Research on Nonlinear Relationship of Uncertain Exponential Function based on STR Model

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Abstract

This paper builds a Non-linear model by using the explained variable SC from January 2014 to December 2019 as the sample and the indeterminacy index as the converted variable to examine the mechanism of macro factors on the explained variable SC under the changes of different explained variables. The research results indicate that in the case of different exponential change rates of the explanatory variable EPU, the influence of macro factors on the explained variable SC shows a clear asymmetric characteristic. When the exponential change rate is less than -43.1283, the effect of macro factors on the explained variable SC shows a linear state, but when the exponential change rate is greater than -43.1283, the effect of macro factors on the explained variable SC shows a Non-linear state.

Keywords

STR Model; Empirical Analysis; Indeterminacy Index; Non-linear Relationship.

1. Introduction

After the financial crisis in 2008, in order to prevent a sharp decline in economic growth, China's central government launched a package investment plan to increase the construction in infrastructure and social security system. At the same time, commercial banks made a positive response to the policy and liberalized the conditions of loans. Since then, the number of city investment bond companies and their loan scale have increased significantly. Subsequently, China Banking Regulatory Commission (the CBRC) and the central bank cooperated with local governments to establish financing platforms and issue corporate bonds, medium term notes and other financing tools, to broaden financing channels, and the net amount of city investment bond financing achieved a "blowout" growth. The opinion that the bearer of hidden guarantee liability and debt paying mechanism of "city investment bonds" issued by city investment companies and local financing platforms are the local governments and fiscal revenue has been recognized by Chinese investors [1].

With the rapid expansion of city investment bond financing scale, the potential debt risk of China's financial system has been accumulated and there is a large hidden risk. In order to prevent the occurrence of systemic risk, reduce the leverage ratio of local governments and promote the stable operation of China's economy, the State Council issued the Opinions of the State Council on Strengthening the Management of Local Government Debts in 2014, which required local financing platforms not to borrow governmental debts and plan to peel off the government financing function of financing platforms. Meanwhile, in order to prevent local debt defaults from happening on a large scale, the Ministry of Finance has carried out the replacement of local city investment bonds. Therefore, in terms of investment bonds, investors pay more attention to the operating conditions of local financing platforms in the current economic environment. The reasonable pricing of city investment bonds becomes a key factor

for investors decision-making, and a key point for the government to successfully replace city investment bonds.

At the same time, China's rapid economic growth over the past 30 years at the cost of consuming resources can no longer be sustained, and has now entered a "shift period" of economic speed, a "throes period" of structural transformation and upgrading and a "digestion period" of previous stimulus policies. For the central government, a single macro policy can no longer adapt to the current economic environment, and it is necessary to adopt a combination of macro policies, which makes decision-making much more difficult. It is also difficult for the public to draw conclusions about the future macroeconomic situation based on a series of macro policies formulated by the central government. Obviously, the rise in economic policy uncertainty will lead investors to change their investment strategies to avoid or mitigate the risks arising from macro policy changes.

Therefore, it is of great theoretical value and practical significance to study the effects of macroeconomic variables on credit spreads of city investment bonds in the context of increased economic policy uncertainty. The structure of this paper is as follows: The second part sorts out the literature on economic policy uncertainty and credit spreads of city investment bonds. The third part clarifies the relationship between macroeconomic variables and credit spreads of city investment bonds. The fourth part uses the collected data to construct a STR model for empirical analysis. The sixth part draws conclusions that are beneficial to the pricing rationalization of city investment bods and provides suggestions on risk prevention and control based on the data model.

2. Literature Review

The existing literature mostly focused on factors such as local policies and local macro economy for the study on macro influencing factors of credit spreads of city investment bonds. Wang Li et al. (2015) started from the local macroeconomic level. The better the economic development of a region, the better the financial position of the government in that region, and the stronger the guarantee willingness and ability of the government, which lowered the credit default risk of city investment bonds and further led to the reduction of credit spreads [2]. As for local policies, local governments were more often only the executors of the policy, while the actual decision maker was the central government. The central government formulated relevant policies with respect to infrastructure investment based on China's overall economic environment, and the local governments, as the executors of the policy, had an effect on scale expansion of city investment bonds and changes of credit spreads. However, there are few studies at present on the effect of the central government policies on credit spreads of city investment bonds.

According to Cao Guangyu et al. (2015), this phenomenon existed mainly because there had been a situation where decisions made by the superior government could only passively be accepted by the subordinate government due to the difference in authority rank among the governments in China. At the same time, subordinate officials took the initiative to increase the indexes and tasks assigned by the superior government for the purpose of promotion [3]. At present, the transformation and upgrading of the economic development mode, Sino-US tensions and other factors make our central government consider more factors when formulating policies, and the difficulty of predicting the impact of policy implementation has increased more substantially. Therefore, for investors, economic policy uncertainty has greatly increased.

Since China's reform tax system in 1994, the serious asymmetry between local governments' financial power and power of office has led to an urgent need for them to find sources of off-budget revenue channels to build local infrastructure and provide other public products. In this

context, local governments set up local investment and financing platform companies to seek funds for local economic development mainly through two channels. First, the local financing platforms grant the state-owned land use right, so that the local financing platforms can use it as collateral to obtain loans from banks and other financial institutions. Second, the local financing platforms issue city investment bonds to raise funds from the public. Therefore, for a long time in the past, China's infrastructure construction funds were mainly raised by local investment and financing platforms through debts. Especially after the international financial crisis in 2008, when local governments, in response to the "four trillion" investment plan formulated by the central government, contracted a large number of loans through investment and financing platforms. However, Ji Hongzhi et al. (2013) and Xu Pengcheng (2017) pointed out that these investment and financing platform companies did not have the ability of independent management and assuming sole responsibility for their profits and losses, and their financing capacity was greatly reduced without policy support [4-5].

According to bond pricing theory, Li Fengyu et al. (2015), Luo Ronghua et al. (2016) and Yang Yuanjie et al. (2020) divided the factors affecting bond credit spreads into macro and micro categories and conducted research and analysis [6-8]. The macro category mainly refers to the state of economic operation, such as monetary policy, gross domestic product, etc., and these macroeconomic variables have an impact on the credit spreads of bonds. The micro category mainly refers to corporate operating conditions, such as company earnings, credit rating, etc. These micro factors only have an impact on individual bond and will not affect the overall bond market. Based on the actual background of uncertainty about the expected direction of China's policies in recent years and the rise of economic policy uncertainty as well as the speculation of the impact of economic policy uncertainty on the credit spreads of city investment bonds, this paper introduces the economic policy uncertainty index to explore the asymmetric impact of macroeconomic variables on the credit spread of municipal investment bonds in the case of changes in economic policy uncertainty. This paper introduces an index of economic policy uncertainty to explore the asymmetric effects of macroeconomic variables on credit spreads of city investment bonds in the presence of changes in economic policy uncertainty. When economic policy uncertainty increases, the consistency of investors' expectations of future economic performance situation decreases, and some investors may reduce their personal consumption and increase their savings due to precautionary motives, resulting in a decrease in the amount of money circulating in the market, which further leads to a wider range of changes in macroeconomic indexes such as interest rates, and ultimately causes deterioration in the corporate financing environment and an increase in financing costs. Since the general multiple linear regression used in the traditional research on credit spreads of city investment bonds cannot express the nonlinear and asymmetric changes among variables, this paper attempts to construct a STR model to study the effects of macroeconomic factors on credit spreads of city investment bonds under different degrees of economic policy uncertainty, in order to offer feasible suggestions on the pricing of city investment bonds and the prevention and control of credit risks.

The main innovation points of this paper are: 1. The economic policy indeterminacy index is introduced to analyze more precisely the impact of macroeconomic factors on the credit spreads of city investment bonds, which enriches the study of the existing literature on the credit spreads of city investment bonds. 2. In contrast to previous studies on credit spreads of city investment bonds using multiple linear regression analysis, this paper applies a STR model to empirically analyze the impact of macroeconomic factors on credit spreads of city investment bonds under different degrees of economic policy uncertainty.

3. Macroeconomic Variables and Credit Spreads of City Investment Bonds

Based on the existing research on city investment bonds, this paper introduces macroeconomic factors in order to comprehensively clarify the influence path of economic policy uncertainty on the credit spreads of city investment bond issuance.

3.1. Explanatory Variable-China's Economic Policy Indeterminacy Index

For the measurement of economic policy uncertainty in China, this paper selects the monthly economic policy indeterminacy index jointly published by Stanford University and the University of Chicago. The index is calculated by searching the keywords of economic policy uncertainty in the South China Morning Post and dividing the number of filtered articles by the total number of articles published in that month.

3.2. Control Variables

(1) Bond Market Index

The bond market index represents the average price level of bond market changes and reflects the overall price trend of the bond market. When the bond market index increases, the bond market has excellent mobility. The quantity demanded for bonds by investors increases, and the compensation for the risk premium of bonds they can obtain decreases. According to bond-related theory, the longer the maturity of bond, the greater the interest rate risk. Since most of the funds raised by local financing platforms to issue city investment bonds are used for infrastructure construction, their issuance period is mostly more than a year. Due to the decline in overall risk premium compensation in the bond market, the compensation for lower risk on risk premium has a slight decrease and the interest rate also has a small range of changes. Therefore, city investment bonds need to increase credit spreads to a certain extent to attract investors. On the contrary, credit spreads of city investment bonds will fall.

(2) Gross Domestic Product

The national economic development status ultimately acts on the credit spreads of its issued city investment bonds through affecting the solvency of local financing platforms. When a country's economy tends to a good prospect, the profitability and solvency of local financing platforms increase, and investors expect a lower default risk on city investment bonds. The risk premium they require decreases accordingly, so credit spreads are smaller. On the contrary, when a country's economy is in a downward trend, the profitability and solvency of local financing platforms decrease, and investors expect a higher default risk on city investment bonds and demand compensation for the excessive risk of city investment bonds, thus credit spreads are higher.

(3) Loans from Financial Institutions

As mentioned earlier, loans from banks and other financial institutions are one of the important channels for local financing platform companies to raise funds, so the amount of loans from financial institutions directly affects the amount of city investment bonds issued by local financing platforms, which ultimately has an impact on the credit spreads of city investment bonds issued by them. When local financing platforms can get more loans from banks and other financial institutions, the pressure to obtain funds from the issuance of city investment bonds is relatively small. When the required financing amount is small, the cost of funds paid by local financing platforms is lower, and the credit spreads of city investment bonds is relatively low. On the contrary, the credit spreads of city investment bonds are higher.

(4) Money Supply

Changes in the money supply directly affect the credit spreads of city investment bonds. When the monetary authority increases the money supply, the money in circulation increases, and the change in the imbalance between money supply and demand leads to a decrease in market

interest rates and credit spreads of city investment bonds. On the contrary, the credit spreads of city investment bonds will rise accordingly.

(5) National Debt Treasury Bonds Return Rate

This paper selects the 5, 7, and 10-year national debt treasury bonds maturity yields and is used to take the value. When the long-term interest rate rises, this indicates that the cost of market funds through financing of the local financing platforms rises, and the profits that enterprises can obtain decreases under the circumstance of the same income. The possibility of enterprise default increases, which makes the credit spreads of city investment bonds rise. On the contrary, the credit spreads of city investment bonds fall.

(6) Inflation Rate

Inflation affects credit spreads by acting on both investors' purchasing power and nominal interest rates. For investors' purchasing power, when the inflation rate is higher, investors' expenditures on necessities are bound to increase, which leads to a decrease in their actual purchasing power and a decrease in the investment demand for city investment bonds. When the amount of city investment bonds does not change with the same range as investors' demand for city investment bonds, the credit spreads of municipal bonds will be widened. For nominal interest rates, when the inflation rate is higher, nominal interest rates naturally rise and investors demand a higher return on investment, ultimately leading to a rise in credit spreads of city investment bonds. On the contrary, it leads to a decrease in credit spreads of city investment bonds.

4. Data and Model

4.1. Model Construction

This paper attempts to use the smooth transition regression (STR) model to explain the impact of macroeconomic variables on the credit spread of urban investment bonds under the premise of different levels of economic policy uncertainty. The general standard STR model is specifically expressed as follows:

$$y_t = \varphi'z_t + (\theta'z_t)G(\gamma, c; s_t) + u_t, t = 1,2,\ldots,T, u_t \sim idd(0, \sigma^2) \tag{1}$$

Where y_t is the explained variable, $z_t = (w_t', x_t'), w_t = (1, y_{t-1}, \ldots, y_{t-p})'$ and $x_t = (x_1, \ldots, x_{kt})'$ are predetermined variables and exogenous variables, $\varphi = (\varphi_0, \varphi_1, \ldots, \varphi_m)'$ and $\theta = (\theta_0, \theta_1')' = (\theta_0, \theta_1, \ldots, \theta_m)'$ are matrix vectors of order$(m+1)\times 1, \varphi$ is the parameter vector of the linear part of the smooth conversion regression model, θ is the parameter vector of the nonlinear part of the smooth conversion regression model, m=p+k. γ is the smoothing parameter, which means the speed of the value of the conversion function $G(\gamma, c; s_t)$ from "0" to "1". The larger the value of γ, the faster the conversion speed. On the contrary, the slower. c is the position parameter, that is, the turning point, which indicates the moment when the expression changes from "linear" to "Non-linear" state. Conversion function $G(\gamma, c; s_t)$ is a bounded and continuous function with a range of [0,1]. When $G(\gamma, c; s_t)$=0, the STR model only has a linear part.

According to the different forms of the conversion function $G(\gamma, c; s_t)$, the smooth conversion regression model(STR) can be divided into two type,One is the ETR (exponential STR) model, and its conversion function is in the form of $G(\gamma, c; s_t) = 1 - exp(-\gamma(s_t - c)^2), \gamma$>0; the other is the LSTR (logistic STR) model, which can be divided into two types according to whether the value of is greater than 0. The first type is the LSTR1 model, and its conversion function is in the form of $G(\gamma, c; s_t) = [1 + exp(-\gamma(s_t - c))]^{-1}, \gamma$ >0; the second type is LSTR2, and its

conversion function is in the form of $G(\gamma, c; s_t) = [1 + exp(-\gamma(s_t - c_1)(s_t - c_2)]^{-1}, \gamma > 0, c_1 \leq c_2$.

Combined with the variables studied, the smooth transformation regression (STR) model set up in this paper is as follows:

$$SC_t = \alpha_0 + \alpha_1 CBI_t + \alpha_2 GDP_t + \alpha_3 IL_t + \alpha_4 M2_t + \alpha_5 NOR_t + \alpha_6 CPI_t + (\beta_0 + \beta_1 CBI_t$$
$$+ \beta_2 GDP_t + \beta_3 IL_t + \beta_4 M2_t + \beta_5 NOR_t) \times G(\gamma, c; EPU_t) + \varepsilon_t \qquad (2)$$

The credit spread of urban investment bonds can be decomposed into a linear part and a Non-linear part, which reflects the linear relationship between the macroeconomic variables and the credit spread of urban investment bonds, as well as the possible Non-linear relationship between the two.

4.2. Data Description and Verification

The credit spread of urban investment bonds is divided into two types: issuance credit spread and transaction credit spread. this paper only studies the issuance credit spread, so the full text is based on the influence of economic policy uncertainty on the credit spread of urban investment bond issuance.

This paper selects urban investment bonds issued by local financing platforms from January 2014 to December 2019, economic policy uncertainty index, and related macroeconomic variables as the research objects, and performs certain treatments on them, as shown in the following table.

Table 1. Explained variables, explanatory variables and control variables and their interpretation

	Variable name	Variable symbol	Paraphrase	Data Sources
Explained variable	Urban Investment Bond Credit Spread	SC	The difference between the urban investment bond issuance interest rate and the yield to maturity of the same maturity treasury bond	Calculated manually
Explanatory variables	Economic policy uncertainty	EPU	Monthly Change Rate of China's Policy Uncertainty Index	*South China Morning Post*
Control variable	Bond market index	CBI	China Bond-Corporate Bond Index Monthly Change Rate	wind database
	gross domestic product	GDP	Domestic GDP quarterly year-on-year growth rate	
	Financial institution loans	IL	Monthly loan balance growth rate of Chinese financial institutions	
	currency supply	M2	Monthly year-on-year growth rate of broad money M2	
	Treasury bond yield	NOR	Lagging First-Order China Treasury Bond Yield to Maturity	
	Inflation rate	CPI	Monthly year-on-year growth rate of China's consumer price index	

4.3.   Correlation Test

4.3.1. Stationarity Test

In order to prevent the phenomenon of "false regression" in the results, before using the model to test the relationship between variables, this paper uses ADF test and PP test to test the stationarity of the data. The test results are shown in the following table:

Table 2. ADF and PP test of each variable

variable	Inspection form (C,T,L)	T statistics	PP inspection (C,T)	PP test statistics
SC_t	(C,0,0)	-6.440111***	(C,T)	-7.408103***
PU_t	(0,0,0)	-10.55720***	(0,0)	-10.55720***
CBI_t	(C,T,0)	-7.185032***	(0,0)	-5.545712***
GDP_t	(0,0,0)	-0.321308	(0,0)	-4.438918***
IL_t	(C,T,0)	-0.2956	(C,T)	-13.86828***
$M2_t$	(C,T,0)	-3.147994	(0,0)	-5.325127***
NOR_t	(0,0,0)	-1.114584	(C,0)	-4.867590***
CPI_t	(C,T,0)	-2.497524	(C,T)	-2.339493

Note: (1) In the test form (C, T, L), C represents whether there is an intercept term, T represents whether there is a trend term, and L represents the lag order of the difference term; (2) ***, ** and * respectively Indicates that the statistics are significant at the 1%, 5%, and 10% levels.

Refer to Zhao et al. (2012), when the results of ADF inspection and PP inspection are inconsistent, because the potential of PP inspection is higher than that of ADF inspection, the results of PP inspection should prevail. The original sequence is a non-stationary sequence, and the stationary sequence is obtained after first-order difference [9].

4.3.2. Non-linearity Test and Model Selection

Refer to *Teräsvirta* (1998), this paper uses Taylor expansion to perform third-order Taylor expansion on the transfer function at =0, and then the equation is as follows [10]:

$$\hat{v}_t = \beta_0' z_t + \beta_1' z_t s_t + \beta_2' z_t s_t^2 + \beta_3' z_t s_t^3 + \eta_t \tag{3}$$

Among them, $\hat{v}_t$ is the least square estimation residual of $y_t = \alpha' z_t + v_t$, $\alpha = (\alpha_0, \alpha_1, \dots, \alpha_m)'$ and $\beta_i = (\beta_{i0}, \beta_{il}, \dots, \beta_{im})'$ are coefficient vectors, $i = 0,1,2,3$, z_t is each explanatory variable. After determining the Non-linear relationship, this paper uses the system test method to determine the specific form of the transfer function in turn on the coefficient $\beta_j (j = 1,2,3)$ in equation (7), namely:

$$H_{04}: \beta_3 = 0 \quad H_{03}: \beta_2 = 0|\beta_3 = 0 \quad H_{02}: \beta_1 = 0|\beta_2 = \beta_3 = 0 \tag{4}$$

In the above three hypothesis tests, if the p-value of rejection H_{03} the smallest, the ESTR model is selected, otherwise the LSTR model is selected.

4.4.   Model Estimation Results

According to the above method, this paper will test the linearity and nonlinearity of the variables involved one by one, and the results are shown in the following table:

Table 3. Results of linear hypothesis testing, transformation variables and model form selection

Conversion variable	F	F4	F3	F2	Model Form
EPU	3.1154e-08	6.2860e-02	1.0852e-04	3.2798e-06	LSTR1
CBI	7.9172e-01	7.6460e-01	4.0943e-01	7.4356e-01	Linear
GDP	4.2441e-04	1.1056e-03	6.3704e-02	1.5873e-01	LSTR1
IL	1.5120e-01	2.9857e-01	1.0391e-01	4.0312e-01	Linear
M2	1.5031e-01	5.3285e-01	2.4719e-01	5.9760e-02	Linear
NOR	5.8536e-03	2.4004e-02	1.3630e-02	5.4251e-01	LSTR2
CPI	9.5114e-09	3.0212e-02	1.2144e-02	5.7113e-09	LSTR1

Note: F, F4, F3 and F2 represent F statistics under the null hypotheses and respectively, and the numbers in the table are their corresponding adjoint probability P values.

Combining the stability and economic meaning of the model, this paper finally chooses the Economic Policy Uncertainty Index (EPU) as the conversion variable. As shown in the above table, the economic policy uncertainty index (EPU) and the urban the original hypothesis that there is a linear relationship in the credit spread of investment bonds, that is, there is a Non-linear relationship. At the same time, among the three statistics of F4, F3, and F2, the P value of the F4 statistic is the smallest. According to the principle of sequential testing, the form of the transfer function $G(\gamma, c; s_t)$ is determined to be LSTR1.
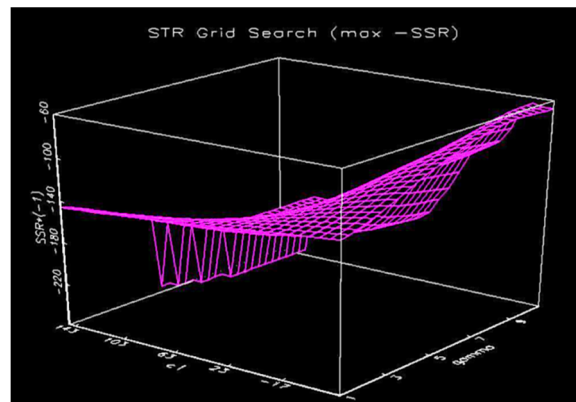

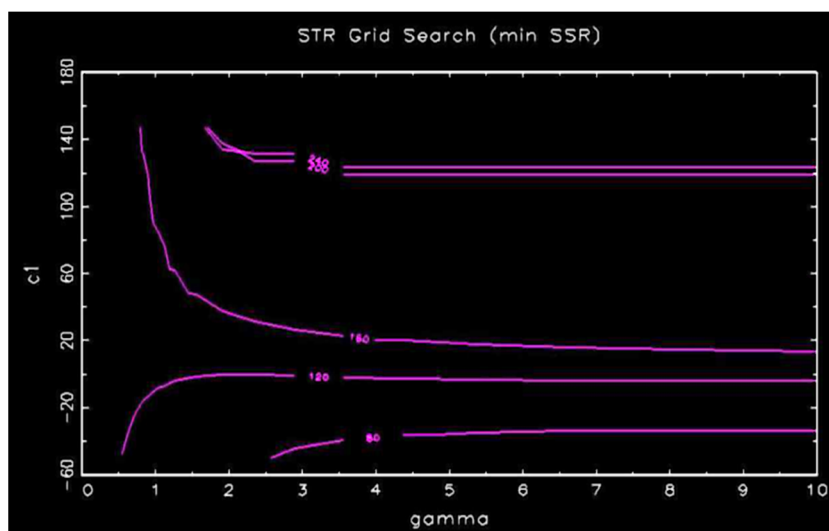**Figure 1.** Three-dimensional perspective view under the grid search method

Figure 2. Contour distribution map under grid point search

Table 4. Initial estimates of smoothing parameters and location parameters

		Interval
SSR	65.4689	-
γ	10	[0.5, 10]
c_1	-43.1283	[-57.22, 147.14]

The smooth transition regression (STR) model uses the grid search method to determine the initial values of γ and c_1. The specific search process is shown in Figure 1. It can be seen from the figure that the value range of c_1 is [-57.22, 147.14], and the value range of γ is [0.5, 10]. Take 30 values equidistantly from the two sets of value intervals to form 900 combinations, and then randomly select a set of parameters γ and c_1 to calculate the residual value of the model. All combinations of the above two-dimensional parameter space are taken one time in turn. The γ and c_1 corresponding to the minimum sum of square differences are the initial values of the nonlinear estimation. According to this optimization method, when the value of γ is 10 and the value of c_1 is -43.1283, the residual sum of squares SSR is 65.4689 minimum. Refer to *Teräsvirta* (2004), when the initial estimated values of the smoothing parameter and the position parameter both fall within the corresponding interval, the Smooth Transformation Regression (STR) model can be used for data for further research and analysis [11]. According to Table 4, it can be seen that both γ and c_1 fall within the interval, so the next step of model processing can be performed.

Table 5. Model estimation results

	variable	Initial value	estimated value	Standard deviation	t statistic	P value
Linear part	CONST	27.42037	12.25176	5.5804	2.1955	0.0324**
	EPU	0.11526	0.13018	0.0640	2.0327	0.0470**
	CBI	0.03726	0.02723	0.0073	3.7449	0.0004***
	GDP	-1.63908	-0.90728	0.2361	-3.8435	0.0003***
	IL	0.32140	-3.91728	2.1621	-1.8118	0.0756*
	M2	-3.57745	1.08808	1.3497	0.8062	0.4237
	NOR	-5.22727	0.03239	1.4934	0.0217	0.9828
	CPI	0.08597	0.08596	0.0160	5.3811	0.0000***
Non-linear part	CONST	-26.88231	-11.68550	5.6532	-2.0671	0.0435**
	EPU	-0.11174	-0.12689	0.0642	-1.9777	0.0531*
	CBI	-0.03590	-0.02682	0.0076	-3.5277	0.0009***
	GDP	1.68684	0.94701	0.2403	3.9417	0.0002***
	IL	-0.05512	4.30534	2.2141	1.9445	0.0570*
	M2	3.76185	-0.93008	1.3714	-0.6782	0.5005
	NOR	5.41438	0.12992	1.5227	0.0853	0.9323
	CPI	-0.08985	-0.08960	0.0171	-5.2272	0.0000***
R^2				8.0286e-01		
adjusted R^2				0.8056		
SSR				65.4689		

Note: ***, ** and * respectively Indicates that the statistics are significant at the 1%, 5%, and 10% levels.

Adjusted R^2=0.8056, which represents the goodness of fit, indicates that the nonlinear model has good explanatory power and can explain 80.56% of the economic phenomena studied in this paper.

Based on the estimation results in Table 5, the insignificant items are eliminated, and the new model form is as follows:

$$SC_t = 12.25176 + 0.02723CBI_t - 0.90728GDP_t - 3.91728IL_t + 0.08596CPI_t$$
$$+(-11.68550 - 0.02682CBI_t + 0.94701GDP_t \qquad (5)$$
$$+ 4.30534IL_t - 0.08960CPI_t) \times G(\gamma, c; EPU_t) + \varepsilon_t$$

Among them, $G(\gamma, c; PU_t) = [1 + exp(0.12689EPU_t + 43.1283))]^{-1}$

Furthermore, the stability and normality tests are performed on the residual sequence obtained from the model estimation, and the results are all stationary sequences, which meet the modeling requirements of the STR model, and the model setting is reasonable.

5. Empirical Analysis

It is generally believed that a smooth conversion coefficient of $\gamma \geq 10$, indicating that the conversion speed is very fast, that is, the adjustment speed of the nonlinear part of the model is very fast. It can be seen from Table 4 that r=10, and the speed of the model's conversion from linear to Non-linear is very fast. When EPU is less than c_1 (c_1=-43.1283), the value of the transfer function tends to 0, and a simple linear relationship is presented between variables. When EPU is greater than c_1, a Non-linear relationship is presented between the variables. This point is confirmed again from Figure 1. When the rate of change of the economic policy uncertainty index is less than the threshold -43.1283, the model is linear at this time, and there is a linear relationship between the macroeconomic variables and the credit spread of urban investment bonds. When the rate of change of the economic policy uncertainty index is greater than -43.1283, there is a Non-linear relationship between the macroeconomic variables and the credit spread of urban investment bonds. It can be seen that changes in economic policy uncertainty make the impact of macroeconomic factors on the credit spread of urban investment bonds appear linear and Non-linear.
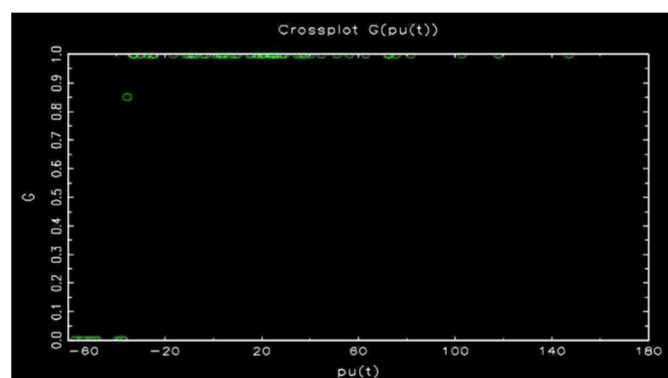

Figure 3. Schematic diagram of the coversion function

Analyzing Table 5, the following conclusions can be obtained:

When the Economic Policy Uncertainty Index (EPU) changes less than -43.1283 compared to the previous period, the economic growth (GDP) changes by 1%, and the urban investment bond credit spread changes by -0.90728%. When the economic policy uncertainty index (EPU) changes more than -43.1283 compared to the previous period, economic growth (GDP) changes

1%, and the credit spread of urban investment bonds changes 0.03973% (0.94701% - 0.90728%). That is, when the uncertainty of economic policy is reduced to a certain extent, consistent with the previous theory, the economic improvement will eventually narrow the spread of urban investment bonds. When the uncertainty of economic policy increases or decreases to a small extent, investors in the market have inconsistent expectations of economic development. At the same time, the upward trend of economic development has caused the yields of various investment products to rise, and investors with lower risk appetites are more inclined to choose lower risk investment products, which ultimately increases the spread of urban investment bonds.

When the change of the Economic Policy Uncertainty Index (EPU) is less than -43.1283 compared with the previous period, the bond market index (CBI) changes by 1%, and the urban investment bond credit spread changes by 0.02723%. When the economic policy uncertainty index (EPU) changed more than -43.1283 from the previous period, the bond market index (CBI) changed 1%, and the credit spread of the city investment bond changed 0.00041% (0.02723%-0.02682%). That is, when the uncertainty of economic policy decreases to a certain extent, consistent with the previous theory, the rise of the bond market index will increase the credit spread of urban investment bonds. When the increase or decrease of policy uncertainty is small, investors prefer lower-risk investment products-bonds. Urban investment bonds are a type of bond, and their risk is still lower than that of stocks. When investors who prefer high-risk and high-yield enter the bond market, they will be more inclined to allocate a certain share of urban investment bonds, so the spread of urban investment bonds will eventually rise slightly.

When the change of the policy uncertainty index (EPU) is less than -43.1283 compared with the previous period, the loan of financial institutions (IL) changes by 1%, and the credit spread of urban investment bonds changes by -3.91728%. When the policy uncertainty index (EPU) has a large change of -43.1283 compared with the previous period, the loan of financial institutions (IL) has changed by 1%, and the credit spread of urban investment bonds has changed by 0.38806% (4.30534% -3.91728%).That is, when the uncertainty of economic policy is reduced to a certain extent, consistent with the previous theory, the increase in the total loan amount of financial institutions will eventually reduce the credit spread of urban investment bonds. When economic policy uncertainty increases or decreases to a small extent, market risks increase, and banks and other financial institutions will be more cautious when making lending decisions, and may raise interest rates to compensate for the increased risks, which in turn will cause local financing platforms to inhibit investment. The company's expansion has slowed down. As a result, investors expect that the company's future cash flow will decrease, and the risk of default will increase, which will eventually increase the credit spread of urban investment bonds.

When the Economic Policy Uncertainty Index (EPU) changes less than -43.1283 compared to the previous period, the inflation rate (CPI) changes by 1%, and the urban investment bond credit spread changes by 0.08596%.When the Economic Policy Uncertainty Index (EPU) changes more than -43.1283 from the previous period, the inflation rate (CPI) changes by 1%, and the urban investment bond credit spread changes by -0.00364% (-0.0896% + 0.08596%). That is, when the uncertainty of economic policy decreases to a certain extent, consistent with the previous theory, the increase in the inflation rate will eventually increase the credit spread of urban investment bonds. When the uncertainty of economic policy increases or decreases to a small extent, investors increase the share of bond investment in order to avoid further depreciation of the currency they hold. The change in the overall supply and demand relationship in the bond market makes the credit spread of urban investment bonds weakly decrease.
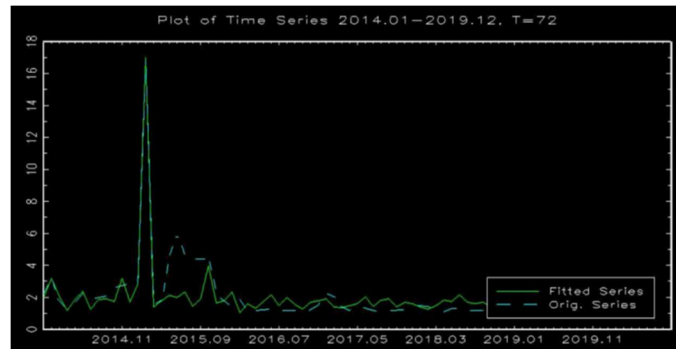
Figure 4. Time series diagram of original and fitted data

As can be seen from Figure 4, it can be found that the fitted data produced by the model is consistent with the changes in the original data, indicating that the smooth transformation regression (STR) model constructed in this paper is accurate and there is indeed a Non-linear relationship between the variables.

6. Policy Enlightenment and Suggestions

This paper analyzes the influence mechanism of economic policy uncertainty on credit spreads of city investment bonds by introducing macroeconomic factors. The empirical evidence finds that under the change of economic policy uncertainty, the role of macroeconomic factors on the credit spreads of city investment bonds shows asymmetry. Therefore, the pricing mechanism of city investment bonds does not fully reflect its own credit risk. In order to make the credit spreads of city investment bonds better reflect the credit risk, reduce the cost of debt of local financing platforms in China, and avoid further accumulation of financial systemic risks, combined with the results of empirical analysis, this paper puts forward relevant suggestions as follows:

1.The government should increase the transparency of policy formulation and appropriately reduce the frequency of policy changes to reasonably guide investors' expectations on the market. As mentioned above, it is clear that changes in economic policy uncertainty affect investors' expectations on the market, which in turn affects their investment behaviors. Therefore, the government should enhance the transparency of policy formulation in economic policies and disclose the basis and process of policy formulation to the public. At the same time, the government should give more consideration to the sustainability of policies and try to improve the stability of policies to avoid large fluctuations in the market caused by policy changes, thus guiding investors to form good expectations of the future policy direction on the market mechanism.

2.The government should establish an access mechanism for city investment bonds and raise the issuance threshold. In the past, local governments provided implicit guarantees for the main issuers of city investment bonds, and the credit spreads of city investment bonds failed to correctly reflect the credit risks. At the same time, local governments are "removed" from city investment bonds, and the issuing body of city investment bonds-the local financing platform companies need some time to transform from extensive operation mode in the past to profit-oriented. In addition, the frequent occurrence of delayed payments and defaults on city investment bonds has made investors be terrified by the sight of city investment bonds. Therefore, the government needs to set up an access mechanism for city investment bonds, raise the issuance threshold and reduce the default risk of city investment bonds.

3.Investors should strengthen the study of economic policies, break the rigid payment expectation and choose investment products rationally. Investors, as an important subject affecting the credit spreads of city investment bonds, have fewer information channels than

institutions and to some extent lack the ability to analyze the policies formulated by the government. Therefore, investors need to increase their understanding of government policies and avoid "crowd mentaily" when making investment decisions. At the same time, investors should break the rigid payment expectation of city investment bonds, and should judge more from the intrinsic value and business condition of the main issuer of city investment bonds whether it is worth to be invested, so that its pricing will be more rationalized.

Acknowledgments

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