# Simulation Study on Chinese Stock Market Development Based on System Dynamics Model

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**Abstract.** This paper selects money supply, interest rate and gross domestic product (GDP) as the key variables that affect the stock market value, and builds a system dynamics simulation model. The annual data from 2011 to 2018 are selected to simulate and analyze the impact of money supply, interest rate and GDP on the development of the stock market by adjusting the values of key variables. The simulation results show that money supply and GDP have a positive effect on stock market value, while interest rate has a negative effect on stock market value.

**Keywords:** Stock market development · System dynamics · Simulation

## 1 Introduction

Since the establishment of the Shanghai stock exchange in the 1990s, China's stock market has experienced 29 years of rapid development. By the end of 2018, China's A-share market value had reached 43.37 trillion yuan, with 3,570 listed companies. The stock market is the barometer of national economic development, and the sustained and stable development of the stock market is crucial to national economic development. On one hand, high-quality enterprises with good development status and capital needs can be listed on the stock market for financing, thus promoting the development of the real economy; On the other hand, the healthy and sustainable development of the stock market also provides investment channels for the idle funds of individual investors and enterprises, thus improving the utilization efficiency of social funds. Conversely, the sustained and healthy development of the national economy can also promote the development and improvement of the stock market.

China's stock market has a long history of "policy market", "bull short bear long" said. Compared with the US stock market, the Chinese stock market started late and developed relatively immaturely. The research on the development and fluctuation of stock market has always been the focus of scholars. In this paper, through the literature analysis method, we use system dynamics theory to build a simulation model, to simulate the stock market under the comprehensive effect of various factors. Based on the simulation results, it is expected to put forward relevant policy suggestions for promoting the development of the stock market and reducing the volatility of the stock market.


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## 2 Literature Review

There are many factors influencing the development and volatility of the stock market. Domestic and foreign scholars mainly study the stock market from the following three aspects:

First, the impact of money supply on stock market volatility and stock market development. Ioannidis and Kontonika (2007) [1] studied the relationship between monetary policy changes and stock market returns in 13 OECD countries from 1972 to 2002. The results showed that monetary policy changes had a significant impact on stock market returns and the stock market transmission mechanism of monetary policy was effective. Jansen and Tsai (2010) [2] divided stock returns into bull market and bear market by using data from 1994 to 2005, and respectively studied the impact of monetary policy on stock market. The empirical results showed that monetary policy had a negative and significant impact on stock market in bear market. Xiao (2012) [3] by using Granger causality test and Vector Autoregressive model, analyzed of the interactions of the money supply and stock market. The empirical results found that changes in the money supply has a certain influence on stock price, but the effect was not significant. However money supply changes affect the stock price volatility to a certain extent. Bekaert et al. (2013) [4] decomposed the stock market volatility index VIX into two parts: risk aversion and stock market expectation risk, building the VAR model, and analyzed the correlation between them by impulse response analysis and variance decomposition. The research results showed that loose monetary policy reduced risk aversion and uncertainty. Xu et al. (2014) [5] took the data of China's money supply and stock market volatility from 1997 to 2013 and used wavelet analysis to study the correlation between money supply and SSE composite index volatility. The empirical results show that M1 change and SSE index volatility have significant interaction effect in the short and medium term, while M2 change and SSE index volatility have significant interaction effect in the short term. Liu et al. (2015) [6] divided Chinese stock market into three interval states by using data from 1997 to 2014 and SSE vector autoregressive model, and analyzed the influence of monetary policy on stock market return rate under different interval states. The results show that monetary policy has an asymmetric effect on stock market return. Fang and An (2019) [7] selected the monthly data of Shanghai composite index and money supply (M2) from 2001 to 2019 and conducted an empirical study on the relationship between money supply and stock market by using VAR model and BEKK-GARCH model. The empirical results showed that money supply had unilateral volatility spillover effect on the stock market.

Second, the impact of interest rate adjustment on stock market volatility. Roberto and Sack (2003) [8] conducted an empirical study on the relationship between interest rate adjustment and stock price volatility. The empirical results showed that when short-term interest rate was increased by 0.25%, the S&P index dropped by 1.9%. Rigobon and Brian (2004) [9] analyzed the relationship between monetary policy changes and stock market fluctuations in the United States, and the results showed that short-term interest rates were negatively correlated with stock prices. Bernanke and Kuttner (2005) [10] used event analysis to study the impact of unexpected changes in the funds rate on stock market returns. The results showed that when the federal funds target rate was unexpectedly lowered by 0.0025%, the stock market index rose by 1%. Stock market

indexes move in the opposite direction of the federal funds rate. Hu (2016) [11] selected monthly data from 2005 to 2015 and empirically analyzed the dynamic time-varying correlation among interest rate, stock price and stock market volatility by using the TVP-VAR model. The empirical results showed that during the sample period, the relationship between China's interest rate change and stock market volatility successively showed positive correlation, non-correlation and negative correlation. This shows that the interest rate transmission channel of China's monetary policy is gradually improving. Yang et al. (2017) [12] used the RS-EGARCH model to study the impact of interest rate adjustment on stock market volatility after 2012. The research results showed that when the Shanghai stock market was on the rise, the reduction of interest rate would significantly increase volatility and yield, but when the Shanghai stock market was on the decline, the yield would be significantly reduced. Wang et al. (2019) [13] selected the monthly interest rate and SSE composite index volatility data from 2001 to 2018, and used the TVP-VAR model to empirically analyze the impact of China's central bank's monetary policy on the volatility of China's stock market. The analysis results showed that the impact of interest rate on stock market volatility should be classified into stages and short and long periods. After 2012, raising interest rates will increase stock market volatility in the short term and reduce stock market volatility in the medium and long term.

Third, the interaction between stock market development and economic growth. In the research on the relationship between stock market development and economic growth, most previous literatures have studied the one-way influence of stock market growth on economic development, but few have studied the influence of economic growth on stock market development. Gavin (2006) [14] believes that the rise in the price of financial assets represented by stocks has a wealth effect. The increase in asset prices will lead to the increase in household wealth. If the marginal propensity to consume remains unchanged, the increase in household wealth will lead to the increase in consumption expenditure, thus promoting economic growth. Saciet et al. (2009) [15] constructed the GMM dynamic panel model and empirically studied the relationship between stock market volatility and economic growth. The empirical results showed that stock market development had a significant impact on economic growth. Zalgiryte et al. (2014) [16] selected GDP as a proxy indicator of economic development and studied the relationship between economic growth and stock market development in the United States and France. The results showed that stock market development was a powerful indicator of economic growth. Lin and Cao (2014) [17] used the quarterly data of stock market and economic growth from 1992 to 2012 to test the relationship between stock market development and economic growth in China by using GMM method. The test results showed that stock market development had a significant negative effect on economic growth. Ding (2018) [18] tested the two-way causal relationship between China's stock market volatility and economic growth from both linear and non-linear perspectives. The test results show that there is no significant linear Granger causality between the two, but the nonlinear Granger causality between the two is significant. Wang and Xu (2019) [19] empirically analyzed the threshold effect of stock market development on economic growth by taking the size of China's stock market as the threshold variable. The empirical results showed that the size of stock market had a negative effect on economic growth on the whole, but showed an increasing trend of marginal effect.

To sum up, domestic and foreign scholars mainly analyze the influence of interest rate, money supply and economic growth on the development and fluctuation of stock market. In terms of methods, Vector Autoregression model and Granger causality test are mainly used to analyze the mutual dynamic influence of various factors and stock market volatility. The factors influencing the development of the stock market are complex and varied, and it is not complete to analyze the explanatory power of stock market volatility only by using a certain influencing factor. At present, there are few literatures studying the development of stock market from the perspective that multiple influencing factors constitute a whole system. Based on this, this paper USES the system dynamics theory to construct a simulation model of stock market development to simulate the development of stock market. By analyzing the simulation results, it is expected to put forward targeted policy Suggestions for the sustainable and healthy development of stock market.

## 3 Model Construction

### 3.1 Data Sources

Combined with the development cycle of China's stock market, this paper selects the annual data of relevant variables from 2011 to 2018. In this period, China's stock market experienced a complete bull - bear market. The market value of the stock market is selected from the market value of Shanghai stock market, the money supply is selected from the broad money supply (M2), the interest rate is selected from the seven-day interbank lending rate, and the economic development is selected from GDP as the proxy indicator. The data came from the wind database, the national bureau of statistics website and the people's bank of China website.

### 3.2 System Boundary Determination and Structure Analysis

According to the theory of system dynamics, the dynamic change and development of things over time is the result of the comprehensive action of internal variables rather than external variables. By constructing the system dynamics simulation model, three problems are mainly solved. Secondly, it systematically analyzes the influence of the changes of variables in each subsystem on the development of the stock market, and the influence of stock market fluctuations on each variable. Third, adjust various variables to simulate the development of the stock market in various economic and financial environments, and provide decision-making basis for relevant departments. In order to solve these three problems, this paper refers to the subsystems divided by Li et al. (2018) [20] when constructing the trust industry simulation system, and constructs the simulation system of stock market development, which consists of four subsystems: the economic subsystem, the financial subsystem, the stock market subsystem and the policy subsystem. The system framework is shown in Fig. 1.

### 3.3 Description of Variables in the System Model

Based on the development status of China's stock market, securities and Banks, this paper selects 44 indicators, including 10 level variables, 19 rate variables and 15 auxiliary

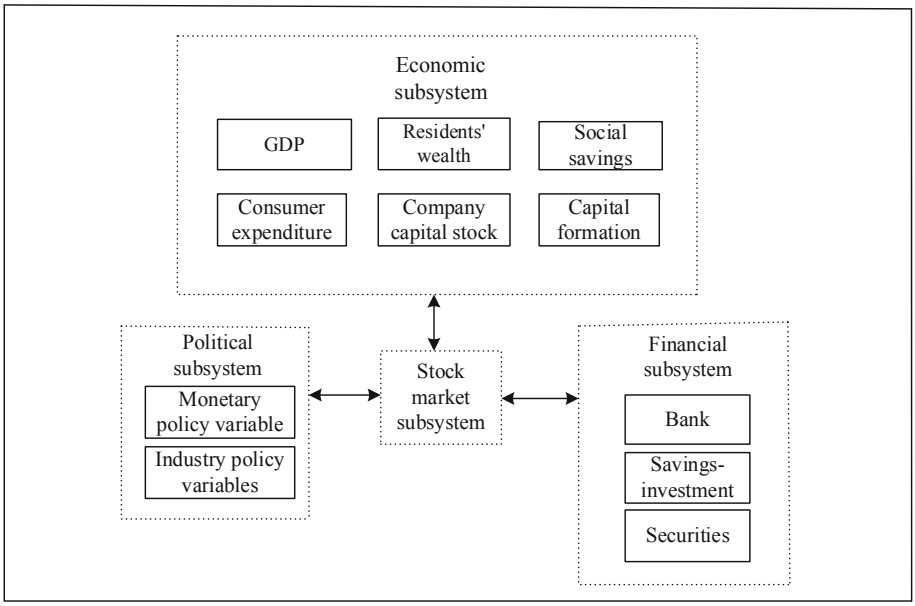


**Fig. 1.** Systematic framework of stock market development.

variables, to simulate the operation of the stock market by constructing a functional relationship between indicators. Among them, three key indicators of money supply, GDP and interest rate are selected to simulate the development of the stock market under different circumstances by adjusting the parameters of these three indicators. This paper ignores the impact of household income, savings-investment, government expenditure and other factors. The description of each variable is shown in Table 1.

### 3.4 Analysis of Main Feedback Loops

This paper divides the main body of stock purchase into three types: individual investors, institutional investors and industrial enterprises. Individual investors invest in stocks through asset allocation to obtain dividend income and capital income, thus increasing personal non-wage income, and then invest in stocks through asset allocation. Institutional investors through the analysis of market conditions, select the stock market investment targets, part of the capital into the stock market. Institutional investors continue to invest part of their money in the stock market after distributing investment income to shareholders and employees. After going public, industrial enterprises will hold part of the shares or carry out stock buybacks. With the development of enterprises, enterprises themselves can gain the benefits brought by the rising stock prices. In addition, the three major purchasers of the stock market obtain investment returns, which will increase savings, thus increasing social savings. Through the savings-investment effect, part of the capital flows into the stock market, promoting the growth of stock market value. In addition, enterprises go public through listing financing to obtain the capital needed for their own development. On the one hand, enterprises can promote the

**Table 1.** Main variables of the system dynamics model of China stock market development.

| Level variable | Rate variable | Rate variable | Auxiliary variable | Auxiliary variable |
|---|---|---|---|---|
| Stockmarket value | Capital inflow | Annual household income | Money supply | Resident stock investment expenditure |
| Institutional holdings | Capital outflow | Annual household expenditure | GDP | Corporate capital income |
| Residents holdings | Institutional buy | Corporate capital inflow | interest rate | Corporate dividend income |
| Corporate holdings | Institutional sell | Corporate capital outflow | Investment profit | Labor compensation |
| Institutional assets | Residents buy | Savings increase | Resident capital income | Corporate deposits |
| Corporate assets | Residents sell | Absorb savings | Resident dividend income | |
| savings stock | Corporate buy | Savings allocation | Institutional stock investment expenditure | |
| Bank capital | Corporate sell | Bank loan | Other income | |
| Savings—investment | Institutional capital inflow | Interest expense | Wage income | |
| Resident wealth | Institutional capital outflow | | Proportion of net capital | |

increase of the gross national product, thus increasing the total social assets and increasing the stock market capital inflow; On the other hand, when the performance of listed enterprises improves, the stock price reflecting the company's operating conditions will also continue to increase.

The correlation among subsystems of the stock market development system is comprehensively studied. In this paper, Vensim PLE software is used to draw the causal circuit diagram of the stock market development system, as shown in Fig. 2. As can be seen from Fig. 2, the development of the stock market takes the market value as the core indicator. With the development and improvement of the stock market, the market value will gradually increase. In the causal loop diagram of the stock market development system, there are 23 positive loops involving the market value:

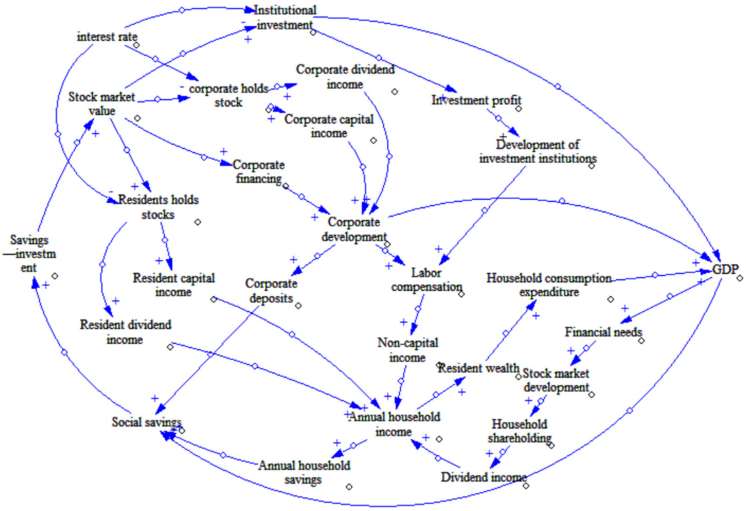


**Fig. 2.** Causal circuit diagram of stock market development system.

### 3.5 Establishment of Stock Market Development System Flow Chart

In this paper, according to the stock market development system module, the internal structure of each system and their mutual relations, the flow diagram of the stock market development system is established, as shown in Fig. 3.

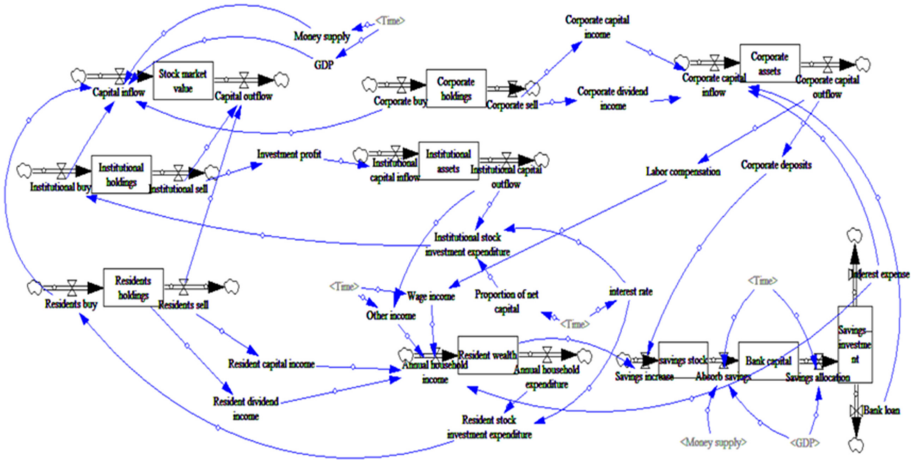


**Fig. 3.** Flow diagram of stock market development system.

The system flow diagram is based on the causal circuit diagram. The mathematical formulas between variables in the system flow diagram are established according to the internal relationship between variables, or the parameter values are obtained by

regression based on historical data, or by referring to the parameter values obtained by relevant experts and scholars [21].

## 4 Model Verification and Simulation

### 4.1 Model Test

There are mainly three kinds of system dynamics simulation model test: (1) intuition test. Combined with the relevant professional knowledge of the research content and the requirements of the simulation model, the determination of the system boundary, variable type, variable definition, function relationship between variables and so on were tested. China's stock market is heavily influenced by external factors. In order to clarify the relationship between variables and improve the approximation between simulation model and actual data, this paper simplifies the model and ignores the impact of exchange rate volatility and foreign stock market volatility on China's stock market. (2) Running test. When Vensim PLE software is used for simulation, the software will automatically conduct repeated tests on the model structure, model equation and parameter rationality, etc. After repeated modifications, the model in this paper passes the internal test of the software system. (3) Historical test. The simulation results are compared with the historical data to verify the fitting degree of the model. This paper will measure the variable of stock market development – stock market value for simulation analysis. The simulation results are shown in Table 2 and Fig. 4. It can be found from Table 2 that the relative error between the simulation value and the historical actual value of the stock market value is controlled within 6%, which can better simulate the development of the stock market. Therefore, the simulation model established in this paper has passed the historical test.

**Table 2.** Simulation results of stock market development system dynamics model.

| Year | Stock market value (RMB 100 million) | | |
|---|---|---|---|
| | Simulation value | Actual value | Relative error |
| 2011 | 148376 | 148376 | 0.00% |
| 2012 | 152828 | 158698 | −3.70% |
| 2013 | 156003 | 151165 | 3.20% |
| 2014 | 231196 | 243974 | −5.24% |
| 2015 | 292171 | 295194 | −1.02% |
| 2016 | 292317 | 284607 | 2.71% |
| 2017 | 345351 | 331325 | 4.23% |
| 2018 | 276256 | 269515 | 2.50% |

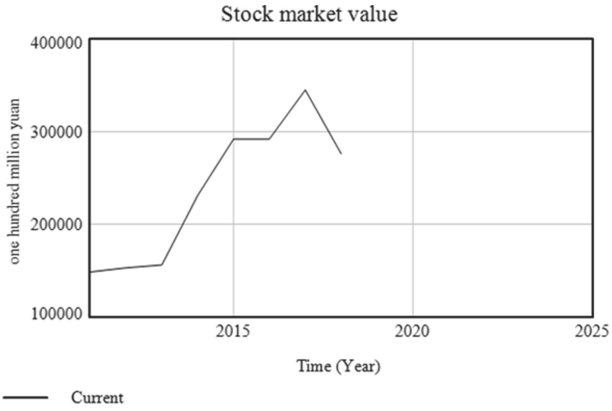


**Fig. 4.** Simulation results of stock market value.

### 4.2 Scenic Setting and Policy Simulation

After testing, the simulation model of stock market development can better simulate the development of China's stock market. In the sensitivity analysis of system dynamics, the changes of the system are observed by setting different situations and changing the values of variables. In general, changing the value of a variable has little impact on the overall system development, that is, the system development has little response to the change of a single variable. When the change of a variable has a great impact on the system, the policy action point is generated. Policy makers adjust the parameter values of variables to promote better development of the system. By adjusting the value of money supply, interest rate and GDP, this paper simulates and analyzes the influence of these variables on the development of the stock market, so as to provide relevant policy Suggestions for policy makers.

(1) The influence of money supply on the development of stock market
Money supply and demand directly affect the liquidity of funds in the market, thus affecting the volatility of stock prices. The money supply in the simulation model is increased by 2%, 4% and 6% respectively, and the changes of stock market value are shown in Fig. 5. As can be seen from Fig. 5, the market value of the stock market is positively correlated with the money supply. With the increase of the money supply, the market value of the stock market also increases gradually. Changes in the money supply have a direct impact on the market value of the stock market. The implementation of monetary policy and fiscal policy will change the money supply, thus affecting the development of the stock market.

(2) The impact of interest rate adjustment on the development of the stock market.
The change of interest rate policy is an important factor affecting the fluctuation and development of the stock market, and adjusting the benchmark interest rate is a common monetary policy tool of the central bank. The central bank indirectly regulates the supply and demand of money in the market by adjusting the benchmark interest rate. The interest rates in the system were reduced by 0.25%, 0.5% and 0.75%, respectively. The changes in the market value of the stock market are shown

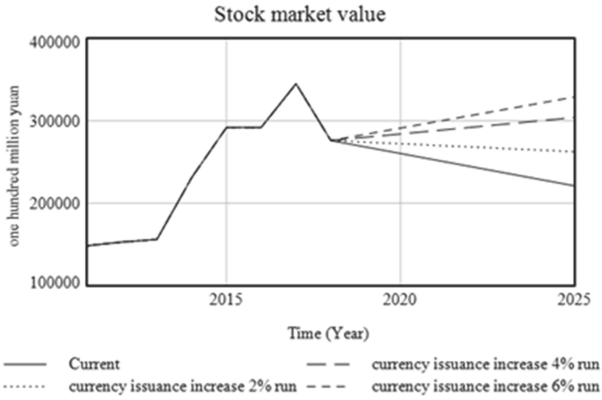


**Fig. 5.** Influence of money supply adjustment on stock market value.

in Fig. 6. With the increase of interest rate reduction, the increase of stock market value gradually increased. The central bank's cut in the benchmark interest rate has had a significant impact on the stock market. First, the yield of savings deposits decreases, and residents are unwilling to deposit their income in Banks. Residents tend to invest more in stocks, so capital flows into the stock market and the market value increases. Second, the larger the rate cut by the central bank, the smaller the financing cost of enterprises, which is conducive to the expansion of reproduction of enterprises, increase the value of enterprises, and the rise of stock prices. Third, the base rate cuts, the central bank to release the flow. When institutional investors issue funds in the securities market, they can integrate funds more quickly. However, stocks are one of the important targets of fund investment, and some funds flow into the stock market.

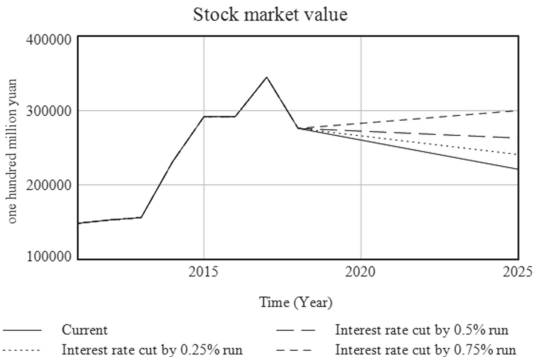


**Fig. 6.** Impact of interest rate adjustment on stock market value.

(3) The impact of economic growth on the stock market
By increasing the GDP in the system by 10%, 20% and 30% respectively, the changes in stock market value are shown in Fig. 7. As can be seen from Fig. 7,

the stock market value is negatively correlated with the interest rate. With the increase of GDP, the growth rate of stock market value will gradually increase. The stock market is the "barometer" of the national economic development. The economic development promotes the improvement of the national income level, so more capital flows into the stock market and promotes the development of the stock market. On the contrary, the sustained and healthy development of the stock market can provide enterprises with necessary funds for production, promote enterprises to expand reproduction, and help the development of the national economy. They promote each other and can achieve coordinated development.

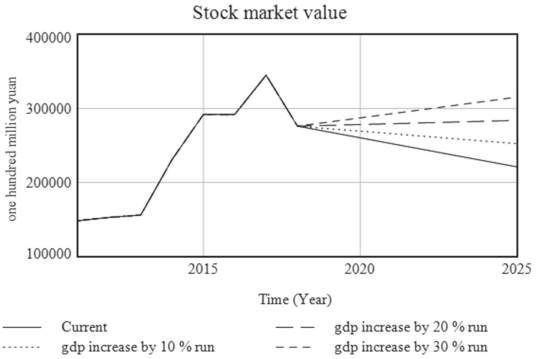


**Fig. 7.** Impact of GDP adjustment on stock market value.

### 4.3 Results Analysis

From the above scenic analysis, it can be seen that changes in money supply, interest rate and GDP can all have a great impact on the market value of the stock market. The change of money supply has a direct impact on the market value of the stock market. On the premise of the same range of GDP growth, the increase of money supply can promote a greater increase in the market value of the stock market. As an important indicator of economic development – GDP growth, on the one hand, residents can obtain the dividend of economic growth and obtain a higher level of annual income. On the other hand, the sustained and healthy development of the national economy can enhance investors' investment confidence, promote the sustained development of the stock market and reduce stock market volatility. The change of the benchmark interest rate can regulate the capital liquidity in the financial market, thus indirectly affecting the market value of the stock market, which is negative.

## 5 Conclusion

Based on the comprehensive analysis of the internal and external factors affecting the development of China's stock market and their impact on social and economic development, this paper constructs a system dynamics simulation model for the development of

China's stock market, and simulates the development of China's stock market. Based on literature analysis, it is concluded that money supply, interest rate and GDP are important factors influencing the development of stock market. Among them, the change of money supply has a direct impact on the stock market volatility, and the adjustment of interest rate affects the market capital liquidity by changing the money supply in the financial market, thus affecting the development of the stock market. When other financial market conditions remain unchanged, changes in money supply, interest rate and GDP will have a significant impact on the development of the stock market.

The system boundary determined in this paper is limited to the domestic financial market, and the effects of exchange rate fluctuations and foreign stock market fluctuations are not included in the stock market development simulation model. However, the error between the simulation data and the real data is small, which has strong explanatory power. In addition to money supply, interest rate and GDP, this paper does not consider other factors that affect the development of China's stock market. It is an important research direction to study the development status and future development trend of China's stock market by using complex system theory in the future.

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