The Dynamic Relationship Between Defense Expenditure and Economic Growth Based on DCC-GARCH Model

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Abstract. The relationship between defense expenditure and economic growth is a key issue in the field of defense economy. Based on the annual data of China's defense expenditure and GDP from 1978 to 2022, the DCC-GARCH model is used to empirically analyze the dynamic relationship between defense expenditure and economic growth in this paper. The research results show that in the past 40 years, there has been a dynamic positive relationship between China's defense expenditure and economic growth over time, especially after 1996, and the relationship between the two has been basically stable and continuously enhanced. The conclusions provide a reference for rationally optimizing the allocation structure of national defense economic resources, which is helpful to improve the efficiency of national defense expenditure and enhance the level of national defense security.

Keywords: Defense expenditure, Economic growth, DCC-GARCH model, Dynamic correlation

1 Introduction

The defense expenditure reflects the economic level of a country's investment in the field of defense construction and the basic trend of defense policy. In recent years, China's peripheral security situation has become increasingly complex, and the national interests have continued to expand and extend overseas. Various risks and opportunities coexisted in the development of the national economy, which has put forward higher requirements for national defense construction [1]. As a non-productive one, defense expenditure is closely related to economic growth. How to clearly understand the relationship between the two and realize the coordinated development of national defense construction and economic construction is a strategic topic that has a bearing on the country's long-term peace and security, and is of guiding significance for the formulation of national defense policy and the overall planning of national defense expenditures.

At present, scholars at home and abroad have established various theoretical models for the study on the relationship between defense expenditure and economic growth. For example, Luo Wei [2] used the Granger Causality test and cointegration analysis to discuss the causal relationship between defense expenditure and economic growth, and concluded that economic growth was the Granger cause of defense expenditure from 1952 to 2004, while defense

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expenditure was not the Granger cause of economic growth. If the significance level is relaxed to 10%, there is a long-term equilibrium relationship between defense expenditure and GDP. Furuoka et al. [3] analyzed the relationship between China's military expenditure and economic growth in the past 30 years based on the cointegration test, and believed that there is a one-way causal relationship between economic development and military expenditure. Deng Yan [4] adopted the VAR model to explore the relationship between defense expending and economic growth, and the results showed that there is there is a long-term stable equilibrium relationship between them, and it will promote economic growth if national defense expenditure is controlled within a certain range, and inhibit economic growth if excessive national defense construction leads to a significant in national defense expenditure. Ti et al. [5] analyzed quantitatively the relationship between defense expenditure and economic growth by using the Feder-Ram model of panel data, and found that defense expenditure has a significant positive effect on the economic growth of developing countries, but not on developed countries. Zheng Yu [6] analyzed the relationship between China's defense expenditure and economic growth based on Feder-Ram model, and discussed the regional and international influencing factors of defense expenditure. Zhang Kan et al. [1] used the unconstrained VAR and the cointegration constrained VEC models to discuss the operation law between defense expenditure, economic growth and residents' consumption, and the empirical analysis showed that economic growth and residents' consumption have a significant positive effect on defense expenditure. Hou Na et.al [7] study the impact of FDI and defense expenditure on economic growth between the economic growth of countries along the Belt and Road based on the economic and geographical correlation, and the results showed that there is a significant spatial correlation, and the defense expenditures of countries along the Belt and Road have a hindering effect on their economic growth compared to other countries in the region.

Most of the existing literatures are static relationship studies, without considering time-varying factors. As a nonlinear correlation research model, the DCC-GARCH model expands the correlation between time series to time-varying, which has great advantages in depicting the dynamic correlation of multiple time series, and can accurately predict the dynamic characteristics of variance, covariance and correlation coefficient of time series distribution. At present, the model has been widely used in the financial and energy fields. For example, Zheng Pengcheng [8] analyzed the relationship between the foreign exchange market and the stock market by using the DCC-GARCH model, and found that the foreign exchange market has a strong correlation with the Shanghai Composite Index stock market, and there is a positive correlation, while the linkage effect between the foreign exchange market and the Shenzhen Composite Index stock market is relatively weak and negative. Ping Zhang et. al. [9] discussed the systemic risk spillover between several financial sectors and the stock market in China using the copula-DCC-GARCH model, and the results showed that there is a high dynamic correlation between the financial sectors and the stock market, varying from 0.7 to 0.9, indicating a strong risk linkage between the financial sectors and the stock market. Zhai Xitong [10] analyzed the dynamic correlation between China Gold and Industry Stock Markets, and found that there are differences in the hedging effects of the gold market on ten industries. In extreme market conditions, gold is highly negatively correlated with industry indices. Therefore, the DCC-GARCH model will be used in this paper to explore the dynamic relationship between defense expenditure and economic growth, for providing the theoretical reference for the coordinated development of China's defense expenditure and economic growth.

The rest of the paper is organized as follows. the principle of DCC-GARCH model is described in Section 2. In Section 3, the empirical analysis is made using DCC-GARCH model to estimate the dynamic correlation coefficient between defense expenditure and economic growth. Section 4 summarizes the conclusion.

2 DCC-GARCH model

The DCC-GARCH model was firstly proposed by Engle [11] in 2002 and consists of a dynamic conditional correlation model (DCC) and a generalized autoregressive conditional heteroskedasticity model (GARCH). The model combines conditional heteroskedasticity and dynamic correlation of time series to depict the linkage between different variables. The DCC-GARCH model is shown as follows:dx

$$x_t = E(Y_t|\Omega_t) + \varepsilon_t \tag{1}$$

$$\varepsilon_t|\Omega \sim N(0, H_t) \tag{2}$$

$$H_t = D_t R_t D_t \tag{3}$$

$$D_t = diag(\sqrt{h_{ii,t}}) \tag{4}$$

$$R_t = diag(Q_t)^{-1} Q_t diag(Q_t)^{-1} \tag{5}$$

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha e_{t-1} e'_{t-1} + \beta Q_{t-1} \tag{6}$$

$$e_t = D_t^{-1} \varepsilon_t \tag{7}$$

$$\bar{Q} = \frac{1}{T} \sum_{t=1}^{T} e_t e'_t \tag{8}$$

where ε_t denotes the random perturbation term, which obeys the t-distribution, and x_t is the data consisted of k time series. H_t denotes the covariance matrix of the residuals, and D_t is a diagonal matrix composed of conditional standard deviation, where the conditional standard deviation is estimated by the univariate GARCH model. R_t is the dynamic conditional correlation coefficient matrix. Q_t is the conditional covariance matrix of the standardized residuals of a single variable, and $\bar{Q}$ represents the unconditional covariance matrix of the standardized residuals of a single variable e_t is the standardized residuals. α and β are the estimated parameters of the DCC model respectively, where α is the intensity of the influence of the standardized residuals with a lag of one period on the conditional variance, and β is the intensity of the influence of the lag of one order on the conditional variance, satisfying $\alpha > 0$, $\beta > 0$, and $\alpha + \beta < 1$. $\rho_{t,ij}$ is the dynamic conditional correlation coefficient.

The value of the dynamic correlation coefficient between two time series variables at time t in DCC-GARCH(1,1) is expressed as:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}}\sqrt{q_{jj,t}}} \tag{9}$$

3 Empirical research

3.1 Data selection and preprocessing

The defense expenditure and Gross Domestic Product (GDP) are selected as research objects in this paper, where GDP is the most direct and effective indicator of a country's economic development level, which can reflect the country's economic growth. The data sample range is from 1978 to 2022, with a total of 45 sets of annual data obtained from the official website of the National Bureau of Statistics. In order to effectively eliminate heteroskedasticity and autocorrelation disturbances and to linearize and smooth the trend of the time series, each time series is processed according to the following method:

$$L_t = ln\left(\frac{Y_t}{Y_{t-1}}\right) \tag{10}$$

where L_t and Y_t are respectively the logarithmic volatility and the annual value at t period. The processed series are represented by LGFZC and LGDP.

3.2 Descriptive statistics

Table 1 shows the descriptive statistical results for each series. The standard deviations of LGFZC and LGDP are relatively small, indicating that the fluctuation degree of defense expenditure and economic growth series is relatively small. The kurtosis of LGFZC and LGDP was greater than 3, showing that there are the characteristics of sharp peaks and fat tails, where the skewness value of LGFZC is greater than 0, showing a right skewed feature, and the skewness values of LGDP is less than 0, showing a right deviation feature. The p-values of the Jarque-Bear test is close to 0, indicating that both LGFZC and LGDP reject the hypothesis that the series follow a normal distribution at a significance level of 1%.

Table 1. The descriptive statistics of two series

	LGFZC	LGDP
MIN	-0.3622	-0.3100
MAX	0.1432	-0.0271
Mean	-0.1017	-0.1316
Median	-0.1114	-0.1130
Std	0.0849	0.0609
Skewness	0.2093	-0.8785
Kurtosis	5.9610	3.4705
	H=1	H=1
JB statistics	16.3946	6.0660
	(0.0054)	(0.0350)

Note: the brackets are statistical p values

3.3 Relationship analysis

(1) The smoothness tests

When constructing the GARCH model for single variable, it is necessary to test the stationarity of each time series to avoid spurious regression. The Augmented Dickey-Fuller (ADF) test is adopted to check whether there is a unit root in LGFZC and LGDP in this paper. The null hypothesis that there is a unit root in the time series is rejected when the p-value is less than the critical value, and the results are shown in Table 2. As can be seen from Table 2, the p-value of LGFZC is less than 0.01, which means that the null hypothesis of the existence of unit roots is rejected at the significance level of 1%, and it is a stationary. The p-value of LGDP is greater than 0.01, which is nonstationary, but the first-order difference is followed by a stationary sequence. The null hypothesis that there is a unit root in the sequence is rejected.

Table 2. The statistics of ADF test results

Series	LGFZC	LGDP	△LGDP
ADF statistics	-3.2654	-1.2170	-6.2699
P	0.0023	0.2015	0.0010
H	1	0	1
results	stationary	nonstationary	stationary

Note:△denotes the series after the first order difference of the original one.

(2) The ARCH effect test

The precondition of using ARCH and GARCH models to characterize time series is that there must have ARCH effect in each time series. In this paper, the Lagrange Multiplier test (LM) is performed on the ARCH effect of LGFZC and LGDP to determine whether each series has heteroscedasticity. From the results of each series under the lag of 5, 10, 15 and 20 orders respectively in Table 3, each series has significant ARCH effect at the 1% confidence level, which meets the conditions for establishing the GARCH model.

Table 3. Results of ARCH effect test

	LGFZC	LGDP
ARCH(5)	21.6702 (0.00060)	17.7765 (0.0009)
ARCH(10)	28.4102 (0.0015)	38.9748 (0.0032)
ARCH(15)	84.3354 (0.0000)	69.2319 (0.0000)
ARCH(20)	599.4832 （0.0000)	1090.6094 (0.0000)

(3) The estimation of DCC-GARCH model

The DCC-GARCH model is used for modeling, which mainly consists of two steps:

①The GARCH modeling is established for each univariate, and the conditional variance and residual of each univariate are estimated.

The GARCH(1,1) model is selected to model each series in this paper, and the estimation results are shown in Table 4. α and β represent the estimators of the coefficients of ARCH(1) and GARCH(1) respectively. The larger the α, the less variability the data is, and the larger the β, the greater the variability of the data. The value of $\alpha+\beta$ is to 1, the more significant the volatility of each series.

Table 4. Parameter estimation results of the univariate GARCH(1,1) model.

Parameters	LGFZC	LGDP
ω	0.0025 0.8176 P=0.4135	0.0067 0.4061 P=0.6847

	0.1085	0.6659
α	1.5081	0.6872
	P=0.1315	P=0.4919
	0.0.1085	0.0000
β	1.2099	0.0000
	P=0.8337	P=1
$\alpha+\beta$	1.0000	0.6659

②The dynamic correlation coefficient is estimated from the standardized residuals estimated in the first step.

The order of the DCC model is set as 1 in this paper. The parameter estimation results of the DCC model are shown in Table 5. The value of $\alpha+\beta$ is less than 1, indicating that the model is stable and the dynamic correlation coefficient is valid. Both the parameter α and β are greater than 0, indicating that the interaction between defense expenditure and economic growth is persistent, and is approximately 1, indicating there is a close dynamic relationship between the two.

Table 5. The DCC parameter estimation results..

Parameters	α	β	$\alpha+\beta$
LGFZC-LGDP	0.0875	0.8714	0.9589

Table 6. Descriptive statistical distribution of dynamic correlation coefficients.

	LGFZC-LGDP
Mean	0.9020
Max	0.9486
Min	0.8512
Median	0.9007
Std	0.0315

Table 6 gives the basic statistical characteristics of the dynamic correlation coefficients between defense expenditure and economic growth, and the Figure 1 shows the time series plot of the dynamic correlation coefficients between the two over time. Combing the results of Table 6 and Figure 1, it can be seen that the dynamic correlation coefficient between defense expenditure and GDP is always positive, fluctuating between 0.852-0.849, and the mean and median are close to 1, which indicates that there is a strong dynamic positive correlation between national defense expenditure and economic growth.

Specifically, the dynamic correlation between defense expenditure and GDP fluctuated sharply from 1978 to 1996, indicating that the relationship between the two may be affected by economic policies. From 1996 to 2022, the relationship shows a steady upward trend, with only a cliff-like decline around 2012, indicating that the dynamic relationship will become stronger over time. Combined with the actual background, from 1978 to 1985, at the beginning of the reform and opening, China's national defense construction was focused on supporting the national economic construction, and the defense expenditure showed a downward trend. During this period, China fought a self-defense counterattack against Vietnam, which led to a sharp increase in defense expenditure due to the needs of the war. The period from 1986 to 1998 was a period of excessive contraction in military expenditure. Since 1997, defense expenditure has been in the compensatory growth stage. In 1999, the national economic aggregate increased sharply, and the government began to consider increasing the investment in national defense construction and increasing national defense expenditure. The relationship between defense expenditure and economic growth has changed from weak to strong, showing a stepwise rise. Since the beginning of the new century, with the tremendous changes that have taken place in China's economic development, GDP and defense expenditure have grown steadily. The financial crisis in 2008 and the dual pressure of the global economic downturn and the transformation and upgrading of the domestic economic structure in 2012 caused China's economic growth to slow down, and there was a significant decline in 2012-2013, resulting in a downward trend in the relationship between defense expenditure and economic growth during these two periods.

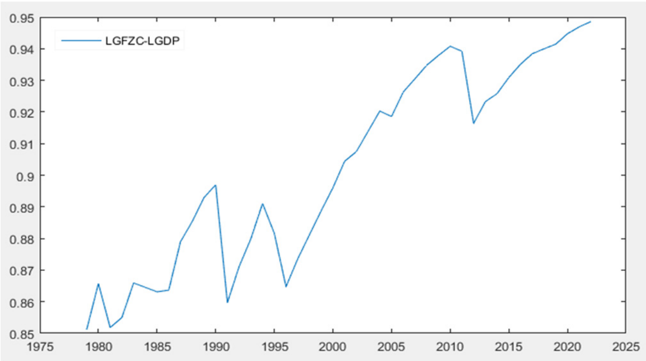

Figure 1. The dynamic correlation coefficients between defense expenditures and GDP.

4 Conclusion

The annual data of defense expenditure and GDP from 1978 to 2022 is taken as the research object in this paper, and the DCC-GARCH model is used to explore the dynamic relationship between China's defense expenditure and economic growth. The study indicates that there is a strong positive dynamic relationship between defense expenditure and economic growth over time. From 1978 to 1996, the relationship between China's defense expenditure and economic growth fluctuated sharply, which may be related to the economic development policies before and after the reform and opening. Since 1996, except for 2012, the relationship between the two has gradually become stronger, showing a steady upward trend.

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