Research on the Early-Warning System of Risks in Local Government Debt

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Abstract—Since the economic crisis erupted in 2008, Chinese government has carried out the proactive fiscal policy and moderate looser monetary policy, which has kept down the tendency of declining economic growth. At the same time, Chinese government debt risk problem has emerged. How to manage the risk of local government debt exposure has been a major challenge to local government. This paper carried on research about the local government debt risk pre-warning problem to find out a more accurate index that can reflect the local government debt risk, and aimed to establish a system model that can properly evaluate and warn the Chinese local government risk. The study adapts the Chinese present financial system reforms, and will have great theoretical significance and practical value.

Index Terms—local government debt, early-warning system, fuzzy comprehensive evaluation, debt risk

I. INTRODUCTION

Since 1998, China has basically practice the expanding domestic demand and expansionary positive fiscal policy. To accelerate the local economic development, the local governments went out of their ways to expand the attracting investment dynamics and debts construction. Especially to cope with the 2008 world financial crisis, China has issued a 4 trillion government investment plan. The ministry of finance released a 200 billion local government bonds in 2009 for the local governments to collect counterpart funds. These measures have kept down the tendency of declining economic growth effectively, because we have already received a good effect in May, 2009. Some research then analyzed the influence of 2008 economic crisis [1-3]. The government debt raising has effectively promoted the regional economic progress and social development. However, since benefit and risk coexists, there are also some risks and problems [4], including the local governments' debt situation which is becoming tighter and tighter. It is increasingly recognized that the debt of the local governments have become one of the most pressing challenges [5-7]. How to manage the risk of local government debt exposure, ensure financial stability and contain sustainable economic and social development has become an inevitable issue for the management of local government debt. At the same time, the disordered management of local government debt has caused the massive existence of local government debt and the lack of effective statistics, the hidden debt crisis threat the safety of China's public finance for the moment.

Establishing debt risk warning and control mechanisms is one of effective counter-measures [8]. However, the existing research rarely referred to the mentioned problems. The only several works are lack of pertinence and has been lag behind, or not applicable for China. Using a multiple indicator multiple cause (MIMIC) model, Andrew and Mark modeled the causes of the 2008 financial crisis together with its manifestations [9]. Ciarlone developed an early warning system for debt crises broadly defined as episodes of outright default or failure of a country to be current on external obligations, and a first generation model based on an alternative policy conflict was developed in Michael’s research [10, 11]. Given the existed models, some research has also examined how they worked and how they performed, while the results seem some not satisfied [12-14]. So, further research for this practical issue is urgent needed. For the purpose of introducing financial warning system to financial risk evaluation area, this paper is proposed to put on the enterprise financial warning methods to the government, and closely combining the particularity of government finance. It also set a series of government debt risk assessment indexes, which not only focused on economic benefits but also paid more attention to the social benefits. At the same time, given the sustainable realization that government debt a dynamic model of concise, intuitive and an appropriateness of fuzzy comprehensive evaluation method in the early-warning field of risks in local government debt, this paper introduced these two kinds of methods to establish pre-warning system, meanwhile in order to satisfy the multifunction early-warning system, which is for the first time happened in the early-warning field of financial crisis.
II. FUZZY EVALUATION THEORY

Fuzzy theory develops on the mathematical basis of the fuzzy sets theory which was established by L.A Zadeh, Professor at the University of California in 1965. It includes fuzzy set theory, fuzzy logic, fuzzy reasoning. Based on fuzzy set theory, its basic spirit is accepting the fact that the phenomenon of ambiguity exists, while its research aim is to deal with things with indefinite and fuzzy concepts.

A. The Basic Principles of Fuzzy Comprehensive Evaluation Method

Fuzzy comprehensive evaluation method is a method of making a comprehensive decision considering various factors for a certain purpose in the fuzzy environment. This method, first of all, shall comprehend and analyze the phenomenon and then establish a scientific and reasonable index system for analyzing and evaluating the phenomenon, determine the appropriate evaluation set to do the first-level comprehensive evaluation of the factors set, adopt the proper operator to calculate fuzzy transformation by the use of the weight vector of each factor. On the basis above, we shall do the secondary-synthetic and even multi-synthetic evaluation. Last, according to the principle of maximum membership, the evaluation results shall be get after the final level judgment results are normalized.

Suppose \( U = (u_1, u_2, u_3, \ldots, u_n) \) is a set with \( n \) kinds of factors, which is called the factors set; \( V = (v_1, v_2, v_3, \ldots, v_m) \) is a set with \( m \) kinds of decisions, which is called the evaluation set. Generally, because the impact of various factors on the things are inconsistent, weight distribution of each factor can be regarded as fuzzy sets on \( U \), written as: \( A = (a_1, a_2, a_3, \ldots, a_n) \), in which \( a_i \) is the \( i \)th factor’s weight and satisfies the normalization condition. Besides, \( m \) decisions is not always an absolute positive or negative. Therefore, the appraisal after the synthesis should be regarded as the fuzzy set on the \( V \) set, written as: \( B = (b_1, b_2, b_3, \ldots, b_m) \), in which \( b_j \) reflects the \( j \)th decision’s status in the evaluation of the overall \( V \).

Suppose between \( U \) and \( V \) there is a fuzzy relation \( R = (r_{ij})_{n \times m} \), which is called fuzzy transformation matrix. Then \( (U, V, R) \) constitutes a fuzzy comprehensive evaluation model. Entering a weight distribution \( A \), then you will get a comprehensive evaluation \( B \). So if \( b_j = \max (b_1, b_2, b_3, \ldots, b_m) \), the decision \( v_j \) will be obtained:

\[
(b_1, b_2, b_3, \ldots, b_m) = (a_1, a_2, a_3, \ldots, a_n) \times \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}
\]

B. Advantages of Fuzzy Comprehensive Evaluation Method

Fuzzy comprehensive evaluation method is a quantitative evaluation method. From the major factor affecting problems and with reference to relevant data and circumstances, evaluators do different levels fuzzy evaluations of complex problems according to judgment, and calculate to get the quantitative and comprehensive evaluation results through methods provided by fuzzy mathematics. Fuzzy comprehensive evaluation method describes the intermediary and transitional state which appears in the social phenomenon by adopting the fuzzy thought with the clear concept connotation, but fuzzy concept extension boundary and also carries a multi-factors comprehensive assessment and valuation. This method effectively avoids such hard-and-fast yardstick as "yes" and "no" and overcomes different degrees of evaluation defects of deviation from the objective reality, which may occur in the traditional synthetic evaluation method [15]. The main feature of fuzzy comprehensive evaluation method is its easy mathematical model and easy to grasp. And it have a preferable evaluation effect for complex problem at all multi-factors and multi-levels, which mainly because it can get a only evaluation value of the object being evaluated and cannot be subject to the impact of the object set where the object being evaluated situates. So it is a method that is hard to replace by other branches of mathematics and models and that currently is used mature relatively in the Corporate Finance Alert[16].

III. THE CONSTRUCTION OF LOCAL GOVERNMENT DEBT RISK EARLY WARNING SYSTEM

A. The Establishment of the Index System of Local Government Debt Risk Warning

To construct the index system of local government debt risk, the guiding idea “full grasp, focused, simple, responsive” must be followed. That means we must follow the basic rules of governmental debt movement and reflect the risk situation of the debt movement honestly and forecast the risk and danger of local government’s debt exactly [17]. Therefore, we should adhere to the following principles when choosing the warning index: first of all, take the debt with complete statistics as the core. The main research object of evaluation system mainly concentrates in the relatively definite government debt. Secondly, consider the local fiscal revenue and GDP are the main reference variables. It is a common notion that GDP reflects a national final debt redemption foundation. However, considering the main local governmental debt risk at present is liquidity difficulty, the financial income variables must be taken into consideration. Thirdly, take both of the two indicators, characteristics of debt and redeem ability, and the main index. For the local governments, if they can pay off debt full and in time, their local finance has the liquidity and solvency, otherwise, there exist debt risks. Fourth, take all factors of local governmental debt into consideration, such as the scale risk, the structural risk,
the changing risk and the redemption risk, and so on. The purpose is to more comprehensively analyze the debt pressure local governments face: the larger the scale of debt is, the greater risk the local government repays the debt for a long-term; the greater risk the local repays debt, the greater pressure the current expenditure; the higher the proportion of external debt and direct debt, the greater the risk which repays a debt.

Based on large amounts of literatures, combined with the views of some experts and governmental fiscal staff, this paper finally determine the Index System of Debt Risk Warning according to the principle of choosing debt warning system index and system construction. (E.g. Fig. 1)

**B. Risk Interval Setting of the Early Warning Index:**

Risk index is ensured, for each index to determine the threshold of different risk status. Before confirming the threshold of each index, the following principles should be adhered to: First, it should be synthetically considered according to the history of economic change or the economic cycle, the functions and nature of each variable in economic activities, and the macro-control policy each time taken by the government and economic development goals; Second, consulting to the related domestic and international research findings; Third, compare different regions, especially the related index of governments of the same type; Fourth, experience standard, which is based on management practice of long-term economic activities development laws, is put forward by experts with extensive experience in the field of financial management after a rigorous analysis. In the premise of upholding the four principles, risk interval (threshold interval) of the index is ultimately divided into three intervals according to an upward trend of risk: security domain, risk early warning domain, and the crisis outbreak domain. Security domain indicates that finance is running in safe condition. Risk early warning domain indicates that certain risks already exist in financial running, but not go beyond a certain warning level. Crisis outbreak domain represents that financial running is facing serious risks of possible outbreak of financial crisis. In the actual operation, there is an internationally recognized standard, by which early warning value is determined, however, if there is no international standard, this article will take example by previous research results, refer to the actual situation of the relevant economic sectors, and combine with our specific local realities as the accumulation of the experience in order to early design a proper early warning value of the debt crisis index. Of course, whether the setting of the threshold is reasonable or scientific and whether it accords with the reality of the region or the government will directly affect the risk value of each index, and ultimately affect the judgments on the debt risk, so the threshold should be determined under the specific circumstances.

**C. The Construction of Local Government’s Debt Risk Early Warning Model**

The reason for adopting the fuzzy comprehensive evaluation method for the government’s debt risk early warning system design is that, first of all, government debt is influenced by various external and internal environment factors, and the relationship between local government debt and its affecting factors is uncertain and fuzzy, because of this fuzziness, local government debt status does not have the clear boundaries, and belongs to the vague categories. Secondly, it is improper to artificially evaluate the quality of local government debt with a specific classification standard. Therefore, in the process of government debt risk’s comprehensive evaluation, it is feasible to analyze and evaluate local government debt situation by using the theory and method of fuzzy mathematics.

After the main body of the early warning is completed, once finding that there exist risks, on the one hand, the regulatory layer not only need research the reason of risks
but also need know whether the current debt situations can be maintained, namely debt sustainability, to make supervision layer clear the priorities and to grasp the probable time of eliminating the risks. Therefore, the early warning system will introduce index analysis to find the reason of risks through individual index status, and introduce the authoritative debt sustainability dynamic model taking government budget flow as the main variable, and then to judge the government debt sustainability.

(i) The construction of debt risk early warning model

Debt risk early warning model evaluates the local government debt situations from the following three points of view. The construction considerations: First, to evaluate and contrast the single index according to the actual local accurate index risk interval, and to find the problem and risk level existing in the local government debt; Second, to synthesize each risk index, and to evaluate the integral debt status from three aspects of local economy, finance and debt itself through the in-depth analysis can reflect the reality of government debt, investigate the risk level, and expose the existing problems; Third, apply the sustainable dynamic model into the local government debt, forecast the future prospect of the local government debt, and check whether the local government debt possesses the sustainability. Through the analysis of the above three aspects, we can timely discover the problems and risk status of local
government debt, give enough attention and make sure to
take measures in time. Debt risk early-warning system is
shown in Fig. 2:
(ii) The construction method of debt risk early
warning model
1. Fuzzy comprehensive evaluation method
The construction of government debt risk early
warning model based on fuzzy evaluation method can be
divided into the following five steps:
(1) Confirm the comprehensive evaluation factors: In
the analysis and evaluation, according to actual
condition and analysis evaluation purpose, research,
analyze and determine the financial analysis evaluation
factors, namely the fuzzy evaluation factors set \( U \).
(2) Confirm the comprehensive evaluation standards: At
present, there’s no unified evaluation standard system,
but level 5 and level 3 evaluation standards are
comparatively used commonly. Level five evaluation
standard, \( V' = \) (better, good, general, bad, worse). Level 3
evaluation standard, \( V' = \) (fine, general, poorer).
(3) Establish Membership Degree functional equation:
Due to the limitations of recognizing things, it is unable
to accurately determine its characteristic, therefore only
the approximation of membership degree can be built to
obtain the general membership degree functions. There
are many forms of membership degree functions, so
specific analysis should be carried out according to the
actual situation.
(4) Construct the weights set of evaluation factors:
Because the Analytic Hierarchy Process can effectively
analyze the non-sequential relationship between the target
standards system level, and effectively measure and
evaluate the judgment and comparison of decision
makers, and local government’s debt risk early-warning
evaluation is a multiple attribute decision making
problem, the Analytic Hierarchy Process (AHP) is chosen
to determine its weight.
(5) Construct the fuzzy set mode: Set object \( j \) on the
relative membership degree \( u_{hj} \) belonging to level \( h \)
standard, so it is the fuzzy recognition
matrix \( U = (u_{hj})_{c \times n} \), meeting the constraint
condition
\[
\sum_{h=1}^{c} u_{hj} = 1, 0 \leq u_{hj} \leq 1.
\]

Use \( u_{hj} \) as object \( j \) about the weight of level \( h \) standard,
and use the weighting generalized weight distance \( D_{hj} \)
to describe the difference between object \( j \) and level \( h \)
standard, so:
\[
D_{hj} = u_{hj} \left( \sum_{i=1}^{n} (w_{ij} | r_{ij} - s_{ih} |)^p \right)^{1/p}
\]
In this equation, \( p \) is the distance parameter.
When \( p = 1 \), \( D_{hj} \) is the Hamming distance; when \( p = 2 \),
\( D_{hj} \) is the Euclidean distance.
To solve the optimal fuzzy recognition matrix, the
objective function is described as: sum of squares for the
general weighted length of all objects in the standard
mode is the least. Because it is a problem of extreme
conditions with the equality constraints, Lagrange
function will be constructed here so that the problem
mentioned above is transformed into the external one
without constraints.
\[
L(u_{hj}, \lambda) = \sum_{h=1}^{c} u_{hj}^2 \sum_{i=1}^{n} (w_{ij} | r_{ij} - s_{ih} |)^p \frac{1}{2/p} - \lambda \left( \sum_{h=1}^{c} u_{hj} - 1 \right)
\]
After mathematical operations, the result is as follows:
\[
u_{hj} = \frac{1}{\sum_{k=1}^{c} \left[ \sum_{i=1}^{n} (w_{ij} | r_{ij} - s_{kh} |)^p \right]^{2/p} - \lambda \left( \sum_{h=1}^{c} u_{hj} - 1 \right)}
\]
Compare the relative membership degree \( r_{ij} \) of the
object \( j \) and the index \( i \) with various standard value of
relative membership \( s_{ij} = (s_{ij,1}, s_{ij,2}, \cdots, s_{ij,c}) \) of index \( i \) in the
matrix \( S \). Let \( a_{min} \) and \( a_{max} \) be the minimum category
and the maximum category in the adjacent interval of all
types of standard relative membership degree of \( r_{ij} \) into \( s_{ij} \).
Obviously, when \( h < a_{min} \) or \( h > a_{max} \), \( u_{hj} = 0 \);
when \( h = a_{min} = a_{max} \), \( u_{hj} = 1 \).
Therefore, the fuzzy recognition pattern of the optimal
relative membership degree of object \( j \) for \( h \) class
standard is ultimately obtained:
\[
u_{hj} = \begin{cases} 
1, & \text{if } h = a_{max} = a_{max} \\
\frac{1}{\sum_{k=a_{min}}^{a_{max}} \left[ \sum_{i=1}^{n} (w_{ij} | r_{ij} - s_{ih} |)^p \right]^{2/p}}, & a_{min} < h < a_{max} \\
0, & h < a_{min} \text{ or } h > a_{max}
\end{cases}
\]
Then the final decision. When the decision-making is
evaluated in the fuzzy recognition pattern, the direct
method is adopted. The so-called direct method is the
application of the principle of maximum membership
degree to accomplish decision-making. The specifics are
as follows:
Let there be \( c \) (the amount of) fuzzy sets \( A_h \) \((h = 1, 2, \cdots, c)\) in the universe of discourse \( U \); \( c \)
known patterns are described as \( \omega_1, \omega_2, \cdots, \omega_c \) respectively; \( u_{hj} \) is denoted as
membership degree of the object \( j \) for the fuzzy set \( A_h \).
If $U_j = \max_{t \in [0,c]} \{ u_{jt} \}$, the object $j$ is classified into the category $I$, that is, the unknown model $X_j$ belongs to the category $\mathcal{O}_I$.

2. The Dynamic Model of Local Government Debt Sustainability

The sustainability of government debt is the process of meeting the needs of economic development under the premise of long-term development strategies and models of government debt with the combination of various economic factors taken into account. On the risk analysis of government debt, the fact that the government is different from the private sector in terms of its power to obtain assets and the fact that the government as a public body has the power to obtain compulsory assets. Local government is able to influence the balance of the debt changes by means of changing the future payment flow. To this end, we use the dynamic model of debt sustainability constructed by Chen Guanyou with government’s payment flow as the main variables \(^{[4]}\) to inspect conditions for achieving the debt sustainability of the local government.

Let $A_0$ be the debt of the local government in the early stage; $D_0$ be the total asset of the local government in the early stage; $T_n$ be the total fiscal revenue of the local government in the $n$ stage; $S_n$ be the total fiscal expenditure of the local government in the $n$ stage; $E_n$ be the primary budget balance resulted from the difference between the flows of fiscal revenue and expenditure of local government in the $n$ stage, i.e. $E_n = T_n - S_n$; $r$ is the discount rate of local debt (interest rate).

As for local government departments, debt sustainability can be expressed as: the sum of the discounted values of the future basic budget balance can at least offset the net indebtedness when the net worth of the current government is negative, leaving the government net worth greater than zero. Therefore, the net worth of the government in the early stage can be expressed as:

$$D_0 - A_0 = \frac{E_1}{1+r} + \frac{E_2}{(1+r)^2} + \frac{E_3}{(1+r)^3} + \ldots + \frac{E_n}{(1+r)^n}$$

$$e = \frac{D_0 - A_0}{Y_0} \times \left[ \frac{1 - \sum_{n=1}^{\infty} \frac{1}{(1+r)^n}}{1 + \frac{1}{1+r}} \right]$$

After making the transformation and the adjustment available to the above equity:

$$e^* = \frac{D_0 - A_0}{Y_0} \times \left( \frac{r - g}{1 + r} \right)$$

There exists an infinite geometric series in the equity above. According to the relevant mathematical formula, the target value of the balance of payment surplus (deficit) rate of the local government can be expressed as:

$$e^* = \frac{D_0 - A_0}{Y_0} \times \left( \frac{r - g}{1 + r} \right)$$

In the equity above, $e^*$ is the target budget surplus (deficit) rate that must be kept by the local government departments to achieve debt sustainability. When the government’s net worth is positive, as long as the actual budget deficit is smaller than the target of sustainability $e^*$, the local government maintains the debt sustainability; when the government’s net worth is negative, as long as the actual budget surplus is bigger than the target of sustainability $e^*$, the local government can also achieve the debt sustainability.

Some scholars used the data on the economy and the debt of the local government in China of the year 2003 in this equity. The results calculated show that the net asset value of the local government is 135.306 billion in that year, the index $e^*$ of the local government debt sustainability is 0.02753, and the deficit then is 6.23%. So they conclude that the debt of the Chinese local government is not sustainable with great risk hidden \(^{[18]}\). Liu Shangxi, an expert in the area of local government debt, makes analysis with the local government debt of the year 2002 linked to the government disposable resources, and comes to the conclusion that an insolvent local government has emerged and that the probability of resisting the risk of government debt through payments flow is very low \(^{[19]}\). After an investigation conducted in 15 cities across the country, Wei Jining, the group leader of the "local debt research group in China", diagnoses that the risk of local government debt is in fact much higher than financial risk, and becomes number one killer in China to threaten the economic security and social stability\(^{[20]}\). It can be seen through the employment of the dynamic model of government debt sustainability to inspect local government debt risk, the similar conclusions with those of the authorities obtained through the investigation are drawn; hence, the validity of this model can be identified. In addition, the Chinese local government debt statistics derive from the data submitted by local governments at all levels, statistics speaking with one voice, so this model is deemed applicable to the study on the debt of a single local government.
(iii) Case study (data omitted)

To verify the effectiveness of debt risk early-warning system, we investigated with debt data of H city in northeast China on its debt situation of the year 2007 and 2008 as samples for the case study. Firstly, we examined local government debt risk level using index analysis method. The results showed that apart from the debt burden rate and the debt increasing rate, all other indicators lay within risk early warning domain. Such debt problems as the increasing level of fiscal expenditure reliance on debt income, a large proportion of debt obtained, poor solvency ability, high risk of debt-repaying were found out. Secondly, we analyzed the data by fuzzy comprehensive evaluation method, the result(D=(0.155, 0.061, 0.126, 0.439, 0.219)) suggested that compared with other cities in the province, H city was very poor. After having evaluated by the dynamic model of sustainable development of government debt, we found that the local government debt of H city was not sustainable and local government bear a large debt risk. These conclusions were supported by provincial debt authorities in H City. And finally some advice on the optimization of the debt in H city were put forward from such three perspectives as resolving the historic debt, optimization of the debt in H city were put forward from such three perspectives as resolving the historic debt, strengthening the management of new debt and implementing the relevant measures.

IV. THE CONCLUSION

Though Chinese government carried out fiscal policy and moderate looser monetary policy to keep down the tendency of declining economic growth during the economic crisis, it also has left a debt risk problem for local governments. Establishing a system which can accurately evaluate and warn government debt risk has become a national security priority. Our work tried to set a series of assessment indexes that can quantitatively measure the local government debt risk accurately. Then we presented an early-warning system, containing index analysis method, fuzzy comprehensive evaluation method and dynamic model of sustainable development of government debt. The feasibility of the early-warning system was examined by a case study, which demonstrated that the system performed well. The practical implications of our study are notable: the early–warning system of risk in local government debt has important consequences for economic policy, which can promote policy transformation in time.

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