Credit Spreads, Probability of Default and Debt Risk Measurement of Prefectural Governments in China: 2014–2017

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In this paper, the concepts of probability of default, loss given default and expected loss in the internal ratings-based approach are introduced into the measurement of local government debt risk. Based on issuing interest rate and credit spreads of provincial government bonds, the default probability models of general debt and special debt are constructed and estimated, and the general and special debt risk of 333 prefectural governments in China from 2014 to 2017 are estimated respectively, and their regional distribution and changes are analyzed. The conclusions are as follows: Both general and special debt risk are different among regions. In terms of vertical changes in 2014–2017, debt risk has increased on the whole, but this increase has been driven more by the increase in the size of the debt, with no significant change in the probability of default, and the debt risk is concentrated in a small number of prefectural governments. The general debt risk accounts for about two-thirds of the total debt risk, the special debt risk accounts for about one-third, and this proportion structure is basically unchanged in 2014–2017. Based on the above conclusions, this paper puts forward corresponding policy recommendations for governance and control of local debt risk.

Keywords: local government debt risk, general debt, special debt, credit spreads, probability of default

1. Introduction and Literature Review

In recent years, the problem of local government debt in China has been more and more concerned by decision-makers, practitioners and even the whole society. Although local debt risk is generally manageable, the regional distribution is uneven. As economic operations and fiscal balances diverge in different regions, the debt risk of some local governments may gradually increase. A basic task to prevent and resolve the risk of local debt is to have comprehensive and accurate measurement, but there is little public and detailed debt data, especially for governments at the provincial level and below before

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2015 even if they owed debts or assumed debt repayment responsibilities, due to the fact that our local governments do not have the right to legally borrow, which has led to research on local debt risk based more on the national or provincial level (Guo *et al.*, 2015; Yang and Hou, 2015; Diao, 2016; Chang *et al.*, 2017), and there is little research at the prefectural level, especially the measurement and analysis of the risk of government debt at the local level. At the same time, most of the current local debt risk research is based on fiscal ideas or perspectives, or urban investment debt of the financing platform is used to analyze the risk premium and default risk of local debt (Ang *et al.*, 2015; Ambrose *et al.*, 2016; Niu *et al.*, 2016; Wang *et al.*, 2016; Zhu and Wang, 2018).

With the formal establishment and development of local government bond market in 2015, the pricing of local bonds can reflect the investors' judgment and evaluation of the risk to some extent, so the relevant data of the bond market can be used to measure the local debt risk. At the same time, under the new *Budget Law of the People's Republic of China*, the debt of local governments at the county level and above should be included in the budget, and the annual balance and other data should be made available to the whole society, which to a large extent makes the study of local debt problems no longer need to estimate the data, but also makes possible the municipal and county-level level research based on more refined space scale and larger sample size, and this will undoubtedly complement and improve the research mainly from national and provincial perspectives.

At present, the measure of local debt risk widely used is the debt rate index, that is, the ratio of debt balance to the comprehensive financial resources of local governments, which measures more about the relative size of the debt risk to the financial resources and does not reflect the absolute size of debt risk. In addition, there are some studies measuring debt risks by standardizing and weighted averaging multiple indicators that will affect or reflect the debt risk (Guo *et al.*, 2015; Diao and Wang, 2017), but this method is more about the horizontal ranking of debt risk between multiple subjects, rather than directly reflecting the size of the debt risk itself, that is, a high ranking does not directly mean that the risk is high, and a low ranking does not directly mean that the risk is low, while the results of horizontal ranking are generally not used for the analysis of vertical changes.

This paper holds that the internal ratings-based appraoch of Basel II is more scientific, systematic and accurate in the measurement of credit risk, so the concepts of probability of default, loss given default and expected loss in the internal rating method are introduced into the measurement of local debt risk in China. Based on the issuance interest rate, credit spreads and other local bond market data, combined with other economic and financial data, the model of probability of default is constructed and estimated. Then general debt risk and special debt risk are measured respectively based on economic data including debt, fiscal income and expenditure data of China's 333 prefectural governments (excluding Sansha City, Hainan Province) in 2014–

2017. Finally, based on the measurement results, the regional distribution and change characteristics of the local government debt risk are reviewed and analyzed, and the corresponding policy recommendations are put forward.

2. Measurement of Debt Risk of Provincial Governments Based on Credit Spreads and Probability of Default

2.1. Basic Idea

In Basel II, the internal ratings-based approach calculates the possible losses of the bank as a result of the default of the borrower or debtor, i.e. the expected loss (*EL*) (Shen and Cui, 2005; Dai and Wu, 2005) based on the three main parameters or indicators of probability of default (*PD*), loss given default (*LGD*), and exposure at default (*EAD*), and the specific calculation is as follows:

$$EL=PD\times LGD\times EAD \tag{1}$$

PD, the probability of default, refers to probability of the debtor failing to repay the principal and interest of debt or to perform related obligations for a certain period of time in the future. *LGD*, the loss given default, refers to the proportion of creditors' loss caused by the debtor after default to the size of the debt exposed to risk. EAD, the exposure at default exposure, is generally measured by the size of the principal of the debt or the face value of the bond in default. (Yu *et al.*, 2004).

As can be seen from the above Formula (1), an important parameter of calculating the expected loss of debt is the probability of default. Generally speaking, the estimation of *PD* requires the actual occurrence of debt default events. In other words, the record of default is an important prerequisite for constructing and estimating *PD* model. However, since the 36 provincial governments began to issue local government bonds in 2015, there has been no case of local government bond default. How to construct and estimate the *PD* model of local government bonds in the absence of default events is a big problem. (Wang *et al.*, 2016).

This paper circumvents the problem of default record from the perspective of local government bonds issuing credit spreads. Under the condition of market equilibrium or without risk-free arbitrage opportunities, credit spreads actually include expected or implicit information of *PD*. By defining the quantitative relationship between credit spreads and expected *PD,* and estimating the parameters by using the observed data, the expected *PD* which cannot be directly observed or hidden in the observed data can be calculated by using the credit spreads obtained from the observed data. The *PD* obtained is used as a dependent variable in the *PD* model of default. By further analyzing and incorporating the main factors affecting the *PD*, the *PD* model

of provincial government debt is constructed and estimated. Then the *PD* model of provincial government debt is applied to the estimation of *PD* of prefectural government debt. After we include other parameters and variables, the expected default loss which can measure prefectural government debt can be calculated.

It should be pointed out that the phenomenon of "inverted yield curve" exists in the issuance of local government debt in China (Wang, 2018), that is, the interest rate of local government bond is lower than the yield on treasury bonds in the same period. In this case, it is impossible to estimate the *PD* based on the credit spreads between local government bond and treasury bonds. However, the proportion of local bonds with "inverted yield curve" is relatively small, and with the gradual standardization of the local government bond market, this phenomenon is becoming less and less. The inverted yield curve mainly appeared in 2015–2016, and it became almost negligible in 2017–2018 (Table 1). At the same time, a single local bond with "inverted yield curve" does not mean that all bonds issued by the issuer in the year have inverted yield curves. The weighted average of all the bonds issued by the issuer in the current year is the overall interest rate level, and some of them are no longer "inverted". In the follow-up data processing and estimation process, this paper eliminates the sample with "inverted yield curve" among 36 provincial bond issuers, which basically does not affect the relevant results because the number is very small.

Table 1. Statistics and Proportion of Local Government Bonds with Inverted Yield Curve 2015–2018

	2015		2016		2017		2018	
	General bonds	Special bonds	General bonds	Special bonds	General bonds	Special bonds	General bonds	Special bonds
Bonds with inverted yield curve	79	22	35	29	17	21	1	2
Total issuance	647	388	662	497	483	651	384	546
proportion	12.21%	5.67%	5.29%	5.84%	3.52%	3.23%	0.26%	0.37%

Source: Wind-Economic Database.

2.2. Measurement and Calculation of PD and LGD

CS refers to credit spreads or risk premiums for local government bonds, i.e.:

$$cs = r_b - r_f \tag{2}$$

r_b is the issuance rate for local government bonds,and r_f is the risk-free rate for the same duration during the same period of time.

Under conditions of market equilibrium or without arbitrage, the expected rate of return on investment in local government bonds and the yield on investment in risk-free assets should be equal, i.e.:

$$(1-p)\times r_b - p\times D^g = r_f \tag{3}$$

p is the PD of a bond, and D^g is the loss rate after the default of the bond.

Based on Formulas (2) and (3), it can be derived that:

$$p = \frac{cs}{cs + r_f + D^g} = \frac{cs}{r_b + D^g} \tag{4}$$

Therefore, the probability of a potential default p can be calculated based on three variables or parameters of r_b, CS, and D^g.

In this paper, the yield on Chinese treasury bonds issued by the Central Government Treasury Registration and Settlement Corporation is regarded as the risk-free interest rate, while the credit spreads of local government bonds are derived from the interest rate of issuance minus the yield on Chinese treasury bonds with the same duration on the same trading day, and the yield on treasury bonds with certain durations is estimated based on Newton interpolation method. At the same time, all local government bonds are categorized in terms of province and year, and the average credit spreads are calculated by weighting the issuance scale. It should be noted that the local government bonds are clearly divided into general bonds and special bonds, and the relevant parameters are calculated respectively. Finally, the issuance interest rate and credit spreads of general bonds and special bonds of 36 provincial governments in China from 2015 to 2018 are obtained.

Estimating PD on the basis of credit spreads also requires D^g, the parameter of the loss rate after the default of the bond. Estimating the loss rate of debt default is a difficult problem both in practice and academia. The loss rate of debt default is influenced by many factors, but there are also many estimation methods and ideas, generally divided into the following categories: historical data averaging, asset valuation, non-parametric method and factor model method (Shen and Cui, 2005). However, almost all of these methods need default records or samples as the basis for estimation, but as mentioned above, up to now, there are almost no explicit default incidents of local governments in our country, so it is very difficult to estimate based on the relevant data of local bonds in China. In this paper, we use the default data of Chinese corporate bonds to estimate the default loss rate of local government bonds.

By the end of 2018, 308 corporate bonds in China's bond market had defaulted, with a default scale of about 190 billion yuan. Based on these default data, the practitioners have also made some estimates on the default recovery rate of Chinese corporate bonds: Everbright Securities calculated that the overall recovery rate of defaulted bonds was 30.37% based on default data as of November 5, 2018, of which 55.13% were state-owned enterprises and 24.18% were private enterprises (Everbright Securities, 2018); CICC, with September 14, 2018 as the deadline, statistically analyzed public bonds that

defaulted by the end of 2017 and obtained the weighted average recovery rate of 31.2%, of which 47.2% were state-owned and 26.2% were non-state-owned companies (CICC, 2018). This paper holds that the credit level of local governments is undoubtedly higher than that of state-owned enterprises and private enterprises, which should also reflect the recovery rate of bonds, that is to say, the default recovery rate of local government bonds should be higher than that of state-owned enterprises and private enterprises. Therefore, based on the above-mentioned data of Everbright Securities and CICC, it can be estimated that the default recovery rate of local government bonds is 86.08% and 68.2%, respectively, with an average of 77.14%, while the corresponding default loss rate (1–default recovery rate) is 22.86%.

Of course, it needs to be further pointed out that there are many factors affecting the default loss rate. Considering the huge differences in debt size and default risk among many local governments in China, the default loss rate may vary, but according to relevant studies (Asarnow and Edwards, 1995; Thorburn, 2000; Altman *et al*., 2005; Hu and Perraudin, 2006; Derbali and Hallara, 2015), the size of the debt or the size of the company is not accurately related to the default loss rate. Although there is a large body of literature that has been verified that there is indeed a positive correlation between the default loss rate and the *PD*, this correlation is more due to the fact that the two indicators are affected by the common systemic risk, due to the fact that the two indicators are in the same time trend, but on the same time node, this correlation may not exist, so it is also common to treat the two as independent variables. Therefore, in light of the above, this paper unifies the *LGD* of local government debt in our country. Finally, according to the above Formula (4), the potential *PD* of provincial governments in China from 2015 to 2018 can be obtained, as shown in Table 2:

Table 2. Estimated *PD* of General and Special Bonds of 36 Provincial Governments in China 2015–2018

Province	General bonds				Special bonds			
	2015	2016	2017	2018	2015	2016	2017	2018
Anhui	0.009	0.008	0.014	0.019	0.012	0.008	0.014	0.018
Beijing	0.011	0.003	0.007	0.005	0.006	0.008	0.010	0.015
Dalian City	0.009	0.012	0.018	0.018	0.013	0.013	0.021	0.017
Fujian (excluding Xiamen)	0.008	0.008	0.017	0.012	0.010	0.011	0.018	0.015
Gansu	0.005	0.008	0.016	0.012	0.006	0.012	0.012	0.015
Guangdong (excluding Shenzhen)	0.006	0.011	0.014	0.015	0.007	0.012	0.011	0.012
Guangxi	0.005	0.008	0.019	0.018	0.006	0.007	0.015	0.016
Guizhou	0.006	0.008	0.012	0.020	0.011	0.008	0.012	0.021
Hainan	0.007	0.009	0.016	0.018	0.014	0.009	0.015	0.017
Hebei	0.006	0.009	0.009	0.017	0.010	0.009	0.013	0.017
Henan	0.006	0.007	0.014	0.014	0.008	0.006	0.013	0.017
Heilongjiang	0.011	0.011	0.018	0.019	0.007	0.012	0.013	0.017

Province	General bonds				Special bonds			
	2015	2016	2017	2018	2015	2016	2017	2018
Hebei	0.006	0.009	0.017	0.016	0.017	0.012	0.017	0.016
Hainan	0.009	0.005	0.017	0.015	NA	0.005	0.017	0.017
Jilin	0.008	0.011	0.000	0.019	0.015	0.013	0.018	0.018
Jiangsu	0.007	0.005	0.010	0.012	0.008	0.005	0.013	0.013
Jiangxi	0.006	0.007	0.016	0.021	0.008	0.007	0.016	0.016
Liaoning (excluding Dalian)	0.011	0.011	0.014	0.017	0.019	0.011	0.017	0.016
Inner Mongolia	0.009	0.012	0.018	0.020	0.011	0.014	0.019	0.016
Ningbo City	0.008	0.009	0.014	0.012	0.009	0.013	0.017	0.010
Ningxia	0.007	0.009	0.018	0.015	0.012	0.010	0.017	0.015
Qingdao City	0.014	0.015	0.017	0.011	0.016	0.011	0.012	0.016
Qinghai	0.004	0.010	0.015	0.017	0.004	0.011	0.016	0.015
Xiamen City	0.001	0.006	0.010	0.014	0.002	0.009	0.012	0.010
Shandong (excluding Qingdao)	0.006	0.009	0.014	0.014	0.006	0.010	0.014	0.015
Shanxi	0.003	0.005	0.009	0.011	0.005	0.003	0.011	0.014
Shaanxi	0.011	0.010	0.017	0.017	0.013	0.012	0.019	0.018
Shanghai	0.003	0.004	0.005	0.006	0.005	0.005	0.006	0.013
Shenzhen City	NA	NA	NA	0.012	NA	NA	—[1]	0.020
Sichuan	0.005	0.007	0.017	0.017	0.014	0.010	0.016	0.016
Tianjin	0.006	0.006	0.012	0.018	0.012	0.010	0.016	0.020
Tibet	NA	—	0.006	0.016	NA	0.005	0.006	0.016
Xinjiang	0.004	0.005	0.014	0.017	0.004	0.005	0.013	0.016
Yunnan	0.007	0.009	0.017	0.017	0.008	0.010	0.017	0.014
Zhejiang (excluding Ningbo)	0.007	0.009	0.007	0.012	0.011	0.008	0.008	0.014
Chongqing	—	0.010	0.017	0.008	0.014	0.009	0.014	0.012

Source: Wind-Economic Database.

3. Construction of Debt Default Model and Parameter Estimation

3.1. Model Construction

The Logistic model is the most classical and widely used default probability model, which establishes a corresponding quantitative relationship between the factors that affect the *PD* and the *PD* itself (Cao *et al.*, 2016):

$$PD = \frac{\exp(\alpha + \beta X)}{1 + \exp(\alpha + \beta X)} \tag{5}$$

[1] Indicates that because the credit spread is negative, the calculated *PD* is also negative, not included in the subsequent regression fitting analysis. The other symbols of "—"in the table mean the same.

Considering the practice of assessment and prevention of local government debt risk in China and the characteristics of the data itself, this paper holds that an important index affecting the judgment of local government debt default is debt rate. At present, the index of debt rate is generally used to prevent and warn the local debt risk. This index can basically reflect the basic situation of debt risk. At the same time, the index is the debt balance at the end of the year divided by the corresponding comprehensive financial resources of the local government in that year. Therefore, this index actually reflects debt default judgment of the next year rather than of the current year. On the other hand, during the issuance of local government bonds, the economic and fiscal data for the year have not yet been collected, and its issuance pricing refers more to the data of the previous year. Based on the above considerations, in the *PD* model, *PD,* as a dependent variable, adopts the value of the next year, while the influencing factor, as an independent variable, adopts the value of the current year, so the local government default model can be written as follows:

$$\ln\left(\frac{PD_{i,t+1}}{1-PD_{i,t+1}}\right)=\beta_0+\beta_1 X_{it,1}+.....\beta_n X_{it,n}+\mu_i+\varepsilon_{i,t+1} \tag{6}$$

where $PD_{i,t+1}$ is the expected *PD* on local debt for the next year, $X_{it,1}$, $X_{it,2}$……$X_{it,n}$ are *n* important factors or key indicators that affect local debt risk,which include the year-end debt rate, and μ_i is the individual effect.[1]

Taking into account that this paper clearly divides local debt into general and special debt, we establish expected *PD* models of general and special debt, respectively, and the expected *PD* model of general debt is shown in Formula (7):

$$\ln\left(\frac{PD^G_{i,t+1}}{1-PD^G_{i,t+1}}\right)=\beta^G_0+\beta^G_1 X^G_{it,1}+.....\beta^G_n X^G_{it,n_G}+\mu^G_i+\varepsilon^G_{i,t+1} \tag{7}$$

where $PD^G_{i,t+1}$ is the expected *PD* of general debt for the following year, $X^G_{it,1}$, $X^G_{it,2}$…, X^G_{it,n_G} are n_G important factors or key indicators that affect the default rate of general debt, including the indicator of general debt rate at the end of the year, and μ^G_i is the individual effect of the general debt default rate.

[1] There is a problem in the fitting model of *PD* based on Logistic, that is, when the debt balance is zero, the estimated *PD* may not be equal to zero, which is inconsistent with the judgment based on common sense. However, in the subsequent calculation process, the *PD* multiplied by the debt balance, the expected loss is zero. Whether the debt balance is zero or not does not affect the whole calculation process and risk estimation. Therefore, this paper does not distinguish samples between zero and non-zero debt.

Table 3. Variable Selection of General Debt Default Risk Fitting Model

Variable type		Indexes	Symbols	Definitions
Explained variable		*PD* of general debt	*PD_g*	*PD* of general debt
Explanatory variables	General debt of local government	General debt rate	*Debt_g*	Ratio of general debt balance to general public budget expenditure
	Macroeconomic situation	Economic development	*lnpGDP*	Logarithmic value of the regional per capita GDP
		Consumption capacity	*Sale*	Ratio of retail sales of commodities to GDP in the whole society
		investment	*Invt*	Ratio of fixed asset investment to GDP
		Industrial structure	*Strc*	Proportion of added value of tertiary industry to GDP
	Financial development	Deposit	*Dpst*	Ratio of deposit balance of financial institutions to GDP
		Loan	*Loan*	Ratio of loan balance of financial institutions to GDP
		Loan-to-deposit ratio	*Ld*	Ratio of loan balance to deposit balance of financial institutions
	Fiscal operation	General public budget revenue	*Pubf*	Proportion of general public budget revenue to GDP

Table 3 shows the explanatory variables included in the general debt default model. The main consideration and basis of this paper is that the *PD* of prefectural governments should be estimated based on this equation. The explanatory variables included in the model should be consistent between the provincial and prefectural samples. Therefore, the explanatory variables do not include the index of total scale, because the provincial total is undoubtedly the sum of corresponding prefectural samples, while the *PD* of provincial debt cannot be obtained from the sum of *PD* at the prefectural level, so the variables included in this paper are relative proportion or proportion indexes. Considering further that the credit level of local governments is a comprehensive concept, in combination with indexes for local governments' credit ratings, this paper divides the influencing factors into four categories: indexes in debt situation, macroeconomic situation, financial development and general public budget operation of local finance.

The model of the expected *PD* of a special debt is shown in Formula (8):

$$\ln\left(\frac{PD_{i,t+1}^{S}}{1-PD_{i,t+1}^{S}}\right)=\beta_0^S+\beta_1^S X_{it,1}^S+.....\beta_n^S X_{it,n_S}^S+\mu_i^S+\varepsilon_{i,t+1}^S \tag{8}$$

where $PD_{i,t+1}^{S}$ is the expected *PD* of special debt for the following year, $X_{it,1}^S, X_{it,2}^S \ldots, X_{it,n_S}^S$ are n_s important factors or key indicators that affect the default rate of special debt, including the indicator of special debt rate at the end of the year, and μ_i^S is the individual effect of the

special debt default rate.

The macroeconomic and financial development indexes included in the special debt default model are the same as those for general debt, except that the special debt status is included in the debt situation, and the government fund budget is included in the local fiscal position, as shown in Table 4:

Table 4. Variable Selection of Special Debt Default Risk Fitting Model

Variable type		Indexes	Symbols	Definitions
Explained variable		*PD* of special debt	*PD_s*	*PD* of special debt
Explanatory variables	Special debt of local government	Special debt rate	*Debt_s*	Ratio of special debt balance to expenditure of government funds
	Macroeconomic situation	Economic development	*lnpGDP*	Logarithmic value of the regional per capita GDP
		Consumption capacity	*Sale*	Ratio of retail sales of commodities to GDP in the whole society
		Investment	*Invt*	Ratio of fixed asset investment to GDP
		Industrial structure	*Strc*	Proportion of added value of tertiary industry to GDP
	Financial development	Deposit	*Dpst*	Ratio of deposit balance of financial institutions to GDP
		Loan	*Loan*	Ratio of loan balance of financial institutions to GDP
		Loan-to-deposit ratio	*Ld*	Ratio of loan balance to deposit balance of financial institutions
	Fiscal operation	Income of government funds	*fund*	Proportion of government funds income to GDP

3.2. Parameter Estimation

In order to obtain the individual effects of sample heterogeneity in each province, LSDV (Least Square Dummy Variables) model is used for regression fitting, that is, *N*-1 (*N* as the number of samples) virtual variables are introduced, and the individual effects of each sample are obtained by estimating the coefficients of dummy variables.

Taking into account that disturbance terms of the same province in different years are often autocorrelated, and that the common standard deviation calculated based on the assumption of independent and identical distribution is not accurate, we use cluster regression to obtain robust standard deviation. Based on the above data, the results of parameter estimation for general and special debt default models of local governments are shown in Table 5, and the results of individual effect intercept term estimation are presented separately, as shown in Table 6.

Table 5. Coefficient of Fitting Equation for *PD* of General Bonds and Special Bonds

Explanatory variable	Symbol	General bonds			Special bonds		
		Coefficient value	Robust standard deviation	*P* value	Coefficient value	Robust standard deviation	*P* value
Constant term	*C*	–36.8913	10.2280	0.001	–30.6913	4.4677	0.000
General debt rate	*Debt_g*	1.0508	0.9113	0.257	—	—	—
Special debt rate	*Debt_s*	—	—	—	0.1088	0.1229	0.382
Economic development	*lnpGDP*	2.7414	0.7847	0.001	1.7583	0.3438	0.000
Consumption capacity	*Sale*	–1.8003	3.3027	0.589	–7.5797	2.8715	0.012
Investment	*Invt*	–0.0120	0.3677	0.974	–0.3197	0.2928	0.282
Industrial structure	*Strc*	3.0270	2.7194	0.273	6.2608	2.4723	0.016
Loan-to-deposit ratio	*Ld*	–7.6539	3.8154	0.053	–2.9889	2.8235	0.297
Deposit	*Dpst*	–1.4409	0.7770	0.072	–0.1049	0.5553	0.851
Loan	*Loan*	4.1728	1.4504	0.007	2.0962	0.9757	0.039
General public budget revenue	*Pubf*	–6.5850	6.3827	0.309	—	—	—
Income of government funds	*Fund*	—	—	—	5.5591	2.4832	0.032
Sample size			138			139	
Goodness of fit R^2			0.5856			0.7131	

Sources: Wind-Economic Database, China Statistical Yearbook, China Financial Yearbook, China Urban Statistics Yearbook, National Economic and Social Development Statistics Bulletin, Financial Accounts Report and its Schedules of Various Local Governments.

Table 6. Individual Effects of Default Fitting Equations for General Bonds and Special Bonds

Individual serial number	Provinces	General bonds			Special bonds		
		Coefficient value	Robust standard deviation	*P* value	Coefficient value	Robust standard deviation	*P* value
1	Beijing	—	—	—	—	—	—
2	Tianjin	3.0660	1.9816	0.131	4.3456	1.4903	0.006
3	Hebei	5.3096	2.6426	0.052	8.0645	1.7935	0.000
4	Shanxi	4.7658	2.3785	0.053	6.6308	1.5368	0.000
5	Inner Mongolia	5.3455	2.4884	0.039	7.5652	2.0428	0.001
6	Liaoning (Excluding Dalian)	3.9540	2.3264	0.098	7.6204	1.8229	0.000
7	Dalian City	1.9272	1.9019	0.318	5.5463	1.6914	0.002
8	Jilin	4.7498	3.0494	0.128	8.7312	2.1250	0.000
9	Heilongjiang	6.2497	3.1283	0.054	8.3753	2.0304	0.000
10	Shanghai	0.1159	0.6408	0.858	1.1199	0.5468	0.048

Individual serial number	Provinces	General bonds			Special bonds		
		Coefficient value	Robust standard deviation	*P* value	Coefficient value	Robust standard deviation	*P* value
11	Jiangsu	3.0562	2.0926	0.153	5.2467	1.5381	0.002
12	Zhejiang (Excluding Ningbo)	2.5882	2.0849	0.223	5.1595	1.5449	0.002
13	Ningbo City	2.3104	2.0309	0.263	4.9391	1.7424	0.008
14	Anhui	6.1460	2.6830	0.028	7.8710	1.7465	0.000
15	Fujian (Excluding Xiamen)	5.4201	2.9942	0.079	7.6637	2.1277	0.001
16	Xiamen City	1.0770	1.4885	0.474	2.3200	1.0993	0.042
17	Jiangxi	6.1527	2.5681	0.022	7.6274	1.6981	0.000
18	Shandong (Excluding Qingdao)	4.9829	2.7911	0.083	7.7171	1.9733	0.000
19	Qingdao City	3.7901	2.3642	0.118	5.7738	1.7732	0.003
20	Henan	5.9760	2.9599	0.051	8.3859	1.9012	0.000
21	Hubei	5.4420	2.8553	0.065	8.2010	1.9247	0.000
22	Hunan	5.5701	2.7239	0.048	7.7912	1.7848	0.000
23	Guangdong (Excluding Shenzhen)	4.3930	2.3077	0.065	6.5920	1.5984	0.000
24	Shenzhen City	-0.1555	0.9040	0.864	1.6283	0.7948	0.048
25	Guangxi	6.5418	2.9464	0.033	8.0872	1.8829	0.000
26	Hainan	4.5026	1.8047	0.017	5.5484	1.3168	0.000
27	Chongqing	4.5494	2.3069	0.057	6.2696	1.5603	0.000
28	Sichuan	5.3281	2.5383	0.043	7.6725	1.6368	0.000
29	Guizhou	5.2777	1.8647	0.008	6.4998	1.4179	0.000
30	Yunnan	6.0073	2.3750	0.016	7.2969	1.6470	0.000
31	Tibet	2.7362	1.7642	0.130	4.3322	1.0786	0.000
32	Shaanxi	5.0228	2.2942	0.035	7.2097	1.5687	0.000
33	Gansu	5.3186	2.6513	0.053	6.7725	1.5711	0.000
34	Qinghai	4.0461	2.1098	0.063	5.8392	1.5574	0.001
35	Ningxia	5.3684	2.3127	0.026	6.3319	1.7152	0.001
36	Xinjiang	5.0219	2.0838	0.021	5.9339	1.4129	0.000

Source: Same as Table 5.

Generally speaking, the regression results of the fitting equation for default of general bonds and special bonds are credible. In terms of the key debt risk variables in the equation, the coefficients of both general bonds and special bonds are positive, that is, the increase of debt risk will increase the credit spreads and *PD*. Looking further at the impact of the financial situation, we find that, for general bonds, the higher the level of public budget

income, the smaller the credit spreads; for special bonds, the higher the level of government funds income, the larger the credit spreads. This seems to be contradictory, but considering that general debt funds are mainly invested in non-profit public welfare projects, and special debt funds are mainly invested in public welfare projects with certain benefits, the above results are also reasonable. Looking at the individual effects of various provinces, for general bonds, the number of significance is more than half, nearly 60%, while for the special equation the number is higher, with all the individual effects being significant.

Of course, the results of fitting equation also have some shortcomings, for example, the statistical significance of some independent variable coefficients is not high, but the main purpose of this paper using regression equation is to fit, so the first thing is to see the overall effect of measuring and estimating *PD*. From the overall fitting situation, the general debt fitting equation R^2 is 0.5856, the special debt fitting equation R^2 is 0.7131, which can basically explain most of the default risk. Therefore, this paper adopts the above fitting equation, and then measures the debt risk of prefectural governments based on its calculation results.

4. Measurement and Analysis of Debt Risk of Prefectural Governments

4.1. Measurement of Debt Risk of Prefectural Governments

After constructing and estimating the fitting model of *PD* of provincial government debt, this paper applies it further to the estimation of default rate of prefectural government debt. Considering that in the model, the debt status, fiscal revenue and other economic indicators of both provincial governments and prefectural government are all non-aggregate data of the region, there are only difference in scales of spatial division, but no fundamental differences in the relationship between independent variables and debt default, so this paper applies the provincial government debt default model to measure the debt risk of prefectural governments. The data of general debt and special debt balance of prefectural governments, general public budget revenue and expenditure and government fund revenue and expenditure mainly come from budget and final accounts report and its schedules. For data that are not made public, the application is made through the application for disclosure and administrative review. There are two main methods to estimate the missing data, one is interpolation method, and the other is to use the corresponding data of the municipal level and the districts and counties under its jurisdiction to obtain the city-wide data.

Considering that all the relevant variables in the fitting equation are known, the known data are substituted into the fitting equation of *PD* listed in Tables 5 and 6, and then the *PD* can be calculated by corresponding conversion. It is necessary to explain the setting of individual effect intercept term in the equation. The basic idea is that, considering that the individual effect of a province can be considered as an average of the individual effect of the prefecture-level government under its jurisdiction, and it is

difficult to estimate the individual effect of each prefecture-level government based on the observed data, this paper takes the individual effect intercept item of the province as the unified individual effect intercept item of all the cities under the jurisdiction of the province, but considering that there are 15 sub-provincial cities (including 5 cities specifically designated in the state plan) in the prefecture-level government of our country, which are relatively special types, this paper carries out a separate study on the individual effects of other 10 sub-provincial cities which are not included in the cities specifically designated in the state plan. In this paper, a separate setting is made, using the average of the individual effect intercept items in the five cities specifically designated in the state plan as their individual effect. Finally, the *PD* of prefectural governments can be calculated based on the individual effect intercept term and the corresponding independent variable values. Then, combined with the *LGD* and debt balance, the expected losses of general debt and special debt can be obtained.

4.2. Regional Distribution and Vertical Change of Debt Risk of Prefectural Governments

Based on the above ideas and methods, the general debt and special risk status of each prefecture government are calculated. Considering the large number of prefecture-level government samples and the obvious regional differences, it is not listed one by one, but divided into seven regions: Northeast China, North China, East China, Central China, South China, Southwest China and Northwest China. In this paper, natural breaks[1] is used to classify the level of debt risk of prefectural governments. At the same time, based on the average value of debt risk of all prefectural governments in the region, the horizontal comparison and vertical analysis are carried out. Then the general debt risk and the special debt risk are merged into the overall risk of government debt and the corresponding analysis is carried out.

4.2.1. Analysis of General Debt Risk

At the national level, the general debt risk in 2017 was higher in six prefectures, from high to low being Ordos City (Inner Mongolia Autonomous Region), Kunming City (Yunnan Province), Zhengzhou City (Henan Province), Haikou City (Hainan Province), Hohhot City (Inner Mongolia Autonomous Region) and Guiyang City (Guizhou Province). The expected losses were 164.59, 132.93, 105.99, 104.14, 78.03 and 5.962 billion yuan, respectively. There were 18 middle-risk governments, and 309 low-risk governments, accounting for 92.8% of 333 prefectural governments in China. It can be seen that the distribution of the general debt risk of local governments is very

[1] Natural breaks classification is a statistical method of grouping according to the distribution law of numerical statistics. The basic idea is that the determination of grouping can minimize the differences within groups and maximize the differences between groups. This paper sets three groups as high, middle and low.

uneven. The high risk mainly concentrates in a few prefecture-level governments. The general debt risk of most prefecture-level governments is relatively low. The average of the general debt risk of the national prefecture-level governments is 394 million yuan.

Figure 1 shows the average scale of general debt risk and its changes of prefectural governments in seven regions in China from 2014 to 2017. The horizontal comparison of the seven regions shows that, in 2017, North China is the highest, South China is the second, followed by Southwest China, Central China and East China, and Northwest China and Northeast China are the lowest. In terms of the vertical changes in 2014–2017, it is the North China and Northeast China that have steadily increased, while other regions have some fluctuations, but overall there is a rising trend.

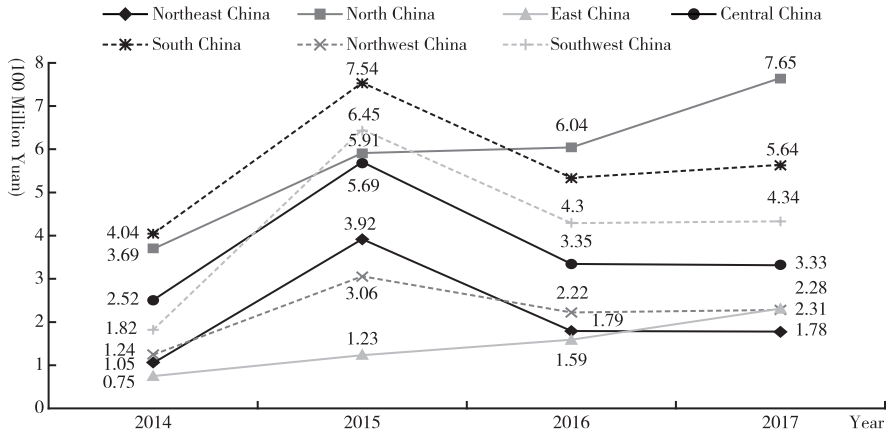

Figure 1. Average Scale of General Debt Risk and Change of Prefectural Governments in Seven Regions of China (2014–2017)

4.2.2. Analysis of Special Debt Risk

At the national level, there are 10 prefectural governments with a middle to high level of special debt risk in 2017, namely, Guiyang City (Guizhou Province), Kunming (Yunnan Province), Lanzhou City (Gansu Province), Zhengzhou City (Henan Province), Taiyuan City (Shanxi Province), Hohhot City (Inner Mongolia Autonomous Region), Hefei City (Anhui Province), Changsha (Hunan Province), Urumqi (Xinjiang Uygur Autonomous Region) and Hangzhou (Zhejiang Province). The expected losses were 178.01, 87.76, 47.71, 41.43, 25.54, 23.36, 22.75, 20.58, 1.917 and 1.712 billion yuan, respectively. It can be seen that prefectural governments with a middle to high risk of special debt only account for 3% of the country. The special debt risk of most prefectural governments is relatively low, with the average of 199 million yuan, about only half of that of the general debt which is 394 million yuan.

Figure 2 shows the average scale and change of special debt risk of prefectural governments in the seven regions in China for 2014–2017. Taking the year of 2017 as an example, the horizontal comparison of the seven regions clearly shows that there are three groups: Southwest China is the highest, Northeast China is the lowest, and the other regions are in the middle. In terms of the vertical changes in 2014–2017, the trend of change in Southwest and in Northeast is basically the same, both rising in fluctuations, while other regions with middle risk are basically rising steadily.

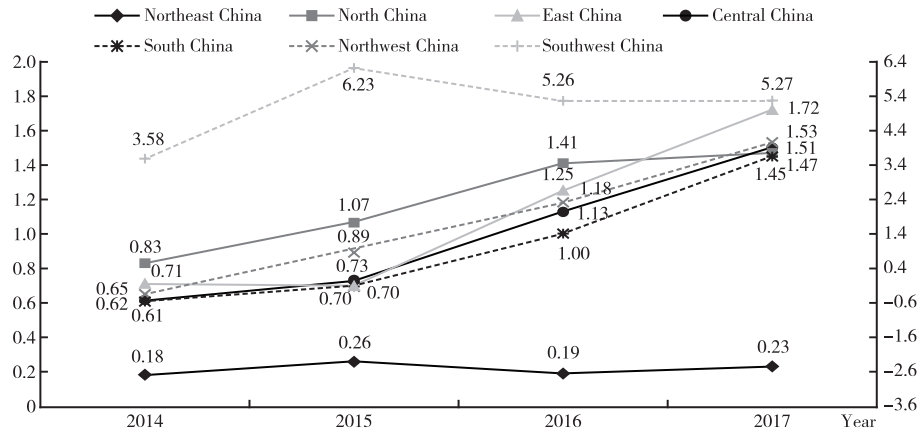

Figure 2. Average Scale of Special Debt Risk and Change of Prefectural Governments in Seven Regions of China (2014–2017)

4.2.3. Analysis of Overall Debt Risk and Its Structure

Above, the general debt risk and the special debt risk are analyzed respectively, which constitute the whole local debt risk. At the national level, the average debt risk of prefectural governments has risen in fluctuations, from 324 million yuan in 2014 to 593 million yuan in 2017 (Figure 3). This increase is more attributed to the growth of debt scale, as the *PD* has not changed significantly, and debt risk is mainly concentrated in a small number of prefectural governments. On the other hand, the composition of general and special debt in overall debt risk varies in the seven regions, with the three regions with the highest proportion of general debt risk in 2017 being the Northeast, North, and South China, at 88.56%, 83.88% and 79.66%, respectively, while the three regions with the highest proportion of special debt risk are the Southwest, East, and Northwest China, at 54.84%, 42.68% and 40.05%, respectively. From a comprehensive perspective, the general debt risk accounts for about two-thirds of the overall debt risk, and the special debt risk accounts for about one-third, and this proportion structure is basically stable in 2014–2017 (Figure 3).

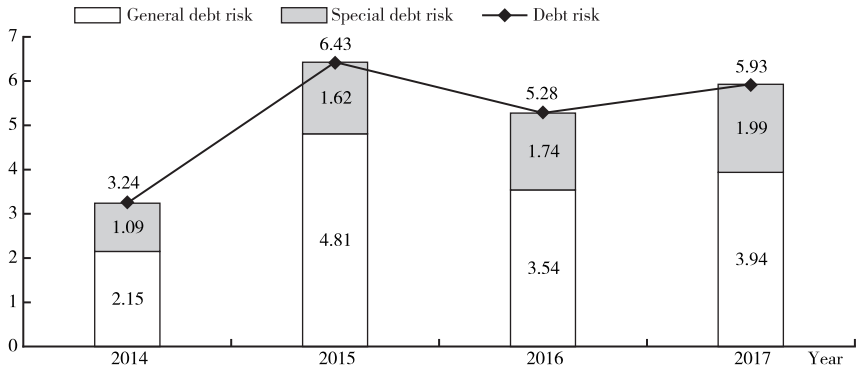

Figure 3. Average Composition and Trend of General Debt and Special Debt in Prefectural Government Debt Risk (2014–2017)

5. Summary and Policy Suggestions

Based on the concepts of *PD* and *LGD* in internal ratings-based approach, this paper constructs and estimates the Logistic *PD* model by using the relevant data of local government bond market, and measures the general debt and special debt risk of 333 prefectural governments in China from 2014 to 2017, respectively. The regional distribution and vertical variation are analyzed based on the estimated results. The basic judgments are as follows: (1) There are great differences in the distribution of general debt risk and special debt risk in different regions; (2) In terms of vertical changes in 2014–2017, debt risk has risen as a whole, but this increase is caused more by the growth of debt scale. There has been no significant change in the *PD*, and debt risk is mainly concentrated in a small number of prefectural governments; (3) In terms of the composition of local debt risk, the general debt risk accounts for about two-thirds of the overall debt risk, and the special debt risk accounts for about one-third, and this proportion structure remained basically stable in 2014–2017. Based on the above judgment, this paper puts forward the following policy recommendations to control the risk of local debt.

On the one hand, further enhance the marketization of local government bond issuance pricing. Market-oriented pricing is an important way to restrain local government bond issuance, and also a key link to fully release the institutional dividend of issuing bonds. However, throughout the four years of issuing bonds by provincial governments in China from 2015 to 2018, the level of market-oriented issuance has not substantially improved. There are many characteristics in the market-oriented issuance of local bonds, not only in the credit spreads between local bonds and national bonds, and in the credit rating classification of nine levels in three classes, but also in the more subtle differences of credit ratings between provincial governments with different financial and debt conditions, as well as in the differences of bond spreads. Therefore, it

is suggested that, in addition to the three-class and nine-level credit rating classification, the credit status of 36 provincial governments issuing bonds independently should be ranked based on the rating index system of credit rating agencies, and in the subsequent disclosure of bond issuance, the issuance spreads of 36 provincial government bonds should be published and compared with the credit status ranking. This can avoid the "inversion" of spreads between provincial governments to a certain extent, so that the level of interest rates positively reflects the credit status of provincial governments.

On the other hand, further strengthen the classification, prevention and management of general and special debt risks. General debt mainly invests in non-profit public welfare projects, so the prevention and control of its risk should focus on scale control and expenditure performance appraisal. If it has good economic and social benefits, it can reduce the risk of general debt by achieving higher growth of general public income in the future. As for the special debt, the public welfare projects it invests in have certain benefits, and it is possible to achieve the balance between income and financing. Therefore, the prevention and control of its risks should focus on the cost of income coverage of investment projects. At the same time, the setting of special debt risk warning line should take into account that the fluctuation of government fund income is greater than that of general public income, and the differentiation between regions is more obvious. Therefore, we should reasonably assess the volatility of government funds and develop a dynamic risk warning line to achieve a more reasonable distribution of the special debt between different regions.

References

Altman, E. I., Brady, B., Resti, A., & Sironi A. (2005). The Link between Default and Recovery Rates: Theory, Empirical Evidence, and Implications. *Journal of Business*, 78 (6), 2203–2228.

Ambrose, B. W., Deng, Y., & Wu, J. (2016). Understanding the Risk of China's Local Government Debts and its Linkage with Property Markets. March 14, *SSRN Electronic Journal*. DOI: 10.2139/ssrn.2557031.

Ang, A., Bai, J., & Zhou, H. (2015). The Great Wall of Debt: The Cross Section of Chinese Local Government Credit Spreads. September 4, *SSRN Electronic Journal.* DOI: 10.2139/ssrn.2603022.

Asarnow, E., & Edwards, D. (1995). Measuring Loss on Defaulted Bank Loans: A 24–Year Study. *Journal of Commercial Lending*, 77 (7), 11–23.

Cao, Y., Li, M., Li, G., & Hong, Y. (2016). The Model and Empirical Study of the Probability of Corporate Default Based on Credit Spreads and Logistic Regression. *Operations Research and Management Science* (*Yunchou Yu Guan li*), 12, 209–223.

Chang, X., Zhang, Y., & Tang, D. (2017). *Debt Risk Stake in Chinese Government*

Departments. National Finance and Development Laboratory of the Chinese Academy of Social Sciences: *Managing Financial Risks in Structural Slowdown*. Beijing: Social Science Academic Press.(in Chinese)

CICC. (2018). *A Full Review of The Disposition of China's Credit Bonds After Default*, September 18.

Dai, G., & Wu, X. (2005). Loan Pricing Study Based on Default Probability and Default Loss Rate. *Studies of International Finance* (*Guoji Jinrong Yanjiu*), 10, 43–48.

Derbali, A., & Hallara, S. (2015). Dependence of Default Probability and Recovery Rate in Structural Credit Risk Models: Empirical Evidence from Greece. *International Journal of Management & Business Research*, 5 (2), 141–158.

Diao, W. (2016). Initial Situation Analysis of China's Local Government Debt Classification into Budget Management: 2014–2015. *Public Finance Research*(*Caizheng Yanjiu*), 8, 28–39.

Diao, W., & Wang, N. (2017). Spatial Pattern and Dynamic Evolution of Local Governments' Solvency in Various Provinces of China—Classified Assessment of General and Special Debts. *Collected Essays on Finance and Economics (Caijing Luncong)*, 4, 26–36.

Everbright Securities. (2018). *Full Review of Bond Defaults in 2018*. November 10.

Guo, Y., Yuan, J., & Li, Y. (2015). Comparison and Evolution of Financial Solvency in China's Provinces: 2005–2012. *Finance and Trade Research (Caimao Jingji)*, 1, 80–90.

Hu, Y., & Perraudin, W. (2006). The Dependence of Recovery Rates and Defaults. Risk Control Limited Research Paper, February, Reference Number: 6/1.

Niu, L., Hong, Z., & Chen, G. (2016). Local Government Debt Worries and Risk Conduction—Analysis based on The Spread of Government Bond Yields and City Investment Bonds. *Economic Research Journal (Jingji Yanjiu)*, 11, 83–95.

Shen, P., & Cui, J. (2005). A Study on the Measurement of Loss Given Default in The Internal Ratings-Based Approach. *Journal of Financial Research (Jinrong Yanjiu)*, 12, 86–95.

Thorburn, K. S. (2000). Bankruptcy Auctions: Costs, Debt Recovery, and Firm Survival. *Journal of Financial Economics*, 58 (3), 337–368.

Wang, Y., Chen, Y., & Du, J. (2016). Soft Budget Constraints and the Risk of Default on Local Government Debt: Evidence from Financial Markets. *Economic Research Journal (Jingji Yanjiu)*, 11, 96–109.

Wang, Z. (2018). "Inverted Yield Curves" in Local Government Bond Issue. *Management World (Guanli Shijie)*, 11, 25–35.

Yang, L., & Hou, H. (2015). Rethinking the Risk of Local Government Debt in the New Urbanization Process, *Collected Essays on Finance and Economics (Caijing Luncong)*, 5, 24–31.

Yu, L., Zhan, J., & Jin, J. (2004). Measurement of the Probability of Default and Loss Given Default in the Internal Ratings-Based Approach. *Statistical Research (Tongji Yanjiu)*, 12, 22–26.

Zhu, Y., & Wang, J. (2018). Can Market Constraints Reduce the Risk Premium of Local Debt?—Evidence from the City Investment Bond Market. *Journal of Financial Research (Jinrong Yanjiu)*, 6, 56–72.