 | -0.91 | -1.10 | -0.80 |
| -4 | -3.16 | -0.91 | -2.31 | -1.12 | -3.00* | -2.37 |
| -3 | -1.19 | -0.40 | -1.99 | -1.09 | -0.64 | -0.51 |
| -2 | -3.07 | -1.03 | -1.25 | -0.75 | -1.49 | -1.14 |
| -1 | 0.39 | 0.11 | -2.06 | -1.21 | -0.13 | -0.09 |
| 1 | -0.68 | -0.46 | -1.47 | -0.91 | -1.61 | -1.11 |
| 2 | -2.26 | -1.75 | -1.86 | -1.01 | -0.74 | -0.60 |
| 3 | -0.18 | -0.09 | -0.45 | -0.28 | -1.45 | -0.78 |
| 4 | -1.01 | -0.47 | -1.12 | -0.69 | -1.23 | -0.72 |
| 5 | -2.20 | -0.95 | -2.44* | -2.04 | -3.14** | -2.15 |
| 6 | -0.21 | -0.09 | 0.78 | 0.28 | -2.34 | -1.23 |
| 7 | 2.21 | 0.86 | 1.44 | 0.46 | -0.96 | -0.61 |
| 8 | 3.03 | 0.85 | 0.77 | 0.31 | -3.00 | -1.61 |
| 9 | 3.43 | 0.94 | -0.51 | -0.20 | -1.75 | -0.87 |
| 10 | 6.45 | 1.57 | 1.94 | 0.59 | -0.49 | -0.24 |
| No. Obs. | 10-12 | | 14-15 | | 16-17 | |

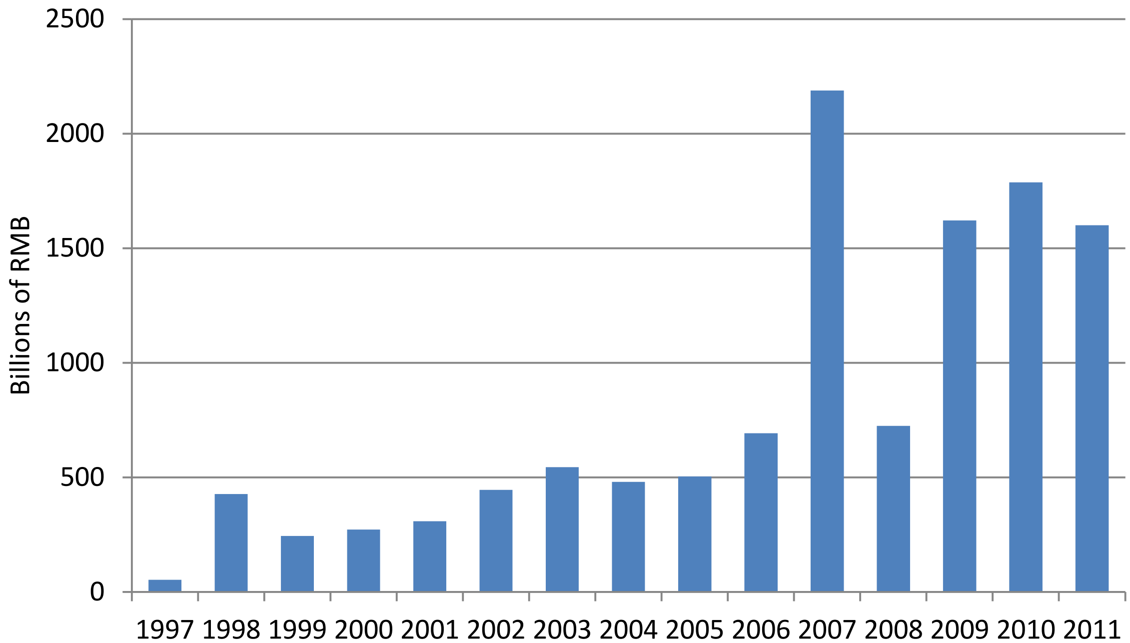
Notes: The table shows the average yield changes for the most recently issued securities around the subsequent auction of a security in the same maturity bucket (either 5, 7, or 10 years) between April 1, 2009 and December 31, 2011. For each auction, we calculate the change in yields as $\Delta Y = yield(t) - yield(0)$, where $t$ ranges from -10 to 10 days, and is equal to 0 on the day of the auction. For each maturity bucket, we report the average change in yields across all auctions in basis points. One-, two-, and three- asterisks indicate statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.
Source: Authors' calculations, based on data from Bloomberg.

Figure 1: Chinese Government Debt Outstanding



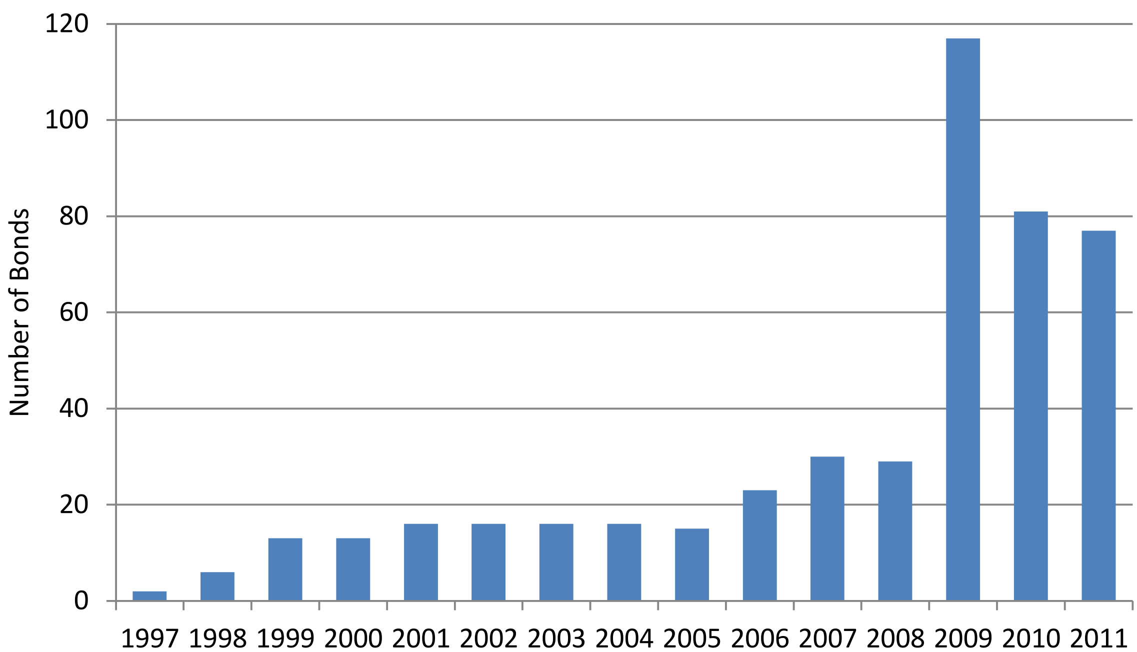

Note: The figure shows the total amount of Chinese government bonds outstanding as of the end of each year. Source: ChinaBond.

Figure 2A: Issuance Volume by Year



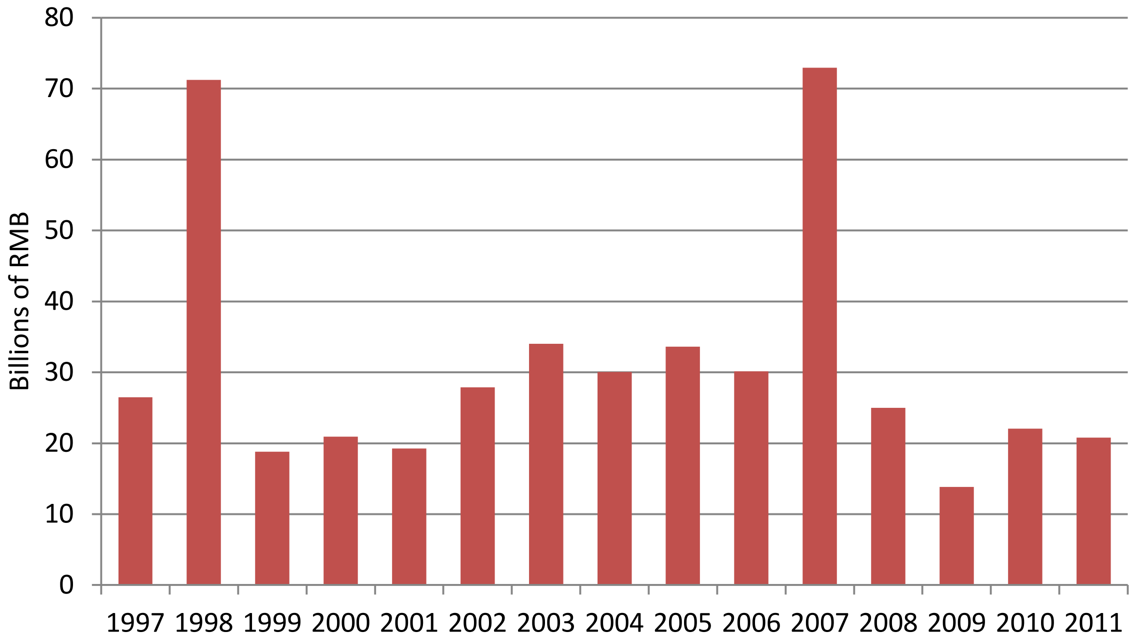

Note: The figure shows the volume of Chinese government bond issuance by year from 1997 to 2011.
Source: Authors' calculations, based on data from ChinaBond.

Figure 2B: Number of Bonds Issued by Year



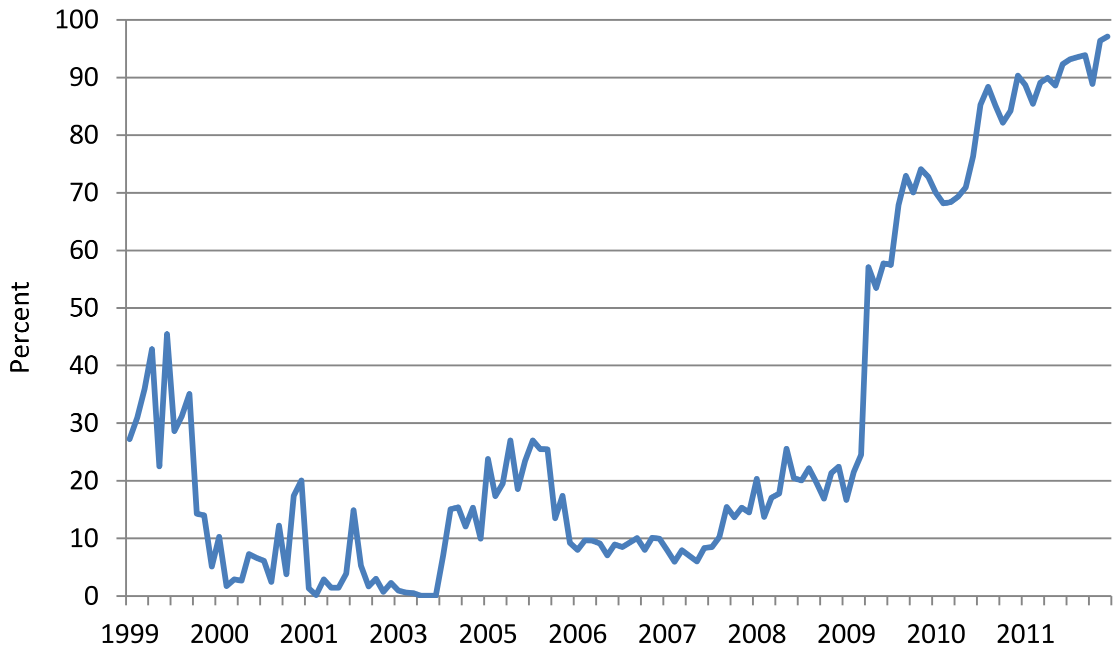

Note: The figure shows the number of Chinese government bonds issued by year from 1997 to 2011.
Source: Authors' calculations, based on data from China Central Depository & Clearing Co., Ltd.

Figure 2C: Issue Sizes by Year



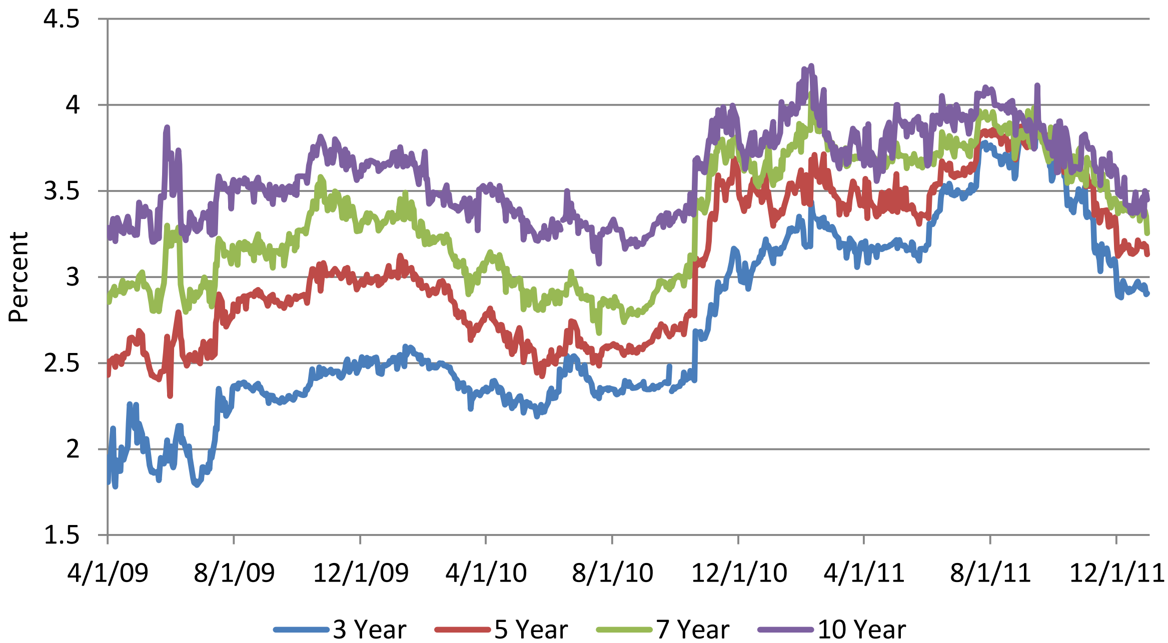

Note: The figure shows average issue sizes by year from 1997 through 2011.
Source: Authors' calculations, based on data from ChinaBond and China Central Depository & Clearing Co., Ltd.

Figure 3: Secondary Market Data Prevalence




Notes: The figure shows the percent of Bloomberg price or yield data available by month across all securities. The percent is calculated as the total number of security-trading days in a month in which we observe either a price or yield for a security, divided by the total number of security-trading days in the month.
Source: Authors' calculations, based on data from Bloomberg.

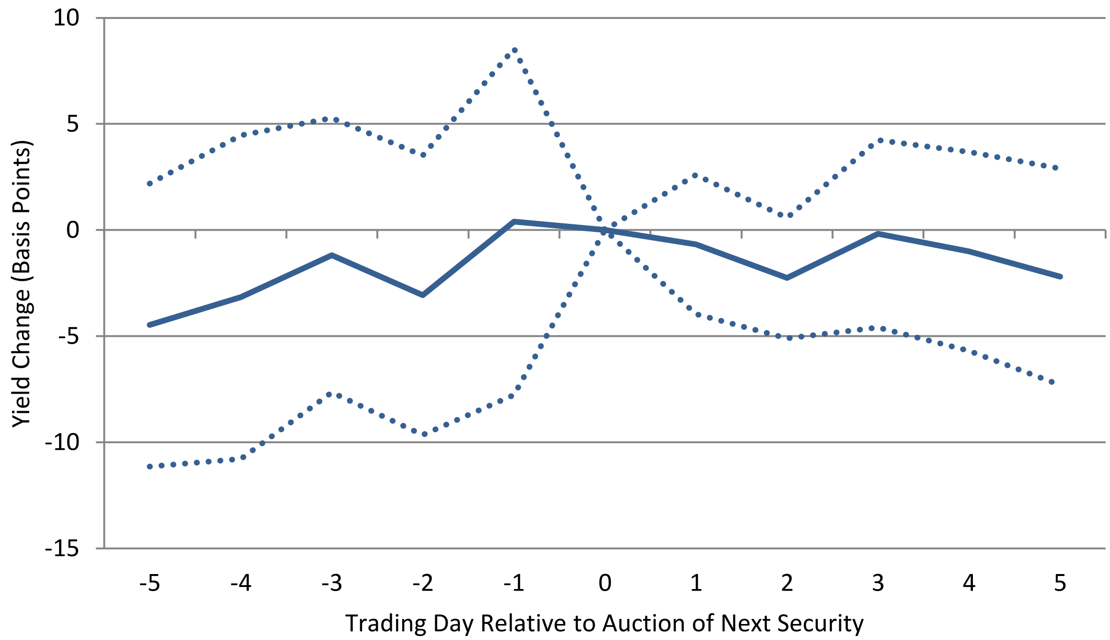
Figure 4: Yields by Sector



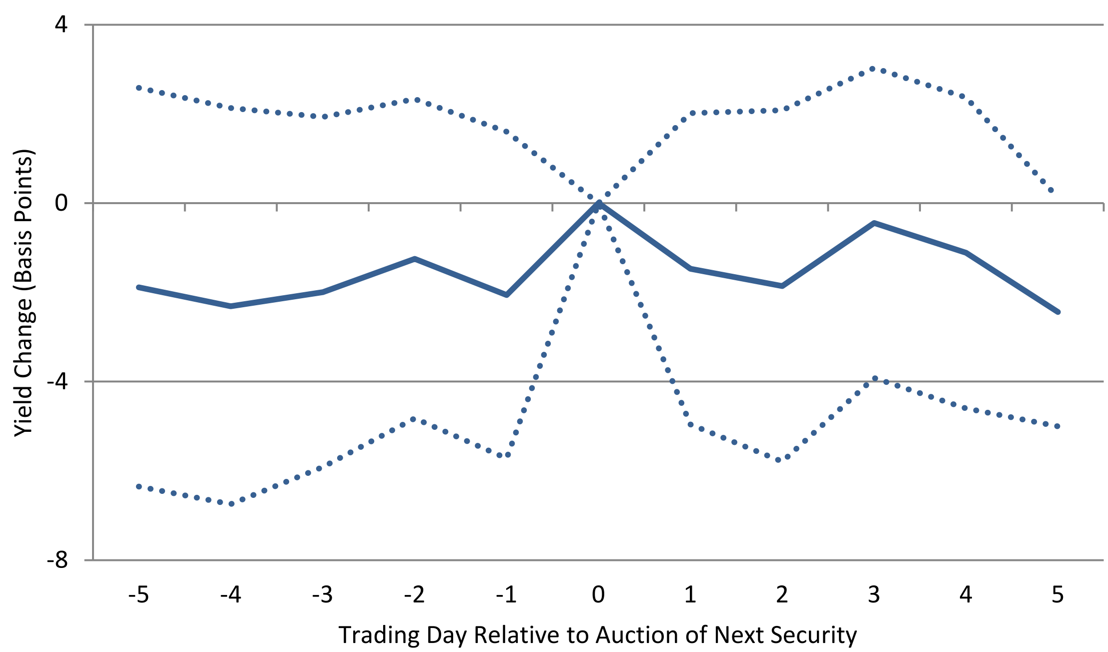

Notes: The figure plots the average daily yield of Chinese government bonds for four maturities from April 1, 2009 to December 31, 2011. On any given trading day, the 3-year maturity bucket includes all bonds with a time-to-maturity between 2.5 and 3.5 years; the 5-year sector includes bonds with a time-to-maturity between 4.5 and 5.5 years; the 7-year sector includes bonds with a time-to-maturity between 6.5 and 7.5 years; and the 10-year sector includes bonds with a time-to-maturity between 9.5 and 10.5 years.
Source: Authors' calculations, based on data from Bloomberg.

Figure 5: Yield Changes around Subsequent Auctions

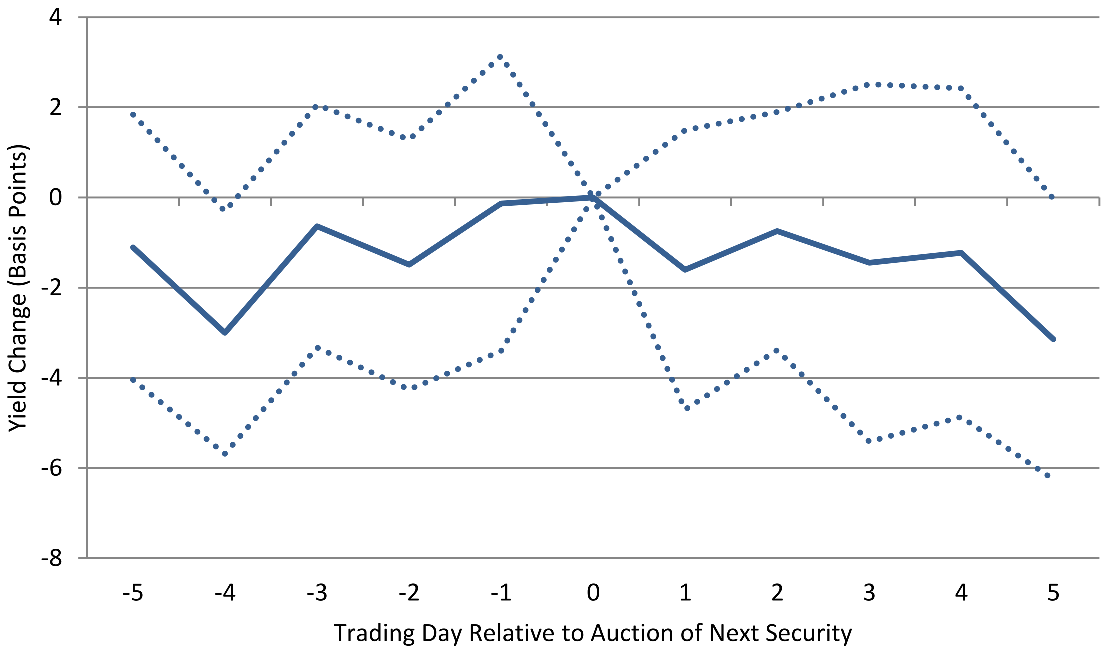
Panel A: 5-Year Note




Panel B: 7-Year Note



Panel C: 10-Year Note




Notes: The figure plots average yield changes of the most recently issued securities around the subsequent auction of security of the same maturity (5, 7, or 10 year note) as a solid line and 95% confidence bands as dotted lines for the April 1, 2009 to December 31, 2011 sample period. For each auction, we calculate the change in yields as $\Delta Y = yield(t) - yield(0)$, where $t$ ranges from -5 to 5 days, and is equal to 0 on the day of the auction. For each maturity, we report the average change in yields across all auctions in basis points.

**Appendix: U.S. Treasury Market Comparison**

Table A1: Correlations across Maturity Sectors for the U.S. Market

Panel A: Yield Correlations

| Sector | 3 Year | 5 Year | 7 Year | 10 Year |
|---|---|---|---|---|
| 3 year | 1.00 | | | |
| 5 year | 0.98 | 1.00 | | |
| 7 year | 0.96 | 1.00 | 1.00 | |
| 10 year | 0.92 | 0.97 | 0.99 | 1.00 |

Panel B: Daily Yield Change Correlations

| Sector | 3 Year | 5 Year | 7 Year | 10 Year |
|---|---|---|---|---|
| 3 year | 1.00 | | | |
| 5 year | 0.93 | 1.00 | | |
| 7 year | 0.87 | 0.97 | 1.00 | |
| 10 year | 0.81 | 0.93 | 0.98 | 1.00 |

Panel C: Weekly Yield Change Correlations

| Sector | 3 Year | 5 Year | 7 Year | 10 Year |
|---|---|---|---|---|
| 3 year | 1.00 | | | |
| 5 year | 0.94 | 1.00 | | |
| 7 year | 0.87 | 0.97 | 1.00 | |
| 10 year | 0.82 | 0.92 | 0.97 | 1.00 |

Notes: The table reports correlation coefficients for bond yields (Panel A), daily yield changes (Panel B), and weekly yield changes (Panel C) between April 1, 2009 and December 31, 2011. All correlations are calculated using the yields of the on-the-run notes.
Source: Authors' calculations, based on data from Bloomberg.

Table A2: Market Efficiency Tests for the U.S. Market

Panel A: Kendall Tau Test

| Bond | Term | Maturity Date | N | Coefficient | Standard Error | P-value |
|---|---|---|---|---|---|---|
| 912828KG4 | 3 | 3/15/2012 | 690 | -0.036 | 6036 | 0.155 |
| 912828KJ8 | 5 | 3/31/2014 | 690 | -0.018 | 6048 | 0.473 |
| 912828KT6 | 7 | 3/31/2016 | 690 | -0.025 | 6048 | 0.326 |
| 912828KD1 | 10 | 2/15/2019 | 690 | -0.032 | 6048 | 0.215 |

Panel B: Variance Ratio Test

| Bond | Term | Maturity Date | N | Number of Lags (Q) | VR(Q) | P-value |
|---|---|---|---|---|---|---|
| 912828KG4 | 3 | 3/15/2012 | 676 | 2 | 1.029 | 0.457 |
| | | | | 4 | 0.926 | 0.306 |
| | | | | 8 | 0.896 | 0.363 |
| | | | | 16 | 0.917 | 0.624 |
| 912828KJ8 | 5 | 3/31/2014 | 676 | 2 | 0.981 | 0.614 |
| | | | | 4 | 0.897 | 0.153 |
| | | | | 8 | 0.915 | 0.456 |
| | | | | 16 | 1.031 | 0.853 |
| 912828KT6 | 7 | 3/31/2016 | 676 | 2 | 0.967 | 0.384 |
| | | | | 4 | 0.896 | 0.149 |
| | | | | 8 | 0.911 | 0.436 |
| | | | | 16 | 1.005 | 0.978 |
| 912828KD1 | 10 | 2/15/2019 | 676 | 2 | 0.942 | 0.129 |
| | | | | 4 | 0.866 | 0.062 |
| | | | | 8 | 0.847 | 0.179 |
| | | | | 16 | 0.907 | 0.583 |

Notes: The table reports results of efficiency tests for the U.S. Treasury securities market for the April 1, 2009 to December 31, 2011 sample period. For the analysis, we use the 3, 5, 7, and 10 year notes that were on the run at the beginning of our sample. We test for market efficiency using each of these four bonds through the Kendall Tau test and the variance ratio test. The Kendall Tau test assesses whether prices follow a random walk through the hypothesis of uncorrelated returns. For each bond and trading date, the return $r_t$ is calculated as the proportional change in price from the previous trading day. If no price was observed on the previous trading day, then the observation is omitted. The variance ratio test assesses whether prices follow a random walk by testing whether variances of the series $r_t$ and $r_{t-k}$ (where k is the number of lagged observations) are distributed as a linear function of k. As is standard in the literature, we test for lags of 2, 4, 8, as well as 16.
Source: Authors' calculations, based on data from Bloomberg.

Table A3: Macroeconomic Announcement Effects for the U.S. Market

Panel A: 3 Year

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Consumer Confidence | 0.70 | | | | | | | | 0.68 |
| | (0.91) | | | | | | | | (0.89) |
| Consumer Price Index | | 0.38 | | | | | | | 0.45 |
| | | (1.04) | | | | | | | (1.01) |
| Durable Goods Orders | | | -0.55 | | | | | | -0.61 |
| | | | (0.90) | | | | | | (0.89) |
| New Home Sales | | | | 0.37 | | | | | 0.46 |
| | | | | (0.92) | | | | | (0.90) |
| NAPM Index | | | | | -0.37 | | | | -0.32 |
| | | | | | (1.11) | | | | (1.08) |
| Producer Price Index | | | | | | 1.02 | | | 0.40 |
| | | | | | | (0.99) | | | (1.00) |
| Nonfarm Payrolls | | | | | | | 5.38*** | | 5.38*** |
| | | | | | | | (0.88) | | (0.88) |
| Retail Sales | | | | | | | | 2.55** | 2.46** |
| | | | | | | | | (1.01) | (1.02) |
| Constant | -0.12 | -0.11 | -0.12 | -0.11 | -0.11 | -0.11 | -0.08 | -0.11 | -0.08 |
| | (0.20) | (0.20) | (0.20) | (0.20) | (0.20) | (0.20) | (0.19) | (0.20) | (0.19) |
| Observations | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 |
| Adjusted R-squared | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.050 | 0.008 | 0.052 |

Panel B: 5 Year

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Consumer Confidence | 1.03 | | | | | | | | 1.04 |
| | (1.16) | | | | | | | | (1.14) |
| Consumer Price Index | | 0.35 | | | | | | | 0.45 |
| | | (1.32) | | | | | | | (1.30) |
| Durable Goods Orders | | | -0.88 | | | | | | -0.93 |
| | | | (1.15) | | | | | | (1.14) |
| New Home Sales | | | | 0.29 | | | | | 0.43 |
| | | | | (1.17) | | | | | (1.16) |
| NAPM Index | | | | | 0.27 | | | | 0.34 |
| | | | | | (1.41) | | | | (1.39) |
| Producer Price Index | | | | | | 1.57 | | | 0.73 |
| | | | | | | (1.26) | | | (1.28) |
| Nonfarm Payrolls | | | | | | | 5.74*** | | 5.74*** |
| | | | | | | | (1.13) | | (1.13) |
| Retail Sales | | | | | | | | 3.53*** | 3.35** |
| | | | | | | | | (1.28) | (1.30) |
| Constant | -0.12 | -0.12 | -0.13 | -0.12 | -0.12 | -0.12 | -0.08 | -0.12 | -0.09 |
| | (0.25) | (0.25) | (0.25) | (0.25) | (0.25) | (0.25) | (0.25) | (0.25) | (0.25) |
| Observations | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 |
| Adjusted R-squared | -0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 | 0.035 | 0.010 | 0.039 |

Panel C: 7 Year

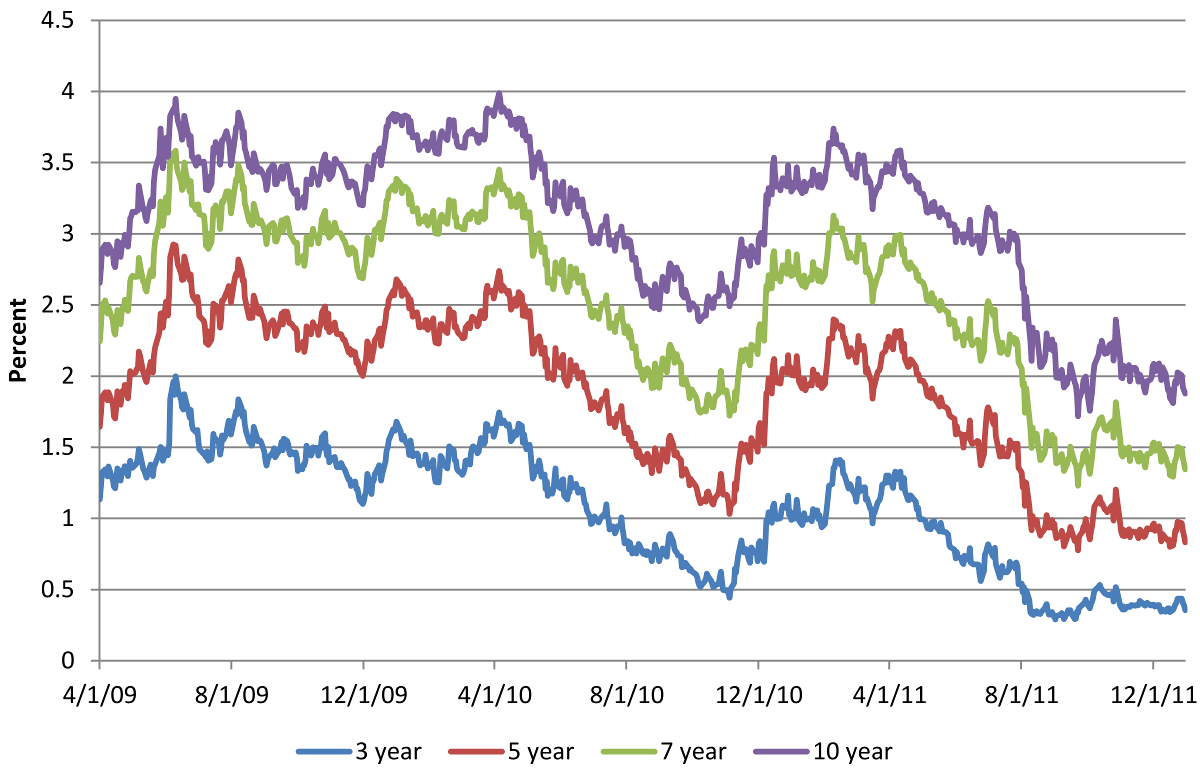
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Consumer Confidence | 1.38 | | | | | | | | 1.40 |
| | (1.24) | | | | | | | | (1.22) |
| Consumer Price Index | | 0.08 | | | | | | | 0.18 |
| | | (1.41) | | | | | | | (1.39) |
| Durable Goods Orders | | | -0.23 | | | | | | -0.27 |
| | | | (1.23) | | | | | | (1.22) |
| New Home Sales | | | | 0.35 | | | | | 0.40 |
| | | | | (1.25) | | | | | (1.25) |
| NAPM Index | | | | | 0.24 | | | | 0.34 |
| | | | | | (1.51) | | | | (1.49) |
| Producer Price Index | | | | | | 1.73 | | | 0.83 |
| | | | | | | (1.35) | | | (1.37) |
| Nonfarm Payrolls | | | | | | | 5.24*** | | 5.24*** |
| | | | | | | | (1.21) | | (1.21) |
| Retail Sales | | | | | | | | 3.83*** | 3.62*** |
| | | | | | | | | (1.37) | (1.40) |
| Constant | -0.14 | -0.13 | -0.13 | -0.13 | -0.13 | -0.13 | -0.10 | -0.13 | -0.10 |
| | (0.27) | (0.27) | (0.27) | (0.27) | (0.27) | (0.27) | (0.26) | (0.27) | (0.26) |
| Observations | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 |
| Adjusted R-squared | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 | 0.025 | 0.010 | 0.029 |

Panel D: 10 Year

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Consumer Confidence | 1.30 | | | | | | | | 1.35 |
| | (1.24) | | | | | | | | (1.23) |
| Consumer Price Index | | -0.19 | | | | | | | -0.10 |
| | | (1.42) | | | | | | | (1.41) |
| Durable Goods Orders | | | 0.19 | | | | | | 0.11 |
| | | | (1.24) | | | | | | (1.24) |
| New Home Sales | | | | 0.64 | | | | | 0.63 |
| | | | | (1.26) | | | | | (1.26) |
| NAPM Index | | | | | 0.72 | | | | 0.82 |
| | | | | | (1.52) | | | | (1.51) |
| Producer Price Index | | | | | | 2.03 | | | 1.19 |
| | | | | | | (1.35) | | | (1.39) |
| Nonfarm Payrolls | | | | | | | 4.09*** | | 4.09*** |
| | | | | | | | (1.23) | | (1.22) |
| Retail Sales | | | | | | | | 3.70*** | 3.39** |
| | | | | | | | | (1.38) | (1.42) |
| Constant | -0.12 | -0.11 | -0.11 | -0.11 | -0.12 | -0.11 | -0.09 | -0.11 | -0.09 |
| | (0.27) | (0.27) | (0.27) | (0.27) | (0.27) | (0.27) | (0.27) | (0.27) | (0.27) |
| Observations | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 | 688 |
| Adjusted R-squared | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.002 | 0.015 | 0.009 | 0.018 |

Notes: The table reports the results of linear regressions of daily yield changes on announcement surprises for the on-the-run 3, 5, 7, and 10-year notes for the April 1, 2009 to December 31, 2011 sample period. Standardized macroeconomic announcement surprises, calculated as the actual minus expected announcement value divided by the standard deviation of the surprises over our sample period, are the independent variables. Standard errors are in parentheses. One-, two-, and three- asterisks indicate statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.
Source: Authors' calculations, based on data from Bloomberg.

Figure A1: Yields by Sector for the U.S. Market




Notes: The figure plots daily yields of on-the-run U.S. Treasury notes from April 1, 2009 to December 31, 2011.
Source: Bloomberg.