

# The Influence of Debt-to-GDP on National Monetary Policy and Bond Market

Ziye Gu<sup>1, \*, †</sup>, Yuxin Huang<sup>2, †</sup> and Haofan Zhong<sup>3, †</sup>

<sup>1</sup>Reading Academy, Nanjing University of Information Science and Technology, Nanjing, China

<sup>2</sup>School of Business, Macau University of Science and Technology, Macau, China

<sup>3</sup>School of Mathematics and statistics, South-Central Minzu University, Wuhan, China

\*Corresponding author: 202183100061@nuist.edu.cn

†These authors contributed equally.

**Abstract.** Debt-to-GDP ratio can commendably indicate the ability of serving debt of a country and it has correlation with inflation ratio, actual ratio, deficit ratio and GDP ratio. Moreover, the debt-to-GDP ratio can be predicted with other ratios. This paper studies on these ratios and explores the impact of these ratios on the US bond and currency market and gives some credible suggestions. The paper uses Pearson analysis to study the correlation of the five ratios. Further, the degree of the correlation is presented. Linear and ridge regression are used to forecast the Debt-to-GDP ratio fluctuations and the prediction model and formula are also given. The result of the paper is significant for investors to grasp the correlation and seize better opportunity. For nation administrator, the paper gives a more accurate method to predict future ratios thus preparing ahead of schedule.

**Keywords:** Debt-to-GDP; US; bond and currency market; linear regression; ridge regression.

## 1. Introduction

The debt-GDP ratio is a quite significant economic indicator. As a kind of basic financial data, the ratio directly shows the ability of a country to repay its debts. The higher the debt-to-GDP ratio, the less the country will be able to service its debts, which could trigger a financial crisis in both domestic and international markets. But in the context of the Ukrainian-Russian war, the oil crisis and the post-Pandemic, governments tend to increase borrowing to stimulate growth and boost aggregate demand. This growth prevents economies from reaching their full output potential, which is reduced by debt whenever output increases. On the other hand, when a country's debt-to-GDP ratio rises, it tends to indicate that the country is in recession. When the debt becomes stable. That means lower GDP, which leads to lower tax revenues, and more government spending to stimulate the economy. Stimulus creates consumption, consumption creates GDP growth. And if things continue this way, the recession is lifted, which is the ideal performance. Finally, Debt-to-GDP Ratio can only reflect the solvency of a country at the level of economic analysis. Solvency and whether to pay the debt are two different things. Taken together, we need to analyze the ratio of debt of these countries to GDP in recent years from the perspective of monetary and bond markets to predict the economic development of these countries in the coming years.

This paper is aimed at ranking this ratio for various countries of the world for which making some sensible forecasting predictions on these countries. The two main directions are currency and bond market. Its significance lies in the fact that Debt-to-GDP ratio reflects a country's ability to repay debt. When a country is default on their bonds, it will cause financial panic in the domestic and overseas. In the context of slowing down the growth of revenue, increasing expenditure and wars, governments of all the countries will be confronted with greater pressure. Besides the currency market will also influence the bond market. The risks caused by exchange rate fluctuations make it much more difficult for a country to manage its international reserves and international debts, because the exchange rate fluctuation will increase or reduce the real value of a country's foreign exchange reserve stock and the actual external debt burden. In this situation, countries which have high Debt to GDP

ratio will be in a dilemma. To alleviate this, my paper forecasts future economic situation and gives some effective suggestions.

## 2. Literature Review

Scholars around the world have made detailed analyses of debt-to-GDP ratios. When a country's debt-to-GDP ratio gets too high, under normal circumstances, this indicator signals a decline in economic activity [1]. The rule has been proven. Therefore, the analysis of the debt-to-GDP ratio has crucial implications for the analysis of the economic development of countries around the world. Previous researchers have analyzed the different factors affecting the GDP ratio from the aspects of government expenditure on the GDP ratio [2], personal debt and so on, and made appropriate explanations and calculations [3]. For example, foreign scholars adopt the dynamic threshold panel method to the analysis of public debt to GDP growth of nonlinear effects [4]. In addition, this ratio of a country's economic situation can be one-sided. Pedro Leão's analysis of the impact of government spending on the GDP share gives this study a certain degree of enlightenment. Debt is extremely complex. Analyzing public debt by focusing only on public debt ignores that the government holds a lot of assets that can be sold to the private sector. This means that the government's liabilities should be considered alongside its assets, and that what ultimately matters is the government's net position [1]. Second, Tanaka has looked at debt-to-GDP ratios from an MMT perspective, which is helpful for our research. MMT stands for Modern Monetary Theory. It discusses the problem of government credit money. Use macroeconomic models to study changes in the ratio of full employment and budget deficits to debt-to-GDP [5]. It provides the basis for this study on the influence of monetary policy to a certain extent.

In terms of the bond market, this study discusses the pros and cons of increasing debt-to-GDP ratio on this financial market from its aspects of interest rate, financial cycle, credit and so on. Previous studies have concluded that only relying on the low interest rate caused by the government's macro-control cannot solve the real problem of high debt. The BIS 84th Annual Report noted that low interest rates have led to a rising debt service burden [6].

As the new global environment continues to evolve, so does the impact of a rising debt-to-GDP ratio. In this research, we expected to analyze the impact of currency and bond markets in the context of global COVID-19 and the war between Ukraine and Russia, so as to predict future economic development. Meanwhile, Lahet, and Prat implemented two complementary methods [7]. Through this model, we study the impact of currency internationalization on national currency issuance. In addition, due to the highly nonlinear relationship between these macro variables, the probability distribution was determined by Monte Carlo simulation method. The main tools used are SPSS and MATLAB.

## 3. Method

### 3.1 Pearson Correlation Coefficient

Continuous variables  $x$ ,  $y$  are given, the coefficients are defined as follows:

$$\rho = \frac{\sum_{i=1}^N (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^N (x_i - \bar{x})^2 \sum_{i=1}^N (y_i - \bar{y})^2}} \quad (-1 \leq \rho \leq 1) \quad (1)$$

$\bar{x}$  represents the mean average of variable  $x$  and  $\bar{y}$  represents the mean average of variable  $y$ . If absolute value of  $\rho$  approaches to 1 and that means the two variables have strong correlation. (1)  $\rho > 0$   $x$ ,  $y$  have positive correlation; (2)  $\rho < 0$   $x$ ,  $y$  have negative correlation.

### 3.2 Multiple Linear Regression Model

Multiple linear regression is mainly used to study the linear correlation between a certain dependent variable and several independent variables. A large number of linear regression analysis practices show that the results of multiple regression model are obviously better than that of single regression model. In addition, a large number of nonlinear regression problems can transfer into linear regression problems through this kind of substitution. So, it has wider applicability [8]. Multiple linear regression analysis generally includes the determination of dependent variables and independent variables, the establishment of regression equation, the evaluation of the influence degree of independent variables and the test of regression model [8]. The main steps are described:

(1) Establishment of multiple linear regression equation

$$Y = \beta_0 + \beta_1 X_1 + \dots + \beta_4 X_4 + \varepsilon \quad (2)$$

$\beta_n$  is an unknown parameter, which is called regression coefficient.  $\varepsilon$  means the error term, which represents the impact on other random factors on production event  $Y$ .

(2) Model test

In order to evaluate the fitting degree of regression equation, R2 method should be used for testing [8].

$$R^2 = 1 - \frac{SSR}{SST} \quad (3)$$

SST represents the sum of the squares of total deviation; SSE stands for residual sum of squares.

$$\begin{cases} SST = \sum_{i=1}^n (y_i - \bar{y})^2 \\ SSE = \sum_{i=1}^n (y_i - \hat{y}_i)^2 \end{cases} \quad (4)$$

The R2 value represents the fitting degree of the fitting equation to the original data. its value is in the range of [0, 1]. the R2 value is positively correlated with the corresponding fitting degree.

### 3.3 Ridge Regression Model

When the design matrix has complex collinearity, the property of least square estimation is not ideal. In this case, some new estimation methods are needed. Among these methods, ridge estimation is the most influential and widely used. For a linear model:

$$Y = X\beta + \varepsilon \quad (5)$$

The regression coefficient estimated by Ridge is defined as

$$\hat{\beta} = (X^T X + KI)^{-1} X^T Y \quad (6)$$

Among them,  $k > 0$  is an optional parameter, which is called the ridge parameter.

Under multicollinearity,  $|X^T X| \approx 0$  due to the high linear correlation between the independent variables. So, a normal number matrix  $KI$  is added. The resulting estimator is much more stable.

The component of the ridge estimate  $\hat{\beta}(k)$  as a function of  $k$ . When  $k \in [0, +\infty)$ . In the planar rectangular coordinate system, the image depicted by  $k - \hat{\beta}_i(k)$  is called ridge curve. The appropriate  $k$  is determined by the changing shape of the ridge trace curve. The meaning of the above-mentioned variables is shown in Table 1.

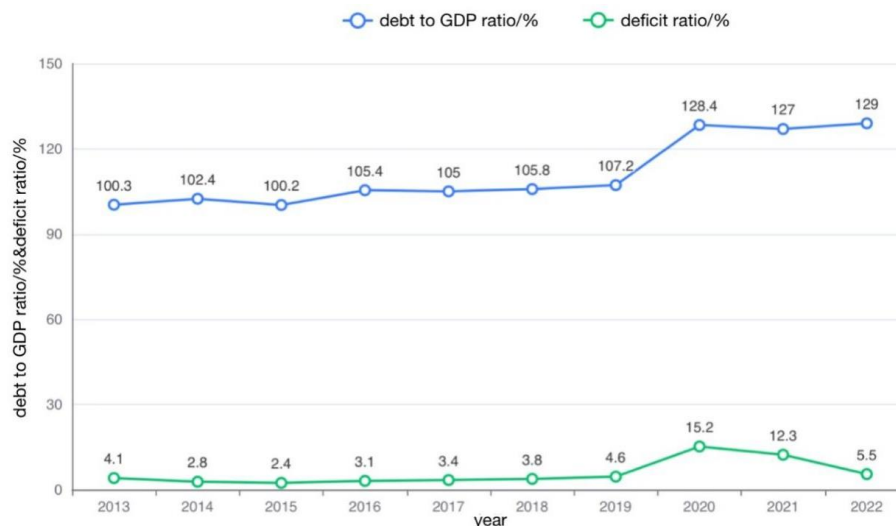
**Table 1.** Variable symbol and variable name

Variable symbol	Variable name
Y	debt to GDP ratio
X1	inflation rate
X2	actual rate
X3	deficit ratio
X4	GDP rate of increase
n	year

## 4. Data Analysis

### 4.1 Basic Analysis

Based on extant literature, report and official statistics, this paper collects and researches on the data of debt to GDP ratio, inflation rate, effective interest rate, deficit rate and GDP growth rate. Fig. 1 will be shown to explain the topic.



**Fig. 1** Debt to GDP ratio and Deficit-to-GDP ratio

Fig. 1 demonstrates the change of government debt to GDP ratio and deficit ratio. Obviously, the two ratios leveled off during 2013 to 2019 though there exists a relatively insignificant increase. However, influenced by public health event, the U.S. economy will also suffer a crisis in 2020. As a result, the United States began printing money and increasing debt transfer efforts. It is understood that the United States has passed a \$3 trillion bailout plan throughout the year, and the United States debt has reached an unprecedented high. The debt to GDP ratio soared to 128.4% in 2020 due to COVID-19. Because of the growth of government spending, the deficit ratio rose sharply to 15.2 in 2020, 3 times more than that of 2019 before epidemic. It completely showed the epidemic made a huge shock to economic and caused great pressure to the government. However, the deficit ratio began to decrease and nearly returned to normal in the next two years while the debt to GDP ratio still kept stable in two years. Obviously, the debt to GDP ratio of USA is more than 100% from 2013-2022. If GDP is used entirely to service debt, it can also be explained by the number of years it takes to service debt.

Table 2 shows that the X1 is strongly correlated with Y, while X3 is significantly correlated with Y. X2, X4 and Y are negatively correlated [9, 10]. According to this table, the analysis of the debt-to-GDP ratio is largely due to the rising fiscal spending of the American government. As a result, the government continues to issue national debt and the debt crisis is serious.

**Table 2.** Correlation coefficient

	Y/%	X1/%	X2/%	X3/%	X4/%
Y/%	1(0.000***)	0.68(0.030**)	-0.302(0.396)	0.819(0.004***)	-0.141(0.697)
X1/%	0.68(0.030**)	1(0.000***)	0.42(0.226)	0.188(0.602)	0.296(0.407)
X2/%	-0.302(0.396)	0.42(0.226)	1(0.000***)	-0.71(0.021**)	0.255(0.477)
X3/%	0.819(0.004***)	0.188(0.602)	-0.71(0.021**)	1(0.000***)	-0.289(0.418)
X4/%	-0.141(0.697)	0.296(0.407)	0.255(0.477)	-0.289(0.418)	1(0.000***)

Note: \*\*\*, \*\* and \* represent the significance level of 1%, 5% and 10% respectively.

Thereinto, inflation rate and effective interest rate has the strongest negative correlation. As the table 2 shows if deficit creases, the inflation rate will also go up. In this situation, borrowers will issue more bonds to the market and lenders will put more money into portfolio investments and less into bond. Since the government is ultimately going to pay its debt by raising taxes thus people begin to realize there is no need to buy more bonds. Eventually the price of bond will go down.

From the other angle, the increase of inflation rate followed by two main problems. One is the rise of real estate price and ordinary commodities price. The other one is national macro-control will control inflation by raising interest rates. Since the global economy has developed relatively synchronously, inflation and rising domestic prices will affect the import and export, and then affect the relationship between supply and demand, and eventually lead to the fluctuation of exchange rate. Suppose that domestic value of a currency goes down, thus leading effect of external value. Due to inflation, public possessed currency of country think the exchange rate is about to decreasing, so the currencies will be transformed into other form, and there will be a phenomenon of reluctant selling. Eventually, the exchange rate will fluctuate. When the United States runs a large fiscal deficit, if bulk of deficit is covered by the overdraft of the central bank, the economic growth will be inevitable exceeded due to money supply, inducing typical fiscal inflation. The issuance of treasury bonds can offset the fiscal deficit, increasing the money supply creates positive pressure on inflation. Since the developed financial markets of the United States, both the central bank and commercial banks hold considerable amounts of Treasury bonds. Increase in money supply occurs, resulting in an inflationary effect and a positive increase in the deficit-to-GDP ratio. By 2052, according to the Congressional Budget Office, US government debt held by the public will reach 185 per cent of GDP, and net interest payments on government debt will reach 7.2 per cent of GDP. As a result, the ratio of government debt to GDP is rising, along with net government spending.

## 4.2 Regression Analysis

This part, linear regression (ordinary least squares) is used to forecast the future debt to GDP ratio and to explore the linear relationship between independent variables and dependent variables: The significance P value of F test was 0.001\*\*\*, which was significant in the horizontal level. The null hypothesis that the regression coefficient is 0 is denied. The model can basically meet the requirements. It can be seen from the data in Table 3 that the inflation rate and the deficit-to-GDP ratio significantly affect the debt-to-GDP ratio. At the same time, R=0.985, indicating a good degree of model fitting. However, the VIF values of other variables except GDP growth rate are all greater than 5. Therefore, the model has serious multicollinearity problems (See Table 3) and deserve further investigations to solve the potential problem (See Table 4 and Fig. 2).

**Table 3.** Linear regression (ordinary least squares)

	Unstandardized coefficient		Standardized coefficient	t	P	VIF
	B	standard error	Beta			
constant	-1044.915	1160.213	-	-0.901	0.419	-
year	0.57	0.574	0.144	0.993	0.377	5.419
X1/%	3.027	0.982	0.614	3.084	0.037**	10.266
X4/%	-0.873	0.453	-0.153	-1.929	0.126	1.633
X2/%	-2.791	3.088	-0.174	-0.904	0.417	9.601
X3/%	1.223	0.438	0.446	2.792	0.049**	6.608
R <sup>2</sup>				0.985		
adjusted R <sup>2</sup>				0.965		
F				F=50.934 P=0.001***		

dependent variable: debt to GDP ratio/%

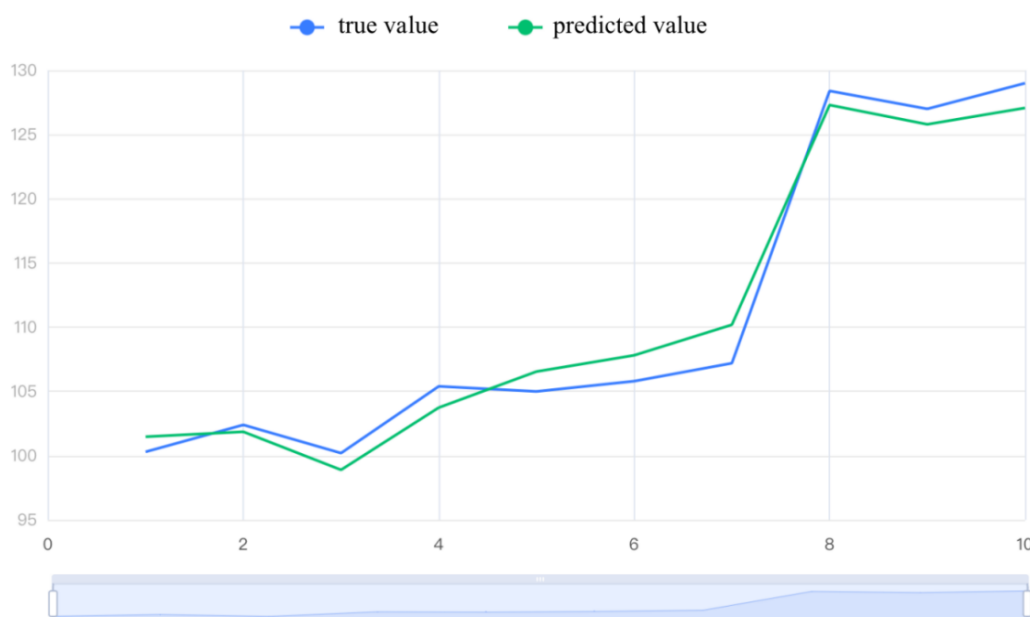
Note: \*\*\*, \*\* and \* represent the significance level of 1%, 5% and 10% respectively.

**Table 4.** Ridge regression results table

K=0.099	unstandardized coefficient		Standardization coefficient	t	P
	B	Standard error	Beta		
constant	-2013.754	710.267	-	-2.835	0.047**
year	1.049	0.353	0.265	2.976	0.041**
X1	2.168	0.404	0.44	5.371	0.006***
X2	-1.338	1.291	-0.083	-1.037	0.359
X3	1.192	0.244	0.435	4.878	0.008***
X4	-0.681	0.402	-0.12	-1.693	0.166
R <sup>2</sup>				0.978	
adjusted R <sup>2</sup>				0.952	
F				36.386 (0.002***)	

Dependent variable: Y

Note: \*\*\*, \*\* and \* represent the significance level of 1%, 5% and 10% respectively.



**Fig. 2** Forecast results

Ridge regression model is used to solve the multicollinearity problem of the model.  $K=0.099$  was determined by variance amplification factor method. Table 4 shows that the significance P value based on F test is  $0.002^{***}$ , which is significant horizontally. Moreover, the goodness of fit  $R^2$  value of the model is  $0.978$ , indicating that the model is excellent. The fitting effect is shown in Fig. 2. The formula of the model is shown below. It is convinced that the model can effectively forecast the future ratio.

$$Y = -2013.745 + 1.049n + 2.168X1 - 1.338X2 + 1.192X3 - 0.681X4 \quad (7)$$

## 5. Conclusion

Taking the United States as an example, this paper is devoted to exploring the relationship between debt to GDP and the national money market and its impact on the national money market. Based on the analysis of the mathematical model, the correlation between the two is concluded: a large number of fiscal expenditures led to fiscal deficit is the main reason for the rise of government debt, accounting for a higher and higher proportion. A rise in the debt-to-GDP ratio would also destabilize money markets.

## References

- [1] Leão P. The Effect of Government Spending on the Debt-to-GDP Ratio: Some Keynesian Arithmetic. *Metroeconomica*, 2013, 64(3): 448–465.
- [2] Baum A., Checherita-Westphal C., Rother P. Debt and growth: new evidence for the euro area. *Journal of international money and finance*, 2013, 32: 809-821.
- [3] Chudik A., Mohaddes K., Pesaran M. H., Raissi M. Rising public debt to GDP can harm economic growth. *Economic Letter*, 2018, 13(3): 1-4.
- [4] Woo J., Kumar M. S. Public debt and growth. *Economica*, 2015, 82(328): 705-739.
- [5] Tanaka Y. Analysis of Debt to GDP Ratio with Microeconomic Foundations: Theoretical Basis for MMT Arguments. *Research in Applied Economics*, 2022, 14(1).
- [6] BIS.URL: <https://www.bis.org/publ/arpdf/ar2014e4.htm>. (Accessed on 29 June 2014)
- [7] Scientific Platform Serving for Statistics Professional 2021. SPSSPRO. (Version 1.0.11) [Online Application Software]. (Retrieved from <https://www.spsspro.com>).
- [8] Yang S. J., Lu O. H., Huang A. Y., Huang J. C., Ogata H., Lin A. J. Predicting students' academic performance using multiple linear regression and principal component analysis. *Journal of Information Processing*, 2018, 26: 170-176
- [9] Xu W. C. A Review on Correlation Coefficients. *Journal of Guangdong University of Technology*, 2012, 29(3): 12-17.
- [10] Rötheli T. F. Expectations of Debt-to-GDP Dynamics: Modeling and Effects. 2022 (Available at SSRN 4095219).