5. RESERVE REQUIREMENT POLICY, BOND MARKET, AND TRANSMISSION EFFECT*

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Abstract

The adjustment of the reserve requirement ratio is one of the most frequently used monetary policy instruments employed by monetary authorities in emerging market economies. According to monetary theories, it was primarily designed to influence the monetary multiplier. However, both academics and practitioners have long questioned whether such a requirement has an impact on commercial bank bond holdings and the output of real economy through price fluctuations in the bond market. In this paper, we set up a macroeconomic equilibrium model that includes central banks, commercial banks, and enterprises, covering a wide range of credit markets, bond markets, and commodity markets. In order to explore the transmission effect of the reserve requirement ratio policy through the bond market, we introduced the method of limit solutions using non-homogeneous linear differential equations with constant coefficients. We empirically examine the existence and effectiveness of transmission mechanisms by applying the TRAMO technique and a cointegration test based on large-sample data from China. The results show that the adjustment of the reserve requirement ratio affects the asset structure of commercial banks, bond market prices, and ultimately the real economy.

Keywords: reserve requirement ratio, bond market, transmission effect, monetary policy

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I. Introduction

The reserve requirement ratio is one of three traditional monetary policy instruments used by central banks. It directly affects the excess reserves of commercial banks and influences the real economy through asset adjustments of commercial banks. In the emerging market economies, the assets of commercial banks mainly consist of loans and bond holdings,4 so there are two monetary policy transmission mechanisms that originated from the adjustment reserve requirement ratio, i.e., "reserve requirement ratio adjustment→ changes in loans→ development of the real economy" and "reserve requirement ratio adjustment→ changes in bond holdings→ development of the real economy." Most studies have focused on the first transmission mechanism (e.g., Davis and Toma, 1995; Mimir *et al.*, 2012; Sumarti *et al.*, 2013); however, the second has been all but neglected. Our findings indicate that adjustments of the reserve requirement ratio could cause bond price fluctuations and ultimately influence output of real economies. What's more, the transmission effect is significant in emerging market economies.

The reason why the transmission effect on reserve requirement policy through the bond market is almost completely ignored lies in the following two factors. First, most developed countries have highly developed financial markets and derivative products; over time, quantitative monetary policy instruments become weak or are abandoned entirely. For instance, the reserve requirement ratio is almost zero in America.5 Since the reserve requirement ratio is no longer an important monetary policy instrument in developed countries, the dramatic point of modern theoretical monetary studies has moved to other subjects. Second, developed market economies adopt open market operations to adjust the money supply. It is generally believed that the effects of the reserve requirement policy are indirect and lagged potentially since this type of monetary policy directly influences commercial banks' reserves, and it has to go, through a balance-sheet effect, in order to change the commercial banks' bond holdings and ultimately lead to fluctuations in the real economy.[6]

In emerging market economies, however, it may remain a possible and important monetary policy transmission mechanism to influence bond market equilibrium and thereby cause fluctuations in the real economy through adjustments of the reserve

4 *According to the latest data released in January 2016 from the public statistics of People's Bank of China website, the total amount of assets of the four biggest commercial banks is 639923.64 hundred million, among which the amount of loan assets is 365715.00 hundred million, accounting for 57.15%; the amount of bond assets is 140701.37 hundred million, accounting for 21.99%.*

5 *According to the Fed's regulations, the reserve ratio for American non-personal time deposits and Eurocurrency liabilities have remained at zero since December 27th, 1990. Please refer to http://www.federalreserve.gov/monetarypolicy/reservereq.htm.*

6 *The changes or uncertainty of monetary policy can impact exchange rates, firm investment, bank lending (quantity and quality), bond prices, inflation rate, real output, and so on (e.g., Thorbecke, 2000; Nagahata and Sekine, 2005; Toyofuku, 2008; Fan* et al.*, 2011). In addition, the issues such as how long the monetary policy maintains and the anticipation of monetary policy are important as well (*e.g.*, Fujiwara, 2007).*

requirement ratio. This is because among the three traditional monetary policy instruments used by central banks in emerging market economy countries, the rediscount policy is more for appearances and not frequently used, while the effects of open market operations are insignificant due to underdeveloped bond markets and a monotonic bond structure. As a result, reserve requirement policy has become the most frequently used monetary policy instrument in most emerging market economies. Meanwhile, as the issuance scale of treasury bonds continues to increase in emerging market economies, treasury bonds have become an important part of commercial bank assets in these economies. Therefore, reserve requirement ratio adjustments influence not only the loan structure, but also the commercial banks' bond holding structure and bond market prices, and ultimately affecting the investment and output of the real economy.

For those reasons above, the study of transmission effects on reserve requirement policy through bond markets in emerging market economies has a strong practical significance. It can not only enrich the theory of the monetary policy transmission research framework, but also help to explain the distortion effects of monetary policy in emerging markets and improve the effectiveness of monetary policy implementation.

Previous studies, aiming at the transmission mechanisms of reserve requirement policy, mostly focused on the impact of reserve requirement regulations on commercial banks' loan assets and analyzed the raised fluctuations in the real economy. For example, Tanaka (2002) began by developing a utility function based on banks' balance sheets, building a multi-stage dynamic model to study the effects of reserve policy. Carpenter *et al.* (2012) used empirical analyses to explain the impact of reserve requirement policy on bank loans and money supply and demand. Ma *et al.* (2013) studied the impact of reserve requirement policy on bank loan structure, especially small business loans, using the numerical solutions of differential equations. However, as the market economy continues to develop, the asset structure of commercial banks becomes complex day by day. Apart from traditional loan assets, banks hold more and more bonds. Therefore, the reserve requirement policy transmission mechanisms through the bond market have become important gradually. For instance, Garcia de Paso (1997) argued that returns on personal deposits and treasury bonds were equal under certain conditions and therefore a change in reserve requirements would lead to a change in bank deposits and loans, ultimately influencing bond prices. Bhattacharya *et al.* (1997) improved the simple money growth model and pointed out that on one hand, reserve requirement policy apparently influences bond prices because it has placed demands on the government's budget deficit while government debt consisted of currencies and bonds. On the other hand, bond markets determined money market equilibrium by influencing the government's budget, and they thereby exerted an impact on the macro-economy. Herrera *et al.* (2010) examined the changes of Columbia's reserve requirement policy over a decade and graphically illustrated the price trend of various bonds to reflect the impact of reserve requirement policy on it. Pericoli and Taboga (2012) developed a two-country arbitrage-free term structure model; they validated the common changes in bond yields, macroeconomic variables and foreign exchange rates, and pointed out that bond yields impacted interest and exchange rates. Kashyap and Stein (2012) held that central banks could control reserve requirement ratios to regulate externalities due to an excess of short-term bonds issued by financial institutions, maintaining the stability of financial markets and macro-economies. Glocker *et al.* (2012) used the VAR model to investigate the macroeconomic effects of reserve requirements in Brazil and found that tightening monetary policy would lead to a decline in domestic credit. Tovar *et al.* (2012) examined the effects of reserve requirement policy and other macroprudential instruments, revealing that the effect of these instruments was moderate and transitory. Federico. Pablo *et al.* (2014) analyzed the effects of the reserve requirement in 52 countries for the period 1970-2011, and found that most developing countries relied on the policy.

The above findings are meaningful and profound, but there are still limitations. Reserve requirement regulation has almost disappeared from prevailing monetary policy in developed market economies. As pointed out by the economists Weiner and Sellon (1996) as well as Hein and Steward (2002), reserve requirement policy has disadvantages and does not fit in developed countries. Existing studies, concerning the transmission mechanisms of reserve requirement policy through the bond market, are scattered without rigorous mathematical analyses, despite previous findings indicate that the adjustment of the reserve requirement ratio correlates to the fluctuation in the bond market and real economy. Consequently, these studies are far from convincing in proving the causality and correlation between them.

This paper explores the weakness of previous studies and makes improvements on their works. First, using the limit solution method for non-homogeneous linear differential equations, we prove that by changing bond price and bond yield through the implementation of open market operations in the first place, followed by guiding investor expectations, the monetary authority stimulates fluctuations in market rates, and eventually guides the development of the real economy. Second, by using the time series regression with ARIMA noise, missed observations and outliers (hereafter TRAMO), and a cointegration method, we prove that the bond markets' transmission path of reserve requirement policy exists in emerging market countries, and its transmission effect is significant. Third, given their current differences in economic environment and market structure, most emerging market countries primarily use monetary policy instruments represented by reserve requirement ratio adjustment. However, with the capital market's continuous evolvement and gradual improvements in a market economy, we predict that more and more attention will be paid to those monetary policy instruments represented by interest rate adjustments.

II. The model

This section introduces psychological expectation variables into the monetary policy implementation. Here, we analyze the transmission mechanism of reserve requirement policy through bond markets using the limit solution method to solve non-homogeneous linear differential equations with constant coefficients.

II.1. Debt-financing based manufacturers system

In a market economy, financing is the core of manufacturing's production process. It determines an enterprise's market competitiveness in terms of procurement, production and marketing, and it influences the equilibrium of commodity markets. Therefore, we begin our analyses with enterprise financing. Under the premise of established commodity prices, we assume that the output of enterprises depends on financing costs. The higher the financing cost is, the lower the output is, and vice versa. These two are in an inversely proportional relationship expressed in equation (1):

$$output = \frac{k}{c_{fund}} \tag{1}$$

where k is a positive parameter, $output$ refers to the enterprise outputs, and c_{fund} is the financing cost. We assume all enterprises raise funds through loans and bond issuances. The former is obtained from financial intermediaries like commercial banks, while the latter is achieved through the capital market according to the expectation of future interest rates in the market. Therefore, enterprises' financing costs consist of the costs of bank financing and of issuing bonds in the market. Enterprises choose a proper financing pattern according to current market conditions.

The more sufficient the loans provided by the commercial banks, the lower the financing costs for the enterprises; the lower the loans provided by the commercial banks, the higher the financing costs for enterprises. Additionally, the higher the future expected bond yields are, the more the enterprise will have to pay for raising the same amount of funds; the lower the expected bond yields become, the lower the costs will be for enterprise financing through the issuance of bonds. Thus we can get equation (2).

$$c_{fund} = \frac{m}{M_{loan}} + nEy \tag{2}$$

where m and n are constant coefficients greater than 0, M_{loan} is the loan amount provided by commercial banks, and Ey is the expected bond yields.[7]

In this model, the monetary policy variable is the reserve requirement ratio R, which is the most frequently used monetary policy instrument nowadays in emerging market countries, such as China. Variable D represents the commercial banks' deposits. After paying required reserves on the basis of R , the rest of the deposits is converted to interest-bearing assets. Assume that interest-bearing assets consist of loans M_{loan} and bonds M_{bond} (collectively referred to Treasury bonds and enterprise bonds). We get the following equation:

$$(1 - R)D = M_{loan} + M_{bond} \tag{3}$$

The scale and structure of the commercial bank's assets is the function of R ; as the regulation in monetary policy continues, the scale and structure of the commercial banks' asset change as well. By affecting the supply and demand of market funds and bonds, the regulation subsequently influences the market economy structure and commodity market equilibrium in a real economy.

[7] *For the purpose of simplification, we ignore transaction costs in our models.*

Bond yields depend on two factors: the market price of bonds (i.e., p in equation (4)) and the expected bond yields. The investment theory indicates that bond yields and the market price of bonds are in inverse proportion, i.e., the lower (or higher) the market price of bonds, the higher (or lower) the bond yields. When investors anticipate a sharp rise in a bond's future return rate (meaning the bond risk increases, i.e., a bond's default rate will surge in the future), they position themselves for large sales of bonds. This leads to a fall in the bond market price and a further surge of bond yields. The above process can be represented by the following equation (4):

$$Yield = l - ap + wEy \tag{4}$$

The first two items on the right side of the equation (4) show the inverse proportion of bond yield and bond price; the third item on the right represents the direct proportion of the yields and the expected yields of bonds. In the equation, $Yield$ is the bond yield, and l, a, and w are constant parameters larger than 0, since the expected yields partially, but not completely, determine the yields, $w<1$.

Commercial banks are the main holders of treasury bonds; their supply and demand of bonds largely determine the market prices of treasury bonds. On one hand, as one of their assets, treasury bonds can bring revenues to commercial banks. Therefore, the demand for treasury bonds depends on price. The higher (lower) the price is, the lower (higher) the demand for treasury bonds is. In this paper, the common right downward-sloping demand curve is used to present the relations of the two with $c<0$:

$$Q_d = b + cp \tag{5}$$

On the other hand, treasury bonds are important subject matters of monetary policy operation for central banks. Central banks flexibly use monetary policy instruments to induce commercial banks to change their asset structure and risk preferences for the purpose of realizing specific monetary policy objectives. For instance, an increase in the reserve requirement ratio will enable commercial banks to sell off low-yield treasury bonds and to use that recovered capital to cover the required reserves unfulfilled as a result of stringent monetary policy. Therefore, the supply of treasury bonds is determined by not only market price but also the implementation of monetary policy by central banks. The following equation is given, where $h>0$ and $u>0$.

$$Q_s = g + hp + uR \tag{6}$$

What we want to investigate is: if a disturbance in monetary policy occurs at the beginning of the period, will there be a steady state in the economy at the end of the period? If the answer to this question is positive, we must further to identify the steady state. For this purpose, we will introduce time variables and examine the bond as a type of commodity. In the classical macroeconomic supply and demand analysis, it is generally assumed that the rate of change in commodity price and the excess demand are in direct proportion, as shown in equation (7), where q is a positive constant:

$$\frac{dp}{dt} = q(Q_d - Q_s) \quad (7)$$

We also assume the price of long-term bonds at the beginning is $p(0)$ as below:

$$p\big|_{t=0} = p(0) \quad (8)$$

The formation of expected bond yield is considered with a complex process because it involves the psychological expectation factors of a rational man. From the outset, investors have a prior expected bond yields. The future expected bond yields are adjusted periodically, according to the current real bond yield level. Thus, for investors, the current bond yields are a signal of allowing them to make adjustments to the final value of expected bond yields. When the bond yields are greater than their expected yields, the investors of anticipating those bond yields will continue to rise in the future; when investors discover that bond yields are smaller than their expected yields, they anticipate a fall in future bond yields. All is shown in equation (9) where j is a parameter larger than 0.[8]

$$E\left(Ey \middle| Yield\right) = \frac{dEy}{dt} = j(Yield - Ey) \quad (9)$$

Also we assume a prior expected bond yield $Ey(0)$ at the beginning, as below:

$$Ey\big|_{t=0} = Ey(0) \quad (10)$$

II.2 Transmission mechanisms of reserve requirement policy

Substituting equations (5) and (6) into equation (7), we have

$$\frac{dp}{dt} = (qc - qh)p + q(b - g - uR) \quad (11)$$

8 To simplify the discussions, equations (4) and (9) in this part consider treasury bonds and enterprise bonds as one study object. There are plenty of studies (as recently Krishnamurthy and Vissing-Jorgensen, 2011 and Swanson, 2011) proving that treasury bond interest rates have a guiding function to the market interest rate and these two kinds of rates have a strong correlation and respond consistently to the monetary policy. So, although during the analysis, the price and yield of treasury bonds and enterprise bonds should be molded separately and then be connected using constant coefficients, because the equation structures of these two are identical and are of positive correlation, this paper only presents one equation to avoid unnecessary complication in the deduction.

Solving this non-homogeneous linear differential equation with a constant coefficient,9 we get the general solution of the variation trend of bond prices under the intervention of monetary policy over time:

$$p = C\exp[q(c-h)t] + \frac{b-g-uR}{h-c} \tag{12}$$

Substituting equation (8) into equation (12), we find its particular solution:

$$p = \left(p(0) + \frac{uR+(g-b)}{h-c}\right)\exp[q(c-h)t] + \frac{b-g-uR}{h-c} \tag{13}$$

In equation (13), we assume that the monetary policy disturbance is certain at the beginning, $\left(p(0) + \frac{b-g+uR}{c-h}\right)$ is a constant, and $(c-h)$ is a negative number. As t tends to an infinite, the bond price is liable to be a definite value. Therefore,

$$\lim_{t\to+\infty} p = \lim_{t\to+\infty}\left(p(0) + \frac{uR+(g-b)}{h-c}\right)\exp[q(c-h)t] + \frac{b-g-uR}{h-c} = \frac{b-g-uR}{h-c} \tag{14}$$

In the equation, when $\left(p(0) + \frac{b-g+uR}{c-h}\right) > 0$, p goes from the positive direction to be $\frac{b-g+uR}{h-c}$, otherwise, p goes from the negative direction to be $\frac{b-g+uR}{h-c}$.

Since b, c, g, h, u are constants, we find:

PROPOSITION 1: *The bond price fluctuation depends on monetary policy adjustments.*

We reconsider the numerical relationship between the bond prices and monetary policy. Because

$$\frac{\partial p}{\partial R} = -\frac{u}{h-c} < 0\,. \tag{15}$$

Bond price and monetary policy are in inverse proportion, which means commercial banks will sell off bonds in the face of stringent monetary policy, causing a decline in bond price.

Substituting equation (13) into (4) and substituting equation (9) in the result, we have

$$\frac{dEy}{dt} = j\big(l - ap + (w-1)Ey\big) = j(w-1)Ey + j\left(l - \frac{a(b-g-uR)}{h-c}\right) \tag{16}$$

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9 We can adapt the constant variation method or use formula $y = e^{\int a(x)dx}[\int b(x)e^{-\int a(x)dx}dx + C]$ to solve the first-order non-homogeneous linear differential equations, such as $\frac{dy}{dx} = a(x)y + b(x)$.

Solving this non-homogeneous linear differential equation, and substituting equation (10) based on the general solution, we get:

$$Ey = \left(Ey(0) + \frac{l(h-c) - a(b-g-uR)}{(h-c)(w-1)} \right) \exp\big(j(w-1)t\big) + \frac{a(b-g-uR) - l(h-c)}{(h-c)(w-1)} \tag{17}$$

Since $w<1$, when t tends to an infinite, we have;

$$\lim_{t \to +\infty} Ey = \frac{a(b-g-uR) - l(h-c)}{(h-c)(w-1)} \tag{18}$$

Equation (18) indicates that under specific monetary policy, the limit of expected bond yield is a constant value. Hence, we can conclude:

PROPOSITION 2: Expected bond yield depends on monetary policy adjustments.

By the partial derivative of Ey with R, we have:

$$\frac{\partial Ey}{\partial R} = \frac{-au}{(h-c)(w-1)} > 0 . \tag{19}$$

With the enhanced intensity of the central bank's monetary policy, commercial banks will likewise enhance their massive sale of bonds, resulting in a plunge in market bond price and a jump in bond yield. This conclusion is consistent with our economic intuition and prior assumptions.

From the partial derivative of equation (2) with R, we get:

$$\frac{dc_{fund}}{dR} = \frac{-m}{M_{loan}^2} \cdot \frac{dM_{loan}}{dR} + n\frac{dEy}{dR} \tag{20}$$

Compared with previous studies (Ma *et al.*, 2011; 2013), we explore the impact of monetary policy adjustments (reserve requirement ratio, R) and regulatory policy (required capital adequacy ratio, θ) on the lending behavior of commercial banks. We conclude that normally strengthening the intensity of monetary policy and regulatory policy would cause a shrink in the scale of loans from commercial banks in the long run.

$$\frac{dM_{loan}}{dR} < 0 , \quad \frac{dM_{loan}}{d\theta} < 0 \tag{21}$$

By substituting equations (21) and (19) into equation (20), we find:

$$\frac{dc_{fund}}{dR} > 0 . \tag{22}$$

Equation (22) indicates that enterprise financing costs and monetary policy intensity are in direct proportion. Hence, we can conclude:

PROPOSITION 3: *A stringent (loose) monetary policy will cause a rise (decline) in the financing costs of enterprises through bond market transmission mechanisms.*

Through the derivative of equation (1) with R and substituting equation (22), we get:

$$\frac{doutput}{dR} = \frac{-k}{c_{fund}^{2}} \cdot \frac{dc_{fund}}{dR} < 0 \quad . \qquad (23)$$

Equation (23) indicates that the output of enterprises and the intensity of monetary policy are in inverse proportion. Hence, we can conclude:

PROPOSITION 4: *A stringent (loose) monetary policy will cause a decline (rise) in the output of enterprises through bond market transmission mechanisms.*

II.3. Impact of capital requirement policies on transmission mechanisms

Over the past three decades, one of the biggest adjustments in banking supervision is the implementation of capital adequacy requirements under the guidance of the Basel Accords. Currently, capital adequacy supervision is widely recognized by monetary authorities around the world as an effective mechanism designed to prevent and control the operating risk of commercial banks. It not only incorporates a type of mechanism that closely links the overall systematic risk of the banking industry to the amount of capital base, motivating commercial banks to internally focus on and guard against their own risks, but also achieves a significant effect in reducing the overall systematic risk of the banking industry. Despite the fact that the supervisory review of capital adequacy was first suggested as a technological method to reduce the overall systematic risk in the banking industry, as a result of commercial banks' growing influence on the real economy, capital requirement acquires a deepening and widening intervention in macro-economy. Hence, it is of great theoretic and realistic significance to explore the impact of capital requirement policy on monetary policy transmission mechanisms.

Assumptions remain unchanged. Commercial banks' assets consist of loans and treasury bonds. According to the Basel Accords, the capital adequacy ratio can be simply expressed as "capital/loan." Generally, treasury bonds are regarded as risk-free assets and excluded from the risk assets involved in the calculation of the capital adequacy ratio. Therefore, capital requirements have a direct impact on loans rather than treasury bonds. Commercial bank loans are a function of two variables, monetary policy, R , and capital requirement policy, θ .

The policy effects are explored and compared under two different cases found as follows. In the first case, only monetary policy is concerned. By calculating the differential of equation (2) and combining it with equation (20), we can get

$$d(c_{fund}1) = \frac{dc_{fund}}{dR} dR = \frac{-m}{M_{loan}^{2}} dM_{loan} + ndEy \qquad (24)$$

By calculating the differential of equation (1) and combining it with equation (24), we can get

$$d(output\ 1) = \frac{km}{c_{fund}^2 M_{loan}^2} dM_{loan} - \frac{kn}{c_{fund}^2} dEy \ . \qquad (25)$$

In the second case, both monetary policy and capital requirement policy are concerned:

By calculating the differential of equation (2) and combining it with equation (24), we can get

$$d(c_{fund}2) = \frac{\partial c_{fund}}{\partial R} dR + \frac{\partial c_{fund}}{\partial \theta} d\theta = \frac{-m}{M_{loan}^2} \frac{\partial M_{loan}}{\partial R} dR + n\frac{\partial Ey}{\partial R} dR + \frac{-m}{M_{loan}^2} \frac{\partial M_{loan}}{\partial \theta} d\theta \qquad (26)$$

Since $\frac{\partial M_{loan}}{\partial \theta} < 0$, the third right item of equation (26) would be greater than 0. Thus we have:

$$d(c_{fund}\ 2) > d(c_{fund}\ 1) \qquad (27)$$

Equation (27) indicates that in the monetary policy transmission analysis, whether capital requirement is considered or not can lead to different conclusions. We can therefore conclude:

PROPOSITION 5: *Imposing a capital requirement policy on the bond market transmission mechanisms of reserve requirement policy would cause an increase in enterprises' financial costs.*

By calculating the differential of equation (1) and combining it with equation (25), we can get

$$\begin{aligned} d(output\ 2) &= \frac{\partial output}{\partial R} dR + \frac{\partial output}{\partial \theta} d\theta \\ &= \frac{km}{c_{fund}^2 M_{loan}^2} \cdot \frac{\partial M_{loan}}{\partial R} dR - \frac{kn}{c_{fund}^2} \cdot \frac{\partial Ey}{\partial R} dR + \frac{km}{c_{fund}^2 M_{loan}^2} \cdot \frac{\partial M_{loan}}{\partial \theta} d\theta \end{aligned} \qquad (28)$$

Comparing this with equation (25), we determine the following:

$$d(output\ \ 2) < d(output\ \ 1) \qquad (29)$$

Hence, we can conclude:

PROPOSITION 6: *Imposing a capital requirement policy on the bond market transmission mechanisms of reserve requirement policy would cause a decline in the output of enterprises.*

Through a comparative analysis, the conclusions of equations (27) and (29) reveal that capital requirement policy indeed changes the original monetary policy transmission mechanisms.

In the above analysis, we prove the existence of bond market transmission mechanisms in reserve requirement policy through a mathematical model. The transmission mechanism is through the channel that central banks adjust their reserve requirement ratio to influence commercial banks' bond holdings as well as bond prices and bond yields in the market, while changes in bond yields will help form long-term interest rates through expected yields[10], changing the long-term financing costs of enterprises, and ultimately leading to fluctuations in the real economy.

III. Empirical studies

In this section, we use the TRAMO and cointegration tests to empirically test the transmission effects of reserve requirement policies through the bond market, based on Chinese data.

III.1. Data and variables

The variables are classified into six kinds: reserve requirement ratio (SR), money supply (M2), benchmark interest rate (R), bond price (Price_Bond), bond yield (Yield_Bond) and output (GDP), and ten time series including seven daily data series, two monthly data series, and one variable-frequency data series.

From 2003 to 2012, according to changes in macroeconomics, China has adjusted the reserve ratio 32 times. The latest adjustment occurred on May 12th, 2012, when the reserve rate was cut to 20%. Thus, there have been 32 monetary policy shocks. SR denotes the sequence of the reserve ratio; the money supplies M2 were the monthly data. These two sets of data were collected from statistics published from the People's Bank of China.[11] The Chinese interbank's offered rate (Chibor) is based on a re-loan interest rate and a rediscount rate from the central bank. It is then freely negotiated between the lending and the borrowing parties according to the supply and demand relation of social funds.

Consequently, the benchmark interest rates (R) selected in this study includes a 30 day Chibor (IR1), a 90 day Chibor (IR2) and a one year deposit interest rate (IR3). These data were collected from information published by the China Banking Regulatory Commission (CBRC).[12] The bond price (Price_Bond) was represented by the government bond index (Ind_Bond), an index reflecting the fluctuations in bond prices; it was calculated using all fixed-rate government bonds listed on the Shanghai Stock Exchange (SSE) as baselines, weighed by bond issuance. These data were collected from information published by the SSE.[13] Government bond yield (Yie_Bond) data were collected from yield curves published on the China Bond Information Network website by the China Government Securities Depository Trust & Clearing Co., Ltd.[14] The selected government bonds were of 3-year, 5-year and 10-year varieties, and the data sequences were denoted as Yie_Bond3, Yie_Bond5 and Yie_Bond10, respectively.

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[10] The expectation of investors can change the direction of economic development; the Fed's Operation Twist in 2011 is a good example. Operation Twist did not change the money supply; however, it brought down the long-term bond yields and long-term financing cost of enterprise by signaling and changing expectations, ultimately guiding investments into long-term areas.

[11] People's Bank of China, http://www.pbc.gov.cn.

[12] China Banking Regulatory Commission, http://www.cbrc.gov.cn

[13] Shanghai Stock Exchange, http://www.sse.com.cn.

[14] ChinaBond.com, http://www.chinabond.com.cn.

III.2. Validation of the existence of transmission mechanism

In order to avoid possible spurious regression, it is important to validate the correlation between the adjustments of reserve requirement ratio and fluctuations in the bond market and output. However, as some data series are non-frequency series (reserve requirement ratio is a variable-frequency series, bond price and bond yield are daily series and output, and GDP is a monthly series), it is impossible to judge their correlation using conventional techniques. Fortunately, TRAMO is one of appropriate techniques in solving this problem.

The TRAMO technique was initiated by the Spanish Central Bank and is adept in identifying structural change points over data series. In this paper, three different kinds of structural changes are considered – including AO (Additive Outliers), TC (Transitory Change), and LS (Level Shift). We intend to identify the structural change points in bond price, bond yield, and GDP series, and we thereby determine if any correlative reserve requirement adjustments exist around these change points. If correlative points indeed exist and such correlation is normal, rather than incidental, then the following conclusion can be made: these non-frequency series indeed correlate to each other, which means that reserve requirement adjustments can cause bond price fluctuations as well as in investments and output.

Based on the above analysis, we get the results of Table 1. Using the TRAMO technique in the sample space, fifteen structural change points of explained variables (bond price, bond yield and output) are identified, among which thirteen change points are significantly correlated to monetary policy (reserve requirement ratio) with a degree of correlation up to 86.67%. It indicates that under current economic conditions, the bond market transmission mechanism of the reserve requirement policy indeed exists.

Table 1

Structural change points identified by the TRAMO and their correspondence to policy

Variable	Time	Type	T-value	Correspondence to monetary policy	Adjustments of reserve requirement ratio
Price_bond	2004/04	TC	-10.77	Yes	Once in Apr 2004.
	2005/11	AO	-3.21	No	
	2008/12	TC	3.59	Yes	Once in Oct 2008 and twice in Dec 2008.
Yield_bond3	2008/12	AO	-5.33	Yes	Once in Oct 2008 and twice in Dec 2008.
	2009/07	TC	4.28	No	
Yield_bond5	2007/06	TC	3.84	Yes	Three times in Apr, May and Jun of 2007.
	2008/12	TC	-3.98	Yes	Once in Oct 2008 and twice in Dec 2008.
	2010/11	TC	3.22	Yes	Twice in Nov 2010.
Yield_bond10	2007/06	TC	3.88	Yes	Three times in Apr, May and Jun of 2007

Variable	Time	Type	T-value	Correspondence to monetary policy	Adjustments of reserve requirement ratio
	2008/12	AO	-5.36	Yes	Once in Oct 2008 and twice in Dec 2008.
	2010/11	AO	4.38	Yes	Twice in Nov 2010.
GDP	2008/04	LS	6.26	Yes	Three times in Jan, Mar and Apr of 2004.
	2009/01	LS	-9.82	Yes	Once in Oct 2008 and twice in Dec 2008.
	2009/04	LS	8.35	Yes	Once in Oct 2008 and twice in Dec 2008.
	2011/10	TC	5.74	Yes	Once in Jun 2011.

III.3. Impact of the reserve requirement policy on the bond market

The above results show that change points in the bond market and the real economy are significantly correlated to monetary policy. Here we use a cointegration test to analyze the relation between the adjustment of the reserve requirement ratio and the fluctuations of bond markets and the real economy.

III.3.1. Impact of the reserve requirement policy

First, the time series of the above variables were subjected to a unit root test; the results are shown in Table 2. The unit root test results showed that all time series were non-stationary. However, after the first order of differentiation they all were stationary time series, i.e., they were all I(1).

A cointegration test was therefore performed on all the variables, and the results are illustrated in Table 3. Here, model 1 represents the effect of reserve requirements on bond price, while models 3, 4, and 5 represent the effect of reserve requirements on bond yield. The results reveal that an upward adjustment of reserve requirement ratio (tightening monetary policy) will cause a fall in bond price (coefficient of -0.16) and a rise in bond yield (coefficient of +0.15, +0.14, +0.1). The adjustment of the reserve requirement ratio is significantly correlated to bond price and bond yield, which tallies well with the conclusions of PROPOSITION 1 and PROPOSITION 2.

Table 2

Unit root test results

Variable	T-value	Critical value at 5%	Critical value at 10%	P-value
Original sequence of SR	-2.77	-3.45	-3.15	0.211
First order differentiation of SR	-4.31	-3.45	-3.15	0.0045
Original sequence of Ind_bond	-2.71	-3.45	-3.15	0.235
First order differentiation of Ind_bond	-8.17	-3.45	-3.15	0.000
Original sequence of Yie_Bond3	-2.21	-2.90	-2.59	0.2029
First order differentiation of Yie_Bond3	-5.41	-2.90	-2.59	0.0000

Variable	T-value	Critical value at 5%	Critical value at 10%	P-value
Original sequence of Yie_Bond5	-2.64	-2.90	-2.59	0.0899
First order differentiation of Yie_Bond5	-5.22	-2.90	-2.59	0.0000
Original sequence of Yie_Bond10	-2.86	-3.48	-3.17	0.1809
First order differentiation of Yie_Bond10	-5.40	-3.48	-3.17	0.0001
Original sequence of IR1	-2.26	-2.89	-2.58	0.188
First order differentiation of IR1	-11.66	-2.89	-2.58	0.000
Original sequence of IR2	-2.01	-2.90	-2.59	0.2811
First order differentiation of IR2	-10.05	-2.90	-2.59	0.0001
Original sequence of IR3	-1.95	-2.89	-2.58	0.3083
First order differentiation of IR3	-6.92	-2.89	-2.58	0.0000
Original sequence of LogM2	-1.85	-3.45	-3.15	0.674
First order differentiation of LogM2	-10.58	-3.45	-3.15	0.000

Table 3

Test results of the empirical models

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Bond price		Bond yield			Output
	Only considering reserve requirements	Also considering regulatory policy	3-year	5-year	10-year	
Constant	1.77 (***)	0.5(*)	29.98(***)	25.51(***)	18.07(***)	-3.03(***)
Reserve requirement ratio	-0.16	-0.12	0.15(***)	0.14(***)	0.1(***)	
Reserve requirement*capital adequacy		-11.73(***)				
Chibor IR1			0.34(***)	0.22(***)	0.13(***)	
Chibor IR2	-0.005(**)					
Deposit interest rate IR3		1.56(***)				
Money supply	0.232(***)	0.33(***)	-2.31(***)	-1.9(***)	-1.23(***)	
Bond price						0.56(***)
Loan						0.83(***)
R^2	0.927	0.944	0.716	0.500	0.334	0.974
AIC	-4.332	-4.583	1.004	1.305	1.065	-2.548
Schwarz	-4.233	-4.460	1.131	1.432	1.192	2.474
F-statistics	443.83	439.80	57.189	22.686	1.366	1973.5
Notes: *, ** and *** denote that the null hypothesis is rejected at 10%, 5% and 1% levels, respectively.						

III.3.2. Impact of combining reserve requirement policy and regulatory policy

In emerging market countries, bonds exist primarily as an asset item of commercial banks. Using China as an example, in recent years all of the bond holdings in large commercial banks have been above 20% as shown in Table 4. The data were collected from statistics published by the People's Bank of China.

Table 4

Bond holdings of four largest Chinese commercial banks

	End of 2009	End of 2010	End of 2011	End of 2012	End of 2013	End of 2014	End of 2015
Bond holdings (billion)	1168.69	994.25	995.67	1067.45	1127.38	1214.68	1420.98
Total assets (billion)	3086.99	3706.28	4227.73	4675.79	5081.63	5531.76	6288.02
Percentage of bond holdings in total assets	37.86%	26.83%	23.55%	22.83%	22.19%	21.96%	22.60%

However, because the capital markets of most emerging market countries are not well developed, the bond variety and structure are monotonous, and central banks cannot use an open market operation to regulate currency handling both continuously and on a large scale. Therefore, central banks can only affect the bank holdings in the asset structure of commercial banks through the reserve ratio adjustment, and then by indirectly regulating market fluctuations. This is an important reason why emerging market countries, here represented by China, have focused on the importance of reserve requirements and have much frequently practiced it. For this reason, policies, relevant to commercial bank behavior adjustments, can affect the bond markets in emerging market countries. Because the latest capital accord, Basel III, has been enacted and implemented worldwide since 2010, the constraint of capital adequacy has had a greater and greater impact on the behavior of banks. Therefore, it is of practical significance to discuss the effects of a policy mix, composed of monetary policy and capital constraint policy, on both the behavior of commercial banks and bond markets.

In order to test the effects of such a policy mix, a cross term "reserve ratio*capital adequacy" was constructed and substituted into the equation. The result is shown as model 2 in Table 3, in which a stringent monetary policy causes a fall (coefficient of -0.12) in bond price while the bond price presents a more significant downtrend (coefficient of -11.73) after the implementation of stringent capital requirements. This indicates that under the dual constraints of stringent monetary and regulatory policies, commercial banks will massively sell off bond assets to satisfy stringent policy requirements, which consequently causes fluctuations in the market prices or yields of bonds. It tallies well with the conclusions of PROPOSITIONS 5 and 6.

III.4. Impact of fluctuations in bond prices on real economy

The economies of most emerging market countries are based on commercial banks, and the primary approach to business financing is still through commercial banks. Therefore, changes in the commercial banks' main asset structure, i.e., loan assets and bond assets, have a significant effect on the real economy. In this study, a long-term analysis of the cointegration equation was performed using the loan item and the bond item as independent variables, using the economy as a dependent variable, to investigate the correlation among the three. The result is illustrated as model 6 in Table 3.

Table 3 shows that the technical indices of all equations are reliable, and the AIC and Schwarz statistics are ideal. Table 5 shows the results of stationary tests on the residual sequences of different equations. As the technical indices indicate, the six models in Table 3 successfully explain the data, and can be used for further economic interpretations.

The empirical results show that fluctuations in either the loan assets or bond assets of commercial banks will influence the output of enterprises. As the commercial banks' loan assets directly act on the enterprise's production process, when compared with fluctuations in bond assets, fluctuations in loan assets exert a more significant impact on the enterprise's output (coefficient of +0.83). On the contrary, as fluctuations in bond assets help shape long-term interest rates via investors' expectations, and then change the cost of the enterprises' long-term financing, the impact of such fluctuations are indirect and less significant (coefficient of +0.56). By combining model 6 with model 1 in Table 3, we can see that a decrease in the reserve requirement ratio (indicating loose monetary policy) can lead to an increase in bond prices and a decrease in bond yields and an enterprise's financing costs, ultimately leading to an increase in the output of real economy. This result tallies well with PROPOSITION 3 and PROPOSITION 4.

Table 5

ADF Test on Residual Sequences

	T-value	5% critical value	10% critical value	P-value
Model 1	-2.42	-1.94	-1.61	0.016
Model 2	-2.77	-1.94	-1.61	0.0058
Model 3	-3.57	-1.95	-1.61	0.0005
Model 4	-2.87	-1.95	-1.61	0.0046
Model 5	-3.03	-1.95	-1.61	0.0029
Model 6	-2.09	-1.94	-1.61	0.0357

Moreover, the model 6 in Table 3 also reveals that the ratio of the fluctuation effects in loan assets on enterprise output to the fluctuation effects on bond assets is unexpectedly 1.48:1.[15] According to the latest data released in January 2016[16,] the ratio of loans to bond holdings is 2.60:1. In China's four largest commercial banks, theoretically, the impact of ratio of their respective on enterprise output should be almost the same. The empirical findings, however, show that the impact of bond price fluctuations is greater than expected. That means in emerging market economy countries, it may remain a possible and important monetary policy transmission

[15] *The ratio of the two coefficients, 0.83:0.56 = 1.48:1.*

[16] *According to the latest data released in January 2016, the amount of loan assets of the four biggest commercial banks is 365715.00 hundred million and the amount of bond assets is 140701.37 hundred million.*

mechanism to influence bond market equilibrium and thus cause fluctuations in real economies through the adjustment of the reserve requirement ratio. And maybe, with the development of bond market in the future, this special transmission mechanism of monetary policy could increasingly highlight its importance.

IV. Conclusions

The paper studies the transmission effects of the reserve requirement policy on real economy through the bonds market by setting up mathematical models and taking empirical tests. The following conclusions can be drawn from the empirical analyses.

First, in emerging market countries represented by China, the monetary policy transmission mechanism "reserve requirement ratio adjustment→ changes in bond holdings→ development of real economy" indeed exists, and is important. The data show that in the first stage regression, the goodness of fit reached 0.927; in the second stage regression, the goodness of fit reached 0.974; in addition, the fitting of all variables passed the significance test at the 95% level.

Second, up-regulation of the reserve ratio leads to a cut in bond price, but an increase in bond yield. This is because strengthened reserve requirements encourage commercial banks to provide more deposit preparations; the banks will liquidate their bond holdings to withdraw funds and satisfy the increased reserve requirements. This leads to corresponding fluctuations in the bond market.

Third, the effects of changes in commercial banks' loan items on the real economy are higher than changes in the bond items. In the models, the estimated coefficient of the former is 0.83, and the latter is 0.56. However, as the bond issue size keeps increasing, the bond market transmission mechanism of monetary policy is becoming important day by day.

Fourth, adding capital constraint policy to the current monetary policy will lead to a further decline in business output. This, from one aspect, also indicates that as the capital constraint policy effectively reduces the overall risks for the commercial bank system, it may cause the negative effect of suppressing the development of the real economy.

Reserve ratio adjustment is not a mainstream monetary policy tool in many developed countries. However, it is still being frequently practiced in emerging market countries. In this paper, this phenomenon is explained by mathematical models and empirical tests: it is determined by an economic environment dominated by underdeveloped capital markets and commercial banks. In addition, under specific conditions, the transmission mechanisms of reserve requirements have been shown to not only exist, but also to be effective. With the commercialization process of most emerging market countries taken into consideration, a monetary policy system dominated by reserve ratio adjustment may still exist for a long period of time in these countries. However, this could lead only to a temporary balance; in the long run, with the continuous development of the capital market and the breakdown of the closed economy, the importance of quantitative monetary policy tools represented by reserve ratio adjustment will keep decreasing, while those targeting at the price level and represented by interest adjustments become more and more important in the future.

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