The Chinese Government Bond Returns

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Abstract

In this paper, we analyze the Chinese Government Bond (CGB) market. We find that CGB returns exhibit three common risk factors, which are well captured by three indices composed of short-, medium-, and long-term bonds. Moreover, these common risk factors exhibit strong momentum. In particular, weekly returns on medium and long maturity bond portfolios have a serial correlation of 27.73% and 31.29%, respectively. We further show that the serial correlation in bond returns allows significant profits from using simple momentum strategies. The strong momentum in bond portfolio returns indicates market inefficiencies. We further compare CGBs facing different restrictions on their trading in different markets and find that bonds with more restrictions allow more momentum profits.

Keywords: Chinese Government Bond; common factors; momentum profit; market segmentation

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1 Introduction

China's Government Bond (CGB) market has experienced a tremendous growth over the last decade. The total issue size was less than RMB100 billion at the end of 1997 and it was more than RMB2.5 trillion by the end of 2006. Although the CGB market is still relatively small compared with the overall size of China's economy, ranging between 3 to 4.5% of China's GDP, it is becoming more prominent as China's economy grows in size and its financial markets develop.

The CGB market has several interesting features compared with more mature markets. First, it is highly segmented, with three market places for secondary trading and each market involves only partially overlapping sets of participants. For example, most individual and retail institutional investors trade on the Shanghai Stock Exchange while a large fraction of institutional investors, such as commercial banks and insurance companies trade in an interbank market. In addition, some CGBs are traded on only one of these markets while some are traded on both. Second, the market faces various trading restrictions, especially, the prohibition of open-end repo transactions.[1] Third, the market is relatively illiquid—the daily trading volume is low compared with more mature markets.[2] These forms of imperfections in the CGB market make it interesting case of study. In particular, two questions arise. Does the market exhibit any forms of inefficiency? If yes, is the inefficiency related in any way to the imperfections present in the market?

In this paper, we provide a preliminary empirical analysis of the CGB market in addressing these questions. We show that individual bond returns exhibit three common factors. We use three bond return indices, returns on three portfolios consisting of short-, medium- and long-maturity bonds, to proxy for the common return factors, and find that they exhibit strong serial correlations. For example, weekly returns of medium-maturity bonds has a serial correlation of 27.73% and those of long-maturity bonds has a serial correlation of 31.29%. We further show that these correlations allow substantial profits from using simple momentum style arbitrage strategies.

[1] An open-end repo refers to a repo transaction in which the party who takes the reverse repo side of the transaction can sell the security. Open-end repos only become feasible in China until recently, the Interbank market's and the Shanghai Security Exchange's starting dates are from 2004/5/20 and 2004/12/6, respectively.

[2] From 2003 to 2006, the average daily turnovers of SSE and Interbank are 0.2225% and 0.9218%, and that of all CGBs is 0.3116%. In contrast, the average daily turnovers of US Treasury bonds for year 2003, 2004, 2005, 2006 are 12.13%, 12.65%, 13.31% and 12.14%, see Security Industry and Financial Market Association (www.sifma.org).

Moreover, we compare the return behavior for bonds facing different market segmentation. In particular, we group the bonds into two groups, those who can only be traded on the Shanghai Stock Exchange (SSE) and those who can be traded on the SSE and the interbank market, where most large institutions trade. We find that for bonds traded only on SSE, more profit can be made from simple momentum strategies.

Our results suggest that significant inefficiencies are present in the CGB market. In addition, these inefficiencies are related to the imperfections in the market, in particular, to the degree of market segmentation.

The paper is organized as follows. Section 2 provides a brief overview of the CGB market. Section 3 describes the data we use and gives several summary statistics for the data. In Section 4, we analyze the cross section properties of CGB returns. In particular, we conduct a principal component analysis to identify common risk factors in the CGB market. In Section 5, we present the results on the statistical and economic significance of serial correlations in bond return indices. In Section 6, we further examine the link between return serial correlation and market segmentation. Section 7 provides several robustness checks on our results and Section 8 concludes.

2 An Overview of the CGB Market

Chinese Government Bonds refer to the bonds issued by the Chinese central government through the Ministry of Finance. In this sense, they are very much the counterpart of, say, U.S. Treasury securities and also refer to as Chinese Treasury Bonds. They are all denoted in RMB, the Chinese currency. [3] The maturity ranges from 1 quarter to 20 years.[4] While bonds with maturity no longer than one years do not carry coupons, most bonds do pay coupons at fixed rate of the principle with annual payments[5]. CGBs are mainly held by domestic financial institutions, non-financial enterprises and individuals.

[3]The exchange rate between US dollar and RMB was around RMB8.3/$ from January 2003 to the mid-year of 2005. It then started appreciating. By the end of 2006, it reached RMB7.8/$.

[4]Other than the Ministry of Finance, two sets of agencies of the central government also issue bonds. The People's Bank of China (the Chinese Central Bank) issues bills (Central Bank Bills), debt instrument with short maturities, ranging from three months to three years. They are used as an instrument for monetary policy operations. In addition, policy banks, including the Agricultural Develop Bank of China, the China Development Bank, the Import-Export Bank of China, can also issue debt to fund certain economic initiatives of the government. These bonds are also called financial bonds. Our analysis focuses only on the Treasury debt and does not include these Central Bank Bills.

[5]In our sample consisting of 46 bonds, there are 33 bonds paying coupon annually and 7 semiannually, the others are discount bonds.

CGBs take three different forms, certificate bonds, bearer-form bonds and book-entry bonds. Both certificate and bearer-form bonds are sold at banks and security houses, who act as retailers. They are mostly targeted at individual investors. Certificate bonds are similar to the savings bonds in the U.S. They are nontransferable but redeemable before maturity at the original selling bank. The bearer-form bonds can be sold at qualified banks and security houses who post two-way prices. Because of the restrictions and costs, the secondary trading of the certificate bonds and bearer-form bonds is quite limited.

Book-entry bonds are registered electronically. Their issuance is through auctions to qualified primary dealers. Secondary trading in book-entry CGBs involves two different market forms, the centralized exchanges and the interbank OTC market. Currently, there are two exchanges where book-entry CGBs can be traded, the Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SzSE), both established by the end of 1990. The interbank market was established in 1997 when commercial banks were banned from trading on the exchanges. Instead, they are allowed to trade their bond holdings deposited at the China Government Securities Depository Trust Clearing Co. through the National Interbank Funding Center's trading system (see, for example, Neftci and Ménager-Xu (2007)). [6] Since most secondary trading in CGBs concerns the book-entry bonds, we will refer to this secondary market simply as the CGB market without the qualifier for the bond form.

In Figure 1, we plot the time trend of the size of CGB market. In Panel A (left), the number of bonds (with the right scale) and the total amount in par value (with the left scale) are plotted over the period from June 1996 to December 2006. Clearly, the market expanded significantly since 1997. The growth slowed slightly since 2003.

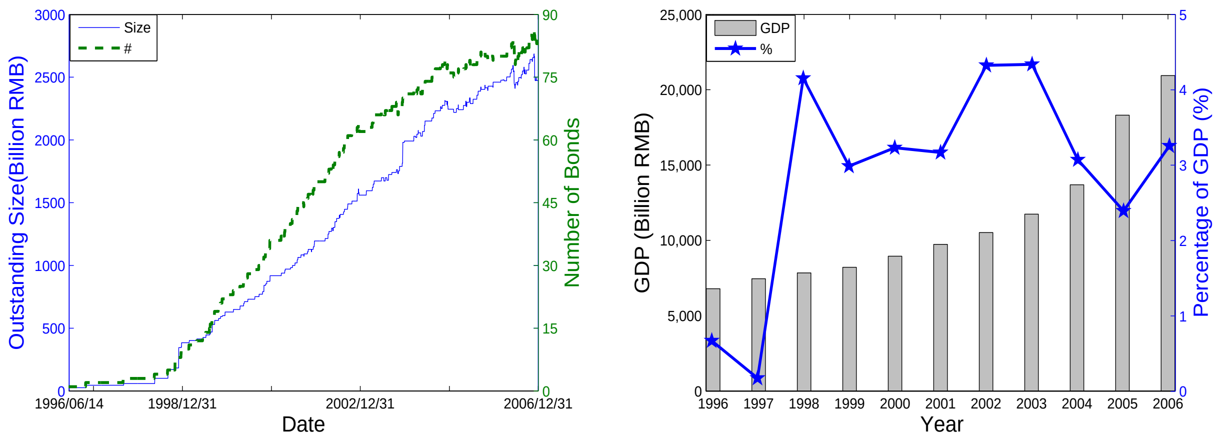
In Panel B of Figure 1, we plot China's GDP from 1996 to 2006 (with the left scale) and the ratio between the CGB market size (in par value) and the GDP. It is interesting to note that although the CGB market had a fast growth in its absolute size, as a percentage of GDP, most of the growth occurred during 1997. Afterwards, the ratio stayed more or less at the same level, between 3% to 4.5%. The ratio actually declined during 2003 to 2005 and bounced back slightly in 2006.

An important feature of the CGB market is its segmentation. The segmentation has two aspects. First, in terms of participants, only banks, insurance companies, credit unions,

[6] In fact, there is also another bank OTC market which is an extension of the interbank bond market to personal investors. Bond trading and related bond custody and settlement are carried on within the bank's branches.

Figure 1: Size of the CGB market.

A. Number of bonds and amount outstanding B. Size of CGB market relative to GDP



Panel A plots the number of bonds (right scale) and the total amount (in par value) outstanding from June 1996 to December 2006. Panel B plots the annual GDP in bars (left scale) and the size of the CGBs as a percentage of GDP (right scale).

trusts, security firms and mutual funds can participate in the interbank market. [7] Individual investors, non-financial firms as well as security firms and mutual funds can all trade on the exchanges, but not insurance companies, credit unions and trusts. Second, not all bonds can be traded in both markets. Some bonds can only be traded in the interbank market while some bonds can only be traded on the exchanges. Yet, some bonds can be traded both in the interbank market and on the exchanges. In this case, only those investors who are allowed to trade in both markets, mainly security firms and mutual funds, can actually do so. Moreover, a small number of bonds can be "moved" from the exchanges to the interbank market, of course only security firms and mutual funds who trade in both markets.

In terms of sizes and trading activities of the two exchanges and the interbank market, Table 1 provides a rough picture, for the period of 2003 to 2006. Clearly, we see that more bonds are traded in the interbank market (a total of 105). Trading in the interbank market has two characteristics, infrequent but of large sizes. Trading actually occurs only 30.59% of the trading days. The average trade size is RMB 443.86 million. For the Shenzhen Stock Exchange, the trading is a little more active, with 66.31% of the trading days with actually trading. However, the volume is rather low, averaging daily to RMB1.46 million.

[7]In the early years of the interbank market, only qualified commercial banks, credit unions and insurance companies traded in there. The market expanded later to include more institutional investors.

The Shanghai Stock Exchange is the most active. We observe trading on 95.06% of all the trading days and the average daily volume reaches RMB35.1 million.

Table 1: Overview of the two exchanges and the interbank market for CGBs

	SSE	SzSE	Interbank
Number of bonds	47	34	105
Percentage of days with trading (%)	95.06	66.31	30.59
Average daily volume (RMB1,000)	35,012.02	1,455.25	443,861.56

This table gives a summary of CGBs traded in three markets, Shanghai Stock Exchange (SSE), Shenzhen stock exchange (SzSE) and the interbank market, from 2003 to 2006. Rows 1 to 3 report the number of bonds traded, the percentage of days with trading, and the mean of individual bonds' average daily trading volume, respectively.

Although the interbank market is a major part of the CGB market, its OTC nature makes it difficult to obtain systematic data on its activities. For this reason, we primarily focus on the exchanges, for which data is available and trading is active.

3 Data Description and Summary

The data we use in this paper are from the GTI Financial Database which is compiled by Shenzhen Genius Information Technology Co. This database stores historical as well as up-to-date financial data covering domestic listed companies, bonds, mutual funds, market indices, macro economy statistics, sectors & industries statistics in China. The structure of the database is very similar to those of CRSP and COMPUSTAT. For comparison, we also use data on the U.S. Treasuries, which is from the Datastream.

A. Sample Description

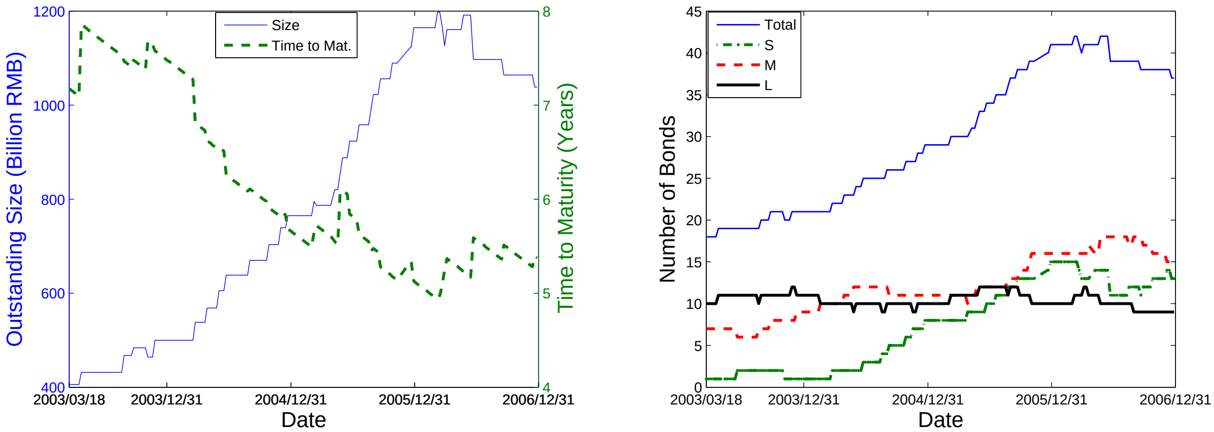
Our analysis will focus on book-entry CGBs traded in SSE from 2003 to 2006. We start our sample at 2003 because the CGB market prior to 2003 is relatively small (only a small number of bonds were traded and trading was rather inactive), and the data is not very good. Compared to SSE, there is only a small number of bonds traded on Shenzhen Stock Exchange and the trading is rather infrequent. Thus, we did not include them in the sample.

The data sample starts from 2003/3/18 to 2006/12/31, including all the book-entry CGBs with complete data on price, trading volume, issuance size, maturity and coupon

Figure 2: Bond maturity and issuance size.

A. Average maturity and size

B. Distribution of bond maturity



The left panel plots the average maturity and size of CGBs over time and the right panel plots the number of bonds for the whole market, and for short, middle and long maturities, respectively.

rate. Finally, we are left with 46 bonds, which are listed in Table A in the appendix.[8] It is worth noting that before 2004, most bonds were medium or long term maturity bonds with fixed coupon rates. From then on, short term bonds were also issued, most of which have no coupons. The average issue size of CGBs is RMB28.71 billion. They have an average maturity of 7.53 years and coupon rate of 3.23%. Figure 2.A plots the time variation of the total amount outstanding and the average time to maturity of all bonds in our sample, weighted by issue size. Figure 2.B illustrates the distribution of bonds in their time to maturity. Here, we group bonds by their time to maturity into three brackets, 0 to 3 years, 3 to 6 years and 6 plus years. The number of bonds in each group is then plotted for each week.

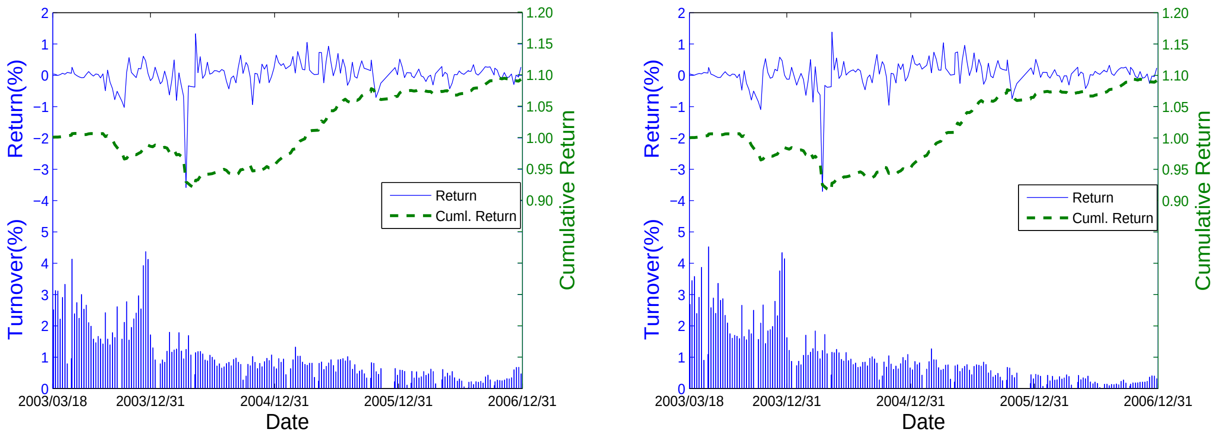
B. Return and Turnover

In Figure 3, we plot average weekly returns and turnover of CGBs. Panel A plots the equal-weighted average of returns and turnover. The top part of the figure show the returns, the solid line represents weekly returns, with the scale on the left vertical axis and the dashed line represents the cumulative returns, with the scale on the right vertical axis. The bottom part

[8]We delete 12 bonds with bond code of 010602, 010606, 010607, 010608, 010609, 010610, 010611, 010612, 010613, 010614, 010615, 010616, because of data errors.

Figure 3: Average bond return and turnover

A. Equal-weighted return and turnover B. Size-weighted return and turnover



The figure plots the equal- (Panel A) and size-weighted (Panel B) average of CGBs weekly return and turnover . In each panel, weekly return and cumulative return are plotted in top part and weekly turnover is plotted in the bottom part. Weekly return and turnover are computed from Wednesday to Wednesday, using log gross return rather than quotient return. The cumulative return is simply the exponential of sum of past log gross returns.

of the figure shows the weekly average turnover. Panel B of Figure 3 plots the size-weighted average of weekly bond returns and turnover.

We make several observations from Figure 3. First, the behavior of returns is relatively stable over time, with the exception date of 2004/04/11 when a large negative return occurred. This large drop in bond prices is due to the unanticipated increase of the reserve requirement ratio from 7% to 7.5% by the Chinese central bank (the People's Bank of China). Second, there seems to be some variation in the volatility of bond returns. Third, the turnover of bonds experienced a steady decline over the sample period. This coincided with the gradual increase in the number of bonds and boom in the stock market during the same period. Fourth, the equal- and size-weighted average return and turnover behave quite similarly. For this reason, we will focus on the equally weighted average return in future analysis for brevity.

Table 2 reports several summary statistics on individual bond returns and turnover. In particular, we calculate the mean, standard deviation, median, skewness, kurtosis, and autocorrelations of up to four lags for individual bond returns weekly, and the mean and standard deviation of turnover, and then report their cross-sectional mean, standard deviation, and the 25th percentile, median and 75th percentile in the table. The mean return of individual bonds is 0.0603% per week (about 3% per year), and mean weekly turnover is 0.6611%. The median first autocorrelation is 0.0904 but the median p-value is about 0.1656. We thus conclude that individual bond returns are serially uncorrelated.

4 Principal Components and Bond Indices

It is well known from studies of government bond markets that bond returns are driven by a small number of common factors (e.g., Litterman and Scheinkman (1986)). In this section, we conduct a similar analysis for the CGBs. We first carry out a principal component analysis of bond returns to examine the presence of principal components in the variation of bond returns. We will then attempt to find a simple representation of these components.

A. Principal Component Analysis

Our sample consists of 46 bonds. With a sufficiently long same period, we would be able to conduct the principal component analysis directly using individual bond returns. However, with barely four years of data, at weekly frequency, the estimation error can be non-trivial even for this relatively small cross section. For this reason, we follow the standard procedure of first forming portfolios and then estimating their return covariance matrix to extract the principal components.

We first divide all the bonds into 10 groups according to their time to maturity from short to long. Given that the time to maturity changes over time, we regroup the bonds every Wednesday. We obtain 10 return series by calculating the equal-weighted average of returns for each group, which we use for the principal component analysis. The results are reported in Table 3, with the sum of eigenvalue normalized to 1. The first factor can explain 72.87% of the return variation, the next two factors can explain 9.18% and 6.18%, respectively; while that of the 4th factor is only 3.12%. The explanatory power of first 3 factors can add up to 88.23%, while that of the 4th factor is only 3.12%.

B. Bond Indices

The principal component analysis shows the presence of three common factors in CGB returns. From a statistical point of view, we can further identify these factors by considering at the eigenvectors associated with the covariance matrix. Such an approach, however, is

Table 2: Summary statistics of individual bonds.

	Return(%)									Turnover(%)	
	Mean	Std.	Med.	Skew.	Kurt.	ρ_1	ρ_2	ρ_3	ρ_4	Mean	Std.
Mean	0.0603	0.4304	0.0715	-0.9472	8.0421	0.0610	0.0082	0.0644	0.0456	0.6611	0.6845
Std.	0.0481	0.2816	0.0438	1.3307	10.1661	0.1941	0.1426	0.1080	0.0977	0.7781	0.6919
25^{th}	0.0382	0.2609	0.0429	-1.5043	1.7873	-0.0154	-0.0970	-0.0130	-0.0046	0.0339	0.0699
						(0.0186)	(0.0847)	(0.1090)	(0.2077)		
Med.	0.0503	0.3869	0.0637	-0.6894	4.1296	0.0904	0.0255	0.0988	0.0682	0.3236	0.3809
						(0.1656)	(0.3205)	(0.3296)	(0.4205)		
75^{th}	0.0689	0.5284	0.0974	0.0324	8.7470	0.2051	0.1142	0.1379	0.1181	1.2364	1.1850
						(0.4376)	(0.6221)	(0.6147)	(0.7013)		

For individual bond returns, the table reports their mean, standard deviation, median, skewness,kurtosis and autocorrelation up to 4 orders, and mean and standard deviation of turnover, and place their mean, standard deviation, 25^{th} percentile, median and 75^{th} in this table. The numbers in parentheses are p-value.

Table 3: Principal component analysis of bond returns.

Factor	Eigenvalue	Cumulative
1	0.7287	0.7287
2	0.0918	0.8205
3	0.0618	0.8823
4	0.0312	0.9134
5	0.0250	0.9384
6	0.0225	0.9609
7	0.0148	0.9757
8	0.0111	0.9869
9	0.0078	0.9947
10	0.0054	1.0000

Bonds are sorted into 10 groups according to their time to maturity from short to long every Wednesday and the average weekly return is calculated for each group. The principal components are then obtained from the ten return series.

less appealing for several reasons. For example, the eigenvectors, though have nice statistical properties such as mutually uncorrelated, may be economically less informative. In addition, the choice of the base portfolios, which the eigenvectors are based on, has an influence which may have little economic bearing. Thus, in choosing the different representations of the common factors, we resort to a more heuristic approach commonly used in the literature, which is relying on returns of portfolios with certain characteristics. In particular, we will use returns of bond portfolios with different maturities. This is very much in the spirit of using short term rate, term spread and curvature as bond returns factors.

We sort all the bonds into three groups according to their time to maturity: short(with maturity in $[0, 3)$ years), medium ($[3, 6)$) and long ($[6, +\infty)$). The variation of number of bonds in each group versus time is displayed in Figure 2. The number of medium and long term bonds are rather stable, and the number of bonds in each group is comparable.

Table 4 summarizes the simple characteristics of bonds in the three portfolios. In particular, it reports the average number of bonds, maturity, coupon and issuance size for the bonds in each of the three portfolios. The average coupon rate of short term bonds is higher than those of medium and long term bonds. The average issuance sizes are pretty close between the three groups.

We denote the average returns for the three bond portfolios as R_S, R_M, and R_L, respectively. In order to see how well the bond return indices capture the commonalities in

Table 4: Characteristics of short-, medium-, long-term bond portfolios.

	Avg. Num. of Bonds	Maturity (Years)	Coupon (%)	Iss. Size (Billion)	Turnover (%)
Portfolio S	7.30	1.59	5.64	24.91	0.7835
Portfolio M	11.99	4.53	3.56	26.42	0.9613
Portfolio L	10.39	10.38	3.33	26.41	0.9577

The table reports averages of number of bonds, time to maturity, coupon, issuance size and weekly turnover for 3 portfolios.

Table 5: Regression of bond returns on bond index returns or principal components.

	R^2 from regressions on	
	Return indices	Principal components
Mean	0.4978	0.4832
Std.	0.2460	0.2335
25$^{\text{th}}$	0.2924	0.2624
50$^{\text{th}}$	0.5483	0.5076
75$^{\text{th}}$	0.7289	0.7297

Individual bond returns are regressed on the three principal factors and the three bond return indices, respectively, and summarize the two R^2s are reported.

individual bond returns, we regress individual bond returns on the three principal components and the three bond return indices, respectively, and compare their explanatory power. Table 5 reports the corresponding R^2. The mean R^2 for the regression on the three bond return indices is 49.78% while the regression on the three principal components is 48.32%. The median R^2s for these two regressions are 54.83% and 50.76%, respectively. Thus, the three bond return indices have the same explanatory power as the first three principal components. In our analysis below, we will simply use the bond return indices as proxies for the common factors in bond returns.

Table 6 reports some summary statistics of the three bond return indices. We have also included the 7-day repo rate on the SSE as the risk-free interest rate, denoted by R_f. The left block provides the mean and standard deviation of the average return and turnover of the three bond portfolios. It also gives the mean and standard deviation of the short term repo rate. The right block gives the contemporaneous correlation matrix between R_S, R_M and R_L and the number in parenthesis is the corresponding p-value. The correlation between R_S, R_M, R_L are pretty high and significant, as expected. For example, the correlation between

R_M and R_L reaches 84.64%.

Table 6: Summary statistics and cross-correlation of bond return indices.

	Return(%)				
	Mean	Std	R_S	R_M	R_L
R_f	0.0262	0.0095			
R_S	0.0574	0.1376	1.0000	0.6129	0.4651
				(0.0000)	(0.0000)
R_M	0.0660	0.3413		1.0000	0.8464
					(0.0000)
R_L	0.0511	0.6758			1.0000

The left part is mean and standard error of bond indices's return, and the right is contemporaneous correlations between bond return indices.

5 Serial Correlation in Bond Return Indices

In order to analyze the efficiency of the CGB market, we examine the serial correlation of the three bond return indices.

A. Serial Correlation

In Panel A of Table 7, we report the serial correlation of the three weekly bond return indices, R_S, R_M, R_L for the CGBs. We find that R_S exhibits no significant serial correlation. However, both R_M and R_L exhibit strong serial correlations. For R_M, for example, the first order serial correlation reaches a level of 27.72% for the whole sample, with a p value of 0.0000. For R_L, the first order serial correlation is even higher, reaching 31.28% with a p value of 0.0000. The serial correlations for R_M and R_L become marginally insignificant after one lag.

We also split the sample into two sub-sample periods and find that the serial correlation for both R_M and R_L remain large and significant for both subperiods. For example, R_M exhibits a serial correlation of 0.1718 and 0.3250 for subperiods 2003–04 and 2005–06, respectively, with corresponding p values of 0.0994 and 0.0012. For R_L, the serial correlation estimates for the two subperiods are 0.2652 and 0.2970, respectively, with corresponding p values of 0.0110 and 0.0031. [9]

[9] One surprising result is that while serial correlation becomes mostly insignificant for both R_M and R_L,

Table 7: Autocorrelation of bond return indices.

A. Chinese Government Bonds

	2003-2006			2003-2004			2005-2006		
	R_S	R_M	R_L	R_S	R_M	R_L	R_S	R_M	R_L
ρ_1	0.0300	0.2772	0.3128	-0.1155	0.1718	0.2652	0.2250	0.3250	0.2970
	(0.6790)	(0.0000)	(0.0000)	(0.2681)	(0.0994)	(0.0110)	(0.0252)	(0.0012)	(0.0031)
ρ_2	0.0496	0.1284	0.1453	-0.0299	0.0904	0.1492	0.1567	0.0912	-0.0181
	(0.4948)	(0.0993)	(0.0671)	(0.7771)	(0.3993)	(0.1802)	(0.1374)	(0.4098)	(0.8678)
ρ_3	0.2170	0.1504	0.1649	0.1551	0.0521	0.0926	0.3050	0.2081	0.2128
	(0.0000)	(0.0570)	(0.0410)	(0.1424)	(0.6300)	(0.4146)	(0.0047)	(0.0617)	(0.0510)
ρ_4	-0.0449	0.1186	0.0363	-0.1705	0.0099	-0.1146	0.1038	0.1535	0.2277
	(0.5554)	(0.1408)	(0.6594)	(0.1151)	(0.9270)	(0.3160)	(0.3717)	(0.1829)	(0.0442)

B. U.S. Treasury Bonds

	1997-2007			1997-2002			2002-2007		
	1-3y	3-5y	7-10y	1-3y	3-5y	7-10y	1-3y	3-5y	7-10y
ρ_1	-0.0946	-0.0007	-0.0198	-0.1004	-0.0065	-0.0390	-0.0925	0.0056	0.0038
	(0.0306)	(0.9866)	(0.6504)	(0.1047)	(0.9170)	(0.5284)	(0.1352)	(0.9285)	(0.9506)
ρ_2	0.1023	-0.0504	-0.0790	0.1174	-0.0561	-0.0780	0.0739	-0.0406	-0.0807
	(0.0206)	(0.2494)	(0.0714)	(0.0603)	(0.3651)	(0.2081)	(0.2367)	(0.5121)	(0.1921)
ρ_3	-0.0432	0.0369	0.0694	-0.0708	0.0051	0.0178	0.0053	0.1046	0.1438
	(0.3331)	(0.4009)	(0.1153)	(0.2641)	(0.9348)	(0.7757)	(0.9332)	(0.0916)	(0.0210)
ρ_4	-0.0210	-0.0191	0.0072	-0.0474	-0.0644	-0.0472	0.0206	0.0763	0.0874
	(0.6384)	(0.6634)	(0.8712)	(0.4568)	(0.2996)	(0.4497)	(0.7422)	(0.2232)	(0.1693)

Autocorrelation of bond indices for CGBs (panel A) and US Treasuries (panel B). For US Treasuries, the three bond return indices are for bonds with maturities between 1 to 3 years, 3 to 5 years and 7 to 10 years, respectively. The left, middle and right blocks are for whole sample, the first and second subperiods respectively. In each block, the first four order autocorrelations are reported with the corresponding p-value in the parentheses below.

It is interesting to note that for individual bond returns, as reported in Table 2, the serial correlation is insignificant at all lags. This raises the question about the source of the serial correlation in bond return indices. There are two possibilities. The first is that the serial correlation is associated with the common components driving bond returns. The individual bond returns, driven by both the common components and their idiosyncratic components, only partially capture such a correlation. Return indices, on the other hand, do a better job as they mainly reflect the common components. This is the motivation behind our analysis to focus on return indices. The other possibility is that such a serial correlation in return indices arises from the cross serial correlation in individual returns, i.e., the lead-lag effect as shown by Lo and MacKinlay (1988) in equity returns. We have done the same analysis for individual bond returns and found no systematic pattern in cross serial correlations in individual or portfolio bond returns. We thus conclude that the serial correlation in bond return indices are not mainly due to the lead-lag effect.

In order to gauge the significance of the serial correlation we find in CGB return indices, we also estimate the serial correlations of return indices of the US Treasury bonds. We also consider three bond return indices, which are computed from the 1-3 Years, 3-5 Years and 7-10 Years US TOTAL DS GOVT (price) INDEX from the Datastream. These maturity brackets are chosen to roughly match those we used to for the CGB return indices. Since a longer history is available for the US Treasuries, we use the ten year sample from 1997 to 2007. The estimates for the first four order serial correlations for the three US Treasury return indices are reported in the Panel B of Table 7. Again, the left, middle and right blocks are for the whole sample, the first and second subperiods, respectively.

Clearly, both the returns for 3-5 Year and 7-10 Year US Treasury indices exhibit no significant serial correlation. Only the 1-3 Year index shows significant serial correlations of -0.0946 and 0.1023 at one and two week lags, with p values of 0.0306 and 0.0206. But the magnitude is relatively small.

The sharp contrast between the CGBs and US Treasuries in the serial correlation in their overall returns suggests the potential inefficiencies in the CGB market. We will explore this question further in the analysis to follow.

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after one lag, it is sometimes shows up significant for the third order serial correlation, even for R_S. We suspect that this is due to estimation errors and examine this in detail in Section 7.

B. Momentum Profit

Given the strong serial correlations in R_M, R_L and their statistical significance, we now examine their economic importance by looking at potential profits they allow for trading strategies to take advantage of them. Given the positive serial correlations, we consider a momentum trading strategy as follows: At the beginning of week $t-1$, we buy or sell short the medium or long term bonds depending the signs of R_M, R_L in the previous weeks and hold the portfolio for one week. If $R_M(t-\tau) < 0$ and $R_L(t-\tau) \geq 0$, where $\tau = 1, 2, 3, 4$, then we buy RMB1 of long term bonds and short sell RMB1 of medium term bonds at the same time. We act oppositely if $R_M(t-\tau) \leq 0$ and $R_L(t-\tau) > 0$. If $R_M(t-\tau) < 0$ and $R_L(t-\tau) < 0$, we short RMB0.5 of both medium term and long term bonds and long RMB1 of repo at R_f (that is we sell the bonds and invest the proceeds at the risk-free 7-day repo rate). If $R_M(t-\tau) \geq 0$ and $R_L(t-\tau) \geq 0$, then we long RMB0.5 of both the medium and long term bonds by borrowing RMB1 at the repo rate R_f. This strategy is similar to trading strategies commonly used in momentum profits literature (see, for example, Jegadeesh and Titman (1993)) and guarantees that the portfolio is self-financing with zero net initial investment and its long position is always RMB1. We denote the corresponding portfolio return series as Profit_τ. To eliminate the worry that some outliers drive the whole result, we drop the top and bottom 2.5% observations of R_M and R_L before we calculate portfolio profits.[10]

In Table 8, we summarize the momentum profits from the above strategy. The first three rows are mean and standard error of the profit; the 4th to the 8th rows report the skewness, kurtosis, maximum, median and minimum of the profit.

The momentum profit from trading on past week's return is high. For the whole sample period, the average of this first order momentum profit reaches 11.84 basis points (i.e., 6.16% per year). Here, the percentage is computed using the long positions (recall that the net investment of the momentum strategy is zero). [11] In order to make sure the profit is not driven by a few outliers, we also report the median profit, which is 8.29 basis points. The fact that it is comparable to the mean, although slightly smaller, indicates that the average profit is robust. We also report the profits from strategies based on lagged returns of two,

[10] We also do the same exercise without dropping the outliers at top and bottom 2.5% observations, the result are very similar and available depend on request.

[11] Although this profit is smaller than the momentum profit of about 1% per month from developed stock markets (Jegadeesh and Titman (1993), Rouwenhorst(1998), and Chan, Hameed, and Tong(2002)), it is pretty high both in economical and statistical sense, compared with the momentum profit of about 0.7% pre year in China's A share stock market (Kang, Liu, and Ni (2002)).

Table 8: Momentum profits on bond portfolios.

	$\text{Profit}_1(\%)$	$\text{Profit}_2(\%)$	$\text{Profit}_3(\%)$	$\text{Profit}_4(\%)$
Mean	0.1184	0.0390	0.0470	0.0366
Std	0.3229	0.3292	0.3303	0.3395
Skew	0.1305	0.1265	0.2723	0.1558
Kurt	0.4347	0.7075	0.5485	0.6415
Max	1.0620	1.0620	1.0620	1.0620
Median	0.0829	0.0144	0.0186	0.0205
Min	-0.8666	-0.9278	-0.8210	-0.8210
α	0.1005	0.0340	0.0350	0.0038
	(3.89)	(1.37)	(1.43)	(0.15)
β_S	0.2308	0.1252	0.1065	0.5047
	(0.84)	(0.48)	(0.42)	(1.79)
β_M	0.2241	-0.2804	-0.1054	0.2957
	(0.86)	(-1.26)	(-0.46)	(1.29)
β_L	-0.0004	0.2711	0.2458	-0.0023
	(-0.00)	(2.17)	(1.99)	(-0.02)
R^2	0.0589	0.0569	0.0837	0.1288

The first seven rows report the summary statistics of the momentum profits: the mean and standard deviation of the profit, skewness, kurtosis, maximum, median and minimum. The momentum profit is further regressed on the bond return indices to calibrate its exposure to market risks. The regression results are reported in the next 9 rows, including parameter estimates and their corresponding t-statistics in parenthesis (based on autocorrelation and heterogeneity corrected standard errors), and R^2.

three and four weeks. They are in general insignificant. This is consistent with the earlier result that momentum becomes insignificant beyond one week lag.

In order to check if the profit from the momentum strategy can be explained by its exposure to market risk factors, we regress Profit_τ on excess returns of the three bond portfolios: $R_S - R_f$, $R_M - R_f$ and $R_L - R_f$. The results are reported at the last nine rows of Table 8. The number in parenthesis under each estimate gives the corresponding p-value after adjusting for serial correlation and heterogeneity.

Here, we focus only on the first order momentum strategy. Clearly, its profits have no significant exposure to market risk factors, using the excess returns on the three bond portfolios. The weekly alpha is 10.05 basis points, with a p value of 0.0000. We thus conclude that the momentum profit is significant and are not attributed to risk premiums associated with bond market risk factors.

6 Market Segmentation

Among the bonds we are considering, some are traded on the SSE, Shenzhen Stock Exchange and the Interbank Government Bond Market while the others are traded only on the SSE. This suggests that the CGB market is segmented and, moreover, different bonds may face different degrees of segmentation. Bonds traded on SSE faces more potential segmentation as they can be only held and traded by participants of SSE, which excludes many institutional investors such as commercial bands. Bonds that can be traded on both the SSE and the interbank market have a larger investor base and face a more integrated market. To the extent that momentum in CGB returns reflects certain degree of market inefficiency, we are interested in exploring its potential link with market imperfections such as segmentation.

In order to do so, we divide the bonds into two groups. Group I consists of bonds traded only on the SSE and group II consists of bonds which can be traded across markets. Within each group, we again divide the bonds into short, medium and long term bond portfolios and calculate the momentum profits according the same procedure we used in the analysis in Section 5 for the full sample. We will examine if there are differences between the two groups of bonds.

Panel A of Table 9 reports the weekly momentum profit for group I and II bond portfolios. We find that the momentum profit for group I bonds is higher than for group II bonds. In terms of raw profit, momentum strategy based on the three portfolios of group I bonds is 11.65 basis points while that based on group II bonds is 9.84 basis points. For risk-adjusted returns, the alpha is 9.52 basis points for group I bonds and 8.39 basis points for group II bonds. Given that group I bonds face more segmentation and have a narrower investor base, these differences seem to suggest a positive link between momentum and market imperfection.

In order to further examine this link, we conduct statistical tests of these differences, in particular, their significance. In the last column of Table 9, we report the results of these tests. For the raw profit, we use a t-test for the equality of profits of the momentum strategies from the two groups. The difference of 1.81 basis points has a t-statistic of 1.18, given in the parenthesis.

For the equality test of the risk adjusted return α, we include dummy variable, which takes a value of 1 for group I bonds and 0 for group II bonds, and report the estimated result of the dummy variable. The coefficient for the dummy variable has an estimated value of 1.13 (in basis points) and a t-statistic of 0.31. All the t-statistics are adjusted for

Table 9: Momentum profit and market segmentation.

Panel A. Weekly profits (%)			
	Group I bonds	Group II bonds	T-test
Obs	189	188	
Mean	0.1165	0.0984	0.0181
Std	0.3609	0.2877	(1.18)
Skew	0.2664	0.3667	
Kurt	0.2782	0.8679	
α	0.0952	0.0839	0.0113
	(3.26)	(3.74)	(0.31)
β_S	0.4770	-0.0100	
	(1.42)	(-0.04)	
β_M	0.2091	0.1866	
	(0.70)	(0.82)	
β_L	-0.0515	0.1094	
	(-0.29)	(0.96)	
R^2	0.0508	0.1076	

Panel B. Daily profits (%)				
	All bonds	Group I bonds	Group II bonds	T-test
Obs	879	878	875	
Mean	0.0360	0.0402	0.0269	0.0133
Std	0.1306	0.1579	0.1213	(2.94)
Skew	0.1967	-0.2419	0.0908	
Kurt	2.1810	5.6487	3.1407	
Max	0.5240	0.6399	0.4907	
Median	0.0246	0.0266	0.0177	
Min	-0.6469	-1.2105	-0.7517	
α	0.0360	0.0403	0.0265	0.0138
	(7.78)	(7.20)	(6.20)	(1.96)
β_S	0.0787	0.1395	0.0582	
	(0.72)	(0.99)	(0.53)	
β_M	-0.1027	-0.1259	-0.0814	
	(-0.98)	(-0.93)	(-0.79)	
β_L	0.0581	0.0566	0.0995	
	(0.84)	(0.59)	(1.66)	
R^2	0.0033	0.0033	0.0130	

This table reports the summary statistics of first order momentum profits from group I (second column) and II bonds (third column), and their decomposition into market risk premia. It also reports the results from tests for the equality of raw profits from the two group bonds and their alphas in the third column. For the raw profits, the difference between group I and II bonds is reported in the first row with its t-statistic in the parenthesis below. For the equality test of α, we regress the profits on the excess returns of bond indices, dummy variable (1 for group I bonds and 0 for group II bonds) and interactive terms and report the estimated result of dummy variable, the number in the parenthesis below is corresponding t-statistic. All the t-statistic in this table are adjusted for autocorrelation and heterogeneity.

autocorrelation and heterogeneity.

Of course, these t-statistics suggest that the difference between the two groups, in both raw and risk-adjusted profits of the momentum strategy, is not significant. This is in part due to the small sample size. In order to increase the significance of the test, we further consider the momentum profits based on daily trading strategies, which will enlarge our sample size but may also bring more noise.

Panel B of Table 9 reports the raw and risk-adjusted momentum profits for both group I and II bonds as well as for them combined. The mean raw profit for all bonds is 3.60 basis points, but on daily basis. The risk-adjusted profit is also 3.60 basis points. The difference in raw profit between the two groups is now 1.33 bps. However, with a sample size now of 879, the t-statistic is 2.94, which makes the difference statistically significant. For the risk-adjusted profit, we arrive at the same conclusion. That is, there is a statistically significant difference, with a t-statistic of 1.96, between the risk-adjusted momentum profit for group I and group II bonds. These results suggest that for bonds with more market segmentation, i.e., group I bonds, we see stronger momentum profits.

7 Robustness Analysis

In this section, we consider various robustness tests on the results obtained above.

A. Daily data

In the bulk of our analysis, we used only weekly returns, except in Section 6 when we examine the impact of market segmentation. In this subsection, we report the results on the serial correlation of bond return indices as in Section 5 using daily returns.

Table 10 reports the number of observations as well as mean, standard deviation, and the serial correlation for the daily returns of the three bond return indices, for short, medium and long maturity bonds, respectively. For the portfolio of short maturity bonds, the daily return exhibits slight positive serial correlation at one-day and two-day lags but slight negative serial correlation at the five-day lag. This is consistent with the fact that on weekly basis, there is no significant serial correlation for R_S. For the portfolios of medium and long maturity bonds, however, we observe significant positive serial correlations for one-day, two-day and three-day lags. For example, the first order daily serial correlation reaches 0.2995 for R_M and 0.2964 for R_L. The second order serial correlation remains at 0.1440 and 0.1064, respectively, with corresponding p values of 0.0000 and 0.0016.

Table 10: Daily autocorrelation of bond index returns, R_S, R_M, R_L.

	R_S	R_M	R_L
Obs.	876	879	879
Mean (%)	0.0129	0.0156	0.0151
Std (%)	0.0528	0.1020	0.1849
ρ_1	0.0994	0.2995	0.2964
	(0.0033)	(0.0000)	(0.0000)
ρ_2	0.0430	0.1440	0.1064
	(0.2032)	(0.0000)	(0.0016)
ρ_3	0.0857	0.1299	0.0821
	(0.0112)	(0.0001)	(0.0150)
ρ_5	-0.0912	0.0750	0.0378
	(0.0070)	(0.0262)	(0.2618)

The table reports the number of observations, mean, standard deviation and the first, second, third and fifth order autocorrelations of daily returns of the three bond return indices. The corresponding p values are in the parenthesis.

Of course, serial correlations at the daily level all contributed to the weekly serial correlation we reported earlier. We thus conclude that momentum in the returns of the three bond portfolios is substantial at both the daily and weekly horizon.

B. Outliers

Given the relatively small sample size available, we would like to make sure that our results are not driven by a few outliers. In Table 11, we eliminate the top and bottom $k\%$ ($k = 0, 2.5, 10, 25$) observations of individual bond returns and calculate the first order weekly serial correlation of R_S, R_M and R_L, the corresponding p-value is given in parenthesis. The serial correlations remain high and significant even after eliminating half of observations. Thus, we conclude that the momentum we observe in the bond return indices is a robust phenomenon in the CGB market.

C. Serial Correlation and Sample Size

In our analysis of the serial correlation in bond return indices, we also considered the estimates for the two subperiods to check how stable it persists over time. Although the serial correlation is quite persistent over the two subperiods, its magnitude seems slightly smaller

Table 11: Weekly serial correlation in bond return indices excluding outliers.

Outliers removed (%)	R_S	R_M	R_L
		Panel A: 2003-2006	
0	0.0300 (0.6790)	0.2772 (0.0001)	0.3128 (0.0000)
2.5	0.1084 (0.1360)	0.3083 (0.0000)	0.3218 (0.0000)
10	0.0488 (0.5099)	0.2360 (0.0013)	0.2895 (0.0001)
25	0.1667 (0.0350)	0.2238 (0.0034)	0.1802 (0.0191)
		Panel B: 2003-2004	
0	-0.1155 (0.2681)	0.1718 (0.0994)	0.2652 (0.0110)
2.5	-0.0324 (0.7570)	0.1915 (0.0662)	0.2717 (0.0092)
10	-0.0684 (0.5334)	0.1526 (0.1476)	0.2065 (0.0501)
25	0.1430 (0.2804)	0.0425 (0.6953)	0.1078 (0.3231)
		Panel C: 2005-2006	
0	0.2250 (0.0252)	0.3250 (0.0012)	0.2970 (0.0031)
2.5	0.2069 (0.0395)	0.2698 (0.0073)	0.2808 (0.0052)
10	0.1902 (0.0585)	0.3054 (0.0025)	0.3166 (0.0016)
25	0.1158 (0.2492)	0.2086 (0.0491)	0.1676 (0.1223)

We remove the top and bottom 0%, 2.5%, 10%, 25% observations of individual bond returns, respectively, and calculate the first order serial correlation of R_S, R_M and R_L, the corresponding p-value is put left and in parenthesis.

than the full sample estimate. We suspect that this is due to the small sample properties of the estimator. We use simulations to explore this possibility.

We simulate return sample of size T from an AR(1) process

$$r(t) = \rho r(t-1) + \varepsilon(t), \quad t = 1, \ldots, T,$$

where $r(1) = 0$, $\varepsilon(t)$ is i.i.d standard normal distributed random variables, ρ is serial correlation. We then estimate the serial correlation for the simulated $r(t)$ series and obtain an estimated serial correlation $\hat{\rho}$ each time. This procedure is repeated 1,000 times to assess the property of the estimate. The summary statistic of $\hat{\rho}$ is reported in table 12.

For a given value of ρ, which takes three values, 0.3, 0.0 and -0.3, we consider different sample sizes, $T = 20, 100, 500, 5,000, 10,000$, and then report the mean and standard deviation of the estimate $\hat{\rho}$. For example, for $\rho = 0.3$, which is comparable to what we observe in the data, the estimate has a mean of 0.1788 for sample size of 20 and 0.2706 for sample size of 100. The standard deviation for the estimate is 0.2164 and 0.1007, respectively. When the sample size exceeds 500, the mean estimate becomes very close to the true value of 0.3

with standard deviation less than 0.05.

Table 12: Sample size.

ρ		T				
		20	100	500	5,000	10,000
0.3	Mean	0.1788	0.2795	0.2965	0.2994	0.2990
	Std	0.2164	0.1007	0.0430	0.0139	0.0293
	1st half	0.0802	0.2619	0.2926	0.2996	0.2990
	2nd half	0.1234	0.2627	0.2916	0.2991	0.2991
0	Mean	-0.0603	-0.0152	-0.0023	0.0000	-0.0024
	Std	0.2194	0.0985	0.0440	0.0140	0.0313
	1st half	-0.1239	-0.0173	-0.0047	0.0001	-0.0006
	2nd half	-0.1060	-0.0262	-0.0091	-0.0012	0.0001
-0.3	Mean	-0.3041	-0.2974	-0.3022	-0.3003	-0.2998
	Std	0.1985	0.0945	0.0433	0.0133	0.0310
	1st half	-0.3168	-0.3022	-0.2969	-0.2998	-0.2993
	2nd half	-0.3168	-0.3045	-0.3000	-0.3012	-0.2986

We simulate the AR(1) process $r(t) = \rho r(t-1) + \varepsilon(t), t = 1, \ldots, T$; first and then estimate the autocorrelation for the simulated $r(t)$ series. Repeat this process 1,000 times, we get an estimated autocorrelation $\hat{\rho}$ each time. The summary statistics of $\hat{\rho}$ is put in this table, in each block, the first two rows are mean and standard error of $\hat{\rho}$. We also divide the simulated stochastic process into two equal sub-process, and estimate the autocorrelation of each sub-process and then put the means of estimated autocorrelation as the first and second half into this table.

We make two observations from the simulation results. First, at the sample size of the data we have, an estimate of ρ can be established with sufficient statistical confidence. Second, for small sample sizes, the estimate tends to be lower than the true value. This is true even when the true value of ρ is around zero or negative.

The second observation helps to explain why for the two subperiods, our serial correlation estimates tend to be smaller than their values for the full sample. To confirm this point, we split the simulated returns into two sub-samples and report their estimates in Table 12, in the last two rows of each panel. They are indeed smaller than the full sample estimates.

D. Simulation

In our analysis of serial correlation, we find the third and fourth order autocorrelations of R_M, R_L are unusually high relative to AR(1) processes. We want to know whether it is a

Table 13: Simulation results.

t-statistic	R_S				R_M				R_L			
	ρ_1	ρ_2	ρ_3	ρ_4	ρ_1	ρ_2	ρ_3	ρ_4	ρ_1	ρ_2	ρ_3	ρ_4
Panel A: 2003-2006												
Mean	0.36	-0.07	-0.07	-0.10	3.71	0.87	0.12	-0.03	4.20	1.15	0.26	0.05
Median	0.35	-0.10	-0.01	-0.12	3.71	0.84	0.12	0.01	4.22	1.14	0.33	0.05
Std	0.95	0.98	0.96	0.97	1.00	1.09	1.10	1.14	1.00	1.10	1.10	1.13
Prob.	0.0540	0.0420	0.0460	0.0520	0.9660	0.1640	0.0800	0.0900	0.9840	0.2300	0.0720	0.0700
Panel B: 2003-2004												
Mean	0.16	-0.09	-0.13	-0.14	2.56	0.53	-0.00	-0.16	2.88	0.75	0.10	-0.09
Median	0.18	-0.08	-0.17	-0.12	2.60	0.52	-0.02	-0.20	2.90	0.71	0.08	-0.10
Std	1.01	0.98	0.98	0.96	1.00	1.08	1.10	1.03	0.97	1.07	1.02	1.04
Prob.	0.0540	0.0360	0.0400	0.0480	0.7140	0.1020	0.0760	0.0560	0.8340	0.1480	0.0620	0.0800
Panel C: 2005-2006												
Mean	2.13	0.32	-0.03	-0.09	3.09	0.88	0.20	-0.05	2.83	0.71	0.07	-0.09
Median	2.15	0.33	-0.02	-0.13	3.09	0.88	0.18	0.01	2.91	0.74	0.10	-0.02
Std	1.03	1.06	1.01	1.03	1.07	1.10	1.13	1.08	1.03	1.03	1.04	1.08
Prob.	0.5700	0.0720	0.0460	0.0580	0.8580	0.1640	0.0960	0.0780	0.8020	0.1140	0.0500	0.0780

We simulate vector AR(1) process such that the number of observations, mean return, standard error, correlation and autocorrelation are the same to those of R_S, R_M, R_L for 1,000 times. For each simulated VAR(1) process, we estimate the first to fourth order autocorrelations and get their t-statistics, and summarize the results in this table. In each panel, the first to fourth rows are mean, median and standard error of t-statistics, and the probability of t-statistics larger than 1.96, respectively.

small probability event in the sense of statistics? if so, there must be other factors driving the price process rather than an AR(1) process. In order to answer this question, we first simulate vector AR(1) process such that the number of observations, mean return, standard error, correlations and autocorrelations are the same to those of R_S, R_M, R_L for 1,000 times. For each simulated VAR(1) process, we estimate the first to fourth order autocorrelations and get their t-statistics, and then summarize the results in table 7. In each panel, the first to fourth rows are mean, median and standard error of t-statistics, and the probability of T values larger than 1.96.

In the simulated results, the t-statistic for the first order autocorrelation is significant but those of other orders are not. For example, the t-statistic for the first order autocorrelation of R_M in whole sample is 3.71 and those for the second to fourth order autocorrelation is 0.86, 0.12, -0.03 respectively. This is consistent with our former results in table 7. For R_M and R_L, the probability of t-statistics larger than 1.96 for the second order autocorrelations are 20%, and those for the third and fourth order autocorrelations are around 8%. The results for subperiods are similar. We can concludes that the third or fourth order autocorrelations are unusual high are not actually unusual, at least in the statistical view.

E. Lower vs. higher turnover bonds

In this subsection, we consider whether our results are driven by illiquid (or lower turnover) bonds. We sort bonds using their last four weeks' average turnovers from low to high, and divide them into two groups within short, medium and long term bond groups. The first half is lower turnover bonds and the second is higher. And then we form three bond return indices using lower or higher bond groups, and calculate the first order autocorrelations and momentum profits respectively.

We put the results in table 14, Panel A reports the first order autocorrelation of weekly returns of the three bond return indices from lower and higher turnover bonds. We also test the equality of these autocorrelations using Fisher's Z-test. The corresponding p values are in the parenthesis. The autocorrelations of R_S, R_L from lower turnover bonds are higher and that of R_M is lower, but all the differences are not significant.

In panel B, we report the summary statistics of first order momentum profits from lower turnover and higher turnover bonds, and their decomposition into market risk premia. It also reports the results from tests for the equality of raw profits from the two group bonds and their alphas. For the raw profits, the difference between two group bonds is reported in the first row with its t-statistic in the parenthesis below. For the equality test of α, we regress the profits on the excess returns of bond indices, dummy variable (1 for lower turnover bonds and 0 for higher turnover bonds) and interactive terms and report the estimated result of dummy variable, the number in the parenthesis below is corresponding t-statistic. Both the raw and risk-adjusted profits are higher from lower turnover bonds but not significant. For example, the difference of raw momentum profit is 0.0173% (equal to 0.1123%-0.0950%) between lower and higher turnover bonds and the corresponding t-statistic is only 0.97.

We conclude that the first order autocorrelations and momentum profits from lower turnover bonds are higher than those from higher turnover bonds but all are not significant. Our results are not driven by illiquid (or lower turnover) bonds.

8 Conclusion

We show in this paper that Chinese government bond market, despite its growth and absolute size, exhibits strong inefficiencies. At both the daily and weekly horizon, bond return indices are strongly serially correlated. Such a correlation allows momentum style arbitrage strategies to yield substantial profits, before or after risk adjustments. Moreover, we show that for bonds whose trading are restricted, their return indices allow larger trading profits.

Table 14: First order autocorrelation and momentum profit of lower and higher turnover bonds.

Panel A. First order autocorrelation			
	Lower	Higher	Z-test
R_S	0.2206	0.0011	0.2195
	(0.0133)	(0.9879)	(0.0554)
R_M	0.2235	0.2495	-0.0261
	(0.0021)	(0.0006)	(0.7900)
R_L	0.3167	0.2849	0.0318
	(0.0000)	(0.0001)	(0.7361)

Panel B. First order momentum profit(%)			
	Lower	Higher	T-test
Obs	187	188	
Mean	0.1123	0.0950	0.0173
Std	0.3168	0.3538	(0.97)
Skew	0.3999	0.1002	
Kurt	1.0256	0.9481	
Max	1.0799	1.1611	
Median	0.0891	0.0647	
Min	-0.8155	-1.1103	
α	0.0892	0.0747	0.0145
	(3.79)	(2.81)	(0.41)
β_S	0.2268	0.4051	
	(0.92)	(1.45)	
β_M	0.3175	0.1881	
	(1.95)	(1.04)	
β_L	-0.0230	-0.0099	
	(-0.25)	(-0.09)	
R^2	0.0547	0.0847	

The table reports the first order autocorrelation and momentum profit of lower and higher turnover bonds. The second and third columns are for bonds with lower and higher turnover respectively, and the fourth column is equality test. Panel A reports the first order autocorrelation of weekly returns of the three bond return indices from lower and higher turnover bonds. The corresponding p values are in the parenthesis. In panel B, we report the summary statistics of first order momentum profits from lower turnover and higher turnover bonds, and their decomposition into market risk premia. It also reports the results from tests for the equality of raw profits from the two group bonds and their alphas in the fourth column. For the raw profits, the difference between two group bonds is reported in the first row with its t-statistic in the parenthesis below. For the equality test of α, we regress the profits on the excess returns of bond indices, dummy variable (1 for lower turnover bonds and 0 for higher turnover bonds) and interactive terms and report the estimated result of dummy variable, the number in the parenthesis below is corresponding t-statistic. All the t-statistic in this table are adjusted for autocorrelation and heterogeneity.

References

[1] K. Chan, A. Hameed, and W. Tong. Profitability of momentum strategies in the international equity markets. *Journal of Financial and Quantitative Analysis*, 35(2):153–172, 2000.

[2] E.F. Fama and K.R. French. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33(1):3–56, 1993.

[3] E.F. Fama and K.R. French. Multifactor explanations of asset pricing anomalies. *Journal of Finance*, 51(1):55–84, 1996.

[4] N. Jegadeesh and S. Titman. Returns to buying winners and selling losers: Implications for stock market efficiency. *Journal of Finance*, 48(1):65–91, 1993.

[5] J. Kang, M.H. Liu, and S.X. Ni. Contrarian and momentum strategies in the China stock market: 1993–2000. *Pacific-Basin Finance Journal*, 10(3):243–265, 2002.

[6] R. Litterman and J. Scheinkman. Common factors affecting bond returns. *Journal of Fixed Income*, 1(1):54–61, 1991.

[7] A.W. Lo and A.C. MacKinlay. When are contrarian profits due to stock market overreaction? *Review of Financial Studies*, 3(2):175–205, 1990.

[8] J.C. Nankervis and N.E. Savin. The exact moments of the least-squares estimator for the autoregressive model: Corrections and extensions. *Journal of Econometrics*, 37(3):381–388, 1988.

[9] S.N. Neftci and M.Y. Menager-Xu. *China's financial markets: An insider's guide to how the markets work*. Academic Press, 2006.

[10] R. Roll. R^2. *Journal of Finance*, 43(3):541–566, 1988.

[11] K.G. Rouwenhorst. International momentum strategies. *Journal of Finance*, 53(1):267–284, 1998.

[12] T. Sawa. The exact moments of the least squares estimator for the autoregressive model. *Journal of Econometrics*, 8(2):159–72, 1978.

Table A. List of CGBs traded on SSE and their characteristics

Bond ID Code	Issue Date	Maturity (years)	Coupon (%)	Issue Size (Billion RMB)
000696	1996-06-14	10.00	11.83	25.53
000896	1996-11-01	7.00	8.56	20.11
009704	1997-09-05	10.00	9.78	13.00
009905	1999-08-20	8.00	3.28	16.00
009908	1999-09-23	10.00	3.30	20.00
010004	2000-05-23	10.00	2.87	14.00
010010	2000-11-14	7.00	2.63	12.00
010103	2001-04-24	7.00	3.27	12.00
010107	2001-07-31	20.00	4.26	24.00
010110	2001-09-25	10.00	2.95	20.00
010112	2001-10-30	10.00	3.05	20.00
010115	2001-12-18	7.00	3.00	20.00
010203	2002-04-18	10.00	2.54	20.00
010210	2002-08-16	7.00	2.39	20.00
010213	2002-09-20	15.00	2.60	24.00
010214	2002-10-24	5.00	2.65	30.00
010215	2002-12-06	7.00	2.93	60.00
010301	2003-02-19	7.00	2.66	35.00
010303	2003-04-17	20.00	3.40	26.00
010307	2003-08-20	7.00	2.66	36.00
010308	2003-09-17	10.00	3.02	16.38
010311	2003-11-19	7.00	3.50	36.00
010401	2004-03-15	1.00	0.00	38.16
010403	2004-04-20	5.00	4.42	30.46
010404	2004-05-25	7.00	4.89	36.75
010405	2004-06-15	2.00	0.00	33.23
010407	2004-08-25	7.00	4.71	31.29
010408	2004-10-20	5.00	4.30	33.61
010410	2004-11-25	7.00	4.86	35.91
010411	2004-12-15	2.00	2.98	25.66
010501	2005-02-28	10.00	4.44	30.00
010502	2005-03-15	1.00	0.00	30.00
010503	2005-04-26	5.00	3.30	33.39
010504	2005-05-15	20.00	4.11	33.92
010505	2005-05-25	7.00	3.37	33.78
010506	2005-06-15	1.00	0.00	35.38
010507	2005-07-15	2.00	1.58	35.08
010508	2005-08-15	3.00	1.93	32.45
010509	2005-08-25	7.00	2.83	31.94
010510	2005-09-15	1.00	0.00	33.17
010511	2005-10-20	5.00	2.14	33.35
010512	2005-11-15	15.00	3.65	34.41
010515	2005-12-26	0.25	0.00	41.10
010601	2006-02-27	7.00	2.51	33.00
010603	2006-03-27	10.00	2.80	34.00
010605	2006-05-16	5.00	2.40	30.80
Mean		7.53	3.23	28.71
Std		4.76	2.27	9.17

From the left to right, the first column is the bond's ID code, and the remaining columns are issuing date, maturity, coupon rate and issuing size, respectively. The bottom two rows give the mean and standard deviation of the variables in the corresponding column.