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Has health care financial expenditure accelerated the convergence consistency of health care resource allocation efficiency in China?

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ABSTRACT

This study measures the efficiency of health care resource allocation in each region of China using the global undesirable output from the Data Envelopment Analysis - Slacks Based Measure (DEA-SBM) model, on the basis of which the concept of economic convergence is introduced to analyze the convergence of health care resource allocation efficiency in China as a whole and in each region. The study found that although the overall health care resource allocation efficiency in China is relatively weakly effective, the trend is U-shaped, and since 2015, the overall health care resource allocation efficiency in China has shown an upward momentum and an overall positive performance. Second, the overall health care resource allocation efficiency in China has obvious characteristics of absolute convergence, and each region shows different degrees of absolute convergence, specifically the eastern region, which has the fastest convergence rate followed by the western region, and the central region has the slowest convergence rate. Third, after controlling for health care expenditure, the convergence rate of health care resource allocation efficiency in China as a whole and in the eastern and western regions increases to different degrees, while the convergence rate of health care resource allocation efficiency in the central region shows a small decrease.

Contribution/Originality: This study contributes to the existing studies by taking the undesirable output factors into account when measuring the efficiency of health care resource allocation, and it conducts a convergence analysis on the efficiency measures to examine the effectiveness of health care expenditure in China.

1. INTRODUCTION

The development of medical and health care is related to the safety and quality of the life of Chinese people and is important for sustainable economic and social development in China (Li & Ma, 2021). Since China has officially become an aging society, medical and health care as a major livelihood issue related to people's well-being is particularly important (Tang, Liu, & Wang, 2021). In the report of the 19th National People's Congress of the Communist Party of China, it is clearly stated that implementing a development strategy for health in China is key to improving people's livelihoods, emphasizing the need to improve the national health policy and deepen the reform of the health system. While accelerating the expansion of medical resources, it is necessary to ensure that they are distributed in a balanced way, optimize the stock, and provide comprehensive and high-quality medical and health services for the Chinese people (Fei, 2021; Li & Ma, 2021). In order to better achieve this goal, the central and local governments in China have gradually increased their financial investment in health care, and in recent years have gradually made a historic leap from a lack of medical care to a high level of investment, with the growth rate of health care spending much higher than that in areas such as education and social security (Zhang & Bie, 2022). According to the National Bureau of Statistics of China, overall, the share of health care expenditure of the total financial expenditure in China has increased from 1.95% in 2010 to 17.59% in 2020. Specifically, the amount of local health care expenditure in China rose from 473.062 billion yuan/RMB in 2010 to 1887.341 billion yuan in 2020, and the amount of central health care expenditure also rose from 7.356 billion yuan in 2010 to 34.278 billion yuan in 2020. Both central and local governments are experiencing a rapid expansion of health care expenditure.

However, it should be noted that in the process of the Chinese government's increasing financial investment in health care, the scarcity of resources dictates that they must be allocated in a reasonable manner through appropriate means. This means that it is necessary to establish a scientific evaluation system so that the limited resources can be allocated efficiently (Du, Ran, Li, & Zhang, 2017), especially after the 19th National People's Congress developed the "Healthy China 2030" strategy, which has put forward a higher test on China's health care resource allocation capacity (Wen, Zheng, & Zhao, 2021). At the same time, it is also necessary to examine the impact of the rapid expansion of health care expenditure on resource allocation efficiency to ensure the effectiveness of fiscal policy, avoid ineffective input, and prevent negative input.

In addition, it should be noted that most of the current Chinese academics only use the traditional DEA-CCR (Charnes-Cooper-Rhodes), DEA-BCC (Banker-Charnes-Cooper), and DEA-SBM models to measure the efficiency of health care resource allocation, which ignore time-varying factors, resulting in less accurate measurement results. They also ignore the impact of undesirable output factors on efficiency values, which can exacerbate the inaccuracy of the measurement results (Du et al., 2017; Li & Ma, 2021; Tang et al., 2021; Zhang & Bie, 2022). Therefore, based on the global undesirable output DEA-SBM model, this study measures the efficiency of health care resource allocation in each region of China, explores the trend of health care resource allocation efficiency and the differences nationwide and in each region, and introduces the concept of economic convergence to examine the impact of health care expenditure on the consistency of efficient health care resource allocation nationwide and in each region.

2. METHODOLOGY

2.1. Indicator System

2.1.1. Input Indicators

Currently, when evaluating health care resource allocation efficiency in Chinese academia, input indicators are usually selected from both labor and capital perspectives. In terms of labor input indicators, this study refers to existing studies for time-series data and combines it with the longitudinal characteristics of the panel data of this study. Therefore, the total number of health personnel (X_1), is used as the labor input indicator (Jiang & Andrews, 2020; Yan, Jiang, Cheng, & Wang, 2016; Yan, 2018). In terms of the capital input indicators, this study refers to existing studies and uses the number of beds (X_2) (Bilsel & Davutyan, 2014; Lepchak & Voese, 2020; Pang, Gao, & Deng, 2018), and the total number of health care institutions (X_3) (Bilsel & Davutyan, 2014; Wang & Zhang, 2019). The input indicators are explained in Table 1.

2.1.2. Output Indicators

Currently, when evaluating health care resource allocation efficiency in Chinese academia, usually, only desirable output indicators are considered, while undesirable output indicators are rarely considered. Therefore, in this study, output indicators are divided into two categories with reference to the existing studies: The first category is the desirable output indicators, including the number of consultations (Y_1) (Bilsel & Davutyan, 2014; Pang et al., 2018; Xia, Leng, Zhang, & Du, 2018; Zhao, 2017), the number of health examinations (Y_2) (Yan, 2018), the number of patients kept in the observation room (Y_3) (Yan, 2018), the number of hospitalizations (Y_4) (Bilsel & Davutyan, 2014; Wang & Zhang, 2019; Xia et al., 2018; Yan, 2018), the number of discharges (Y_5) (Chen, Wang, Zhu, Sherman, &

Chou, 2019; Lepchak & Voese, 2020; Pang et al., 2018), the number of surgeries (Y_6) (Du et al., 2017; Lepchak & Voese, 2020; Pang et al., 2018), and the bed occupancy rate (Y_7) (Li, Wang, & Lin, 2012; Yan, 2018; Zhou, 2021). The second category comprises the undesirable output indicators, which are the emergency medical death rate ($BadY_1$) and patients kept in the observation room death rate ($BadY_2$). The output indicators are also presented in Table 1.

Table 1. Input and output indicators.

Indicator category	Indicator name	Indicator meaning
Input indicators	X_1	Total number of health technicians, rural doctors and other technicians, managers and skilled workforce in the reporting period by region
	X_2	Total number of beds at the end of the reporting period by region
	X_3	Total number of hospitals, primary health care institutions, specialized public health institutions, and other health care institutions in the reporting period by region
Desirable output indicators	Y_1	Number of visits to medical and health care institutions in the reporting period by region
	Y_2	Number of outpatient health checkups at medical and health care institutions during the reporting period by region
	Y_3	Number of patients kept in observation rooms of health care institutions during the reporting period by region
	Y_4	Number of hospitalizations to medical and health care institutions in the reporting period by region
	Y_5	Number of discharges from medical and health care institutions in the reporting period by region
	Y_6	Number of inpatient surgeries in health care institutions during the reporting period by region
	Y_7	Hospital bed utilization rate by region for the reporting period
Undesirable output indicators	$BadY_1$	Emergency medical death rate in health care facilities during the reporting period by region
	$BadY_2$	Patients kept in the observation room death rate in health care facilities during the reporting period by region

2.2. Data Sources

The data for this study were obtained from the National Bureau of Statistics of China, from 2011–2019, covering data from 31 provinces, municipalities and autonomous regions in mainland China and is divided into eastern, central and western regions according to the division criteria of the National Bureau of Statistics of China.[1]

2.3. Measurement Model Selection

In order to take the undesirable output indicators into account and better reflect the time-varying nature of the longitudinal comparison analysis, this study chooses the global undesirable output DEA-SBM model as the measurement model. The global undesirable output DEA-SBM model has two advantages over the traditional DEA-CCR and DEA-BCC models as follows: Firstly, the DEA-SBM model with global reference conditions can overcome the problem that the efficiency values of decision units measured by the traditional DEA-CCR and DEA-BCC models are not comparable across periods (Liu, Qiao, & Yin, 2021). Secondly, after considering the undesirable outputs, the efficiency measure results are more realistic and can more accurately reflect the true efficiency of the decision units (Liu & Yin, 2020).

[1] The Eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan, a total of 11 provinces (municipalities, autonomous regions). The Central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan, a total of 8 provinces (municipalities, autonomous regions). The Western region includes Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Inner Mongolia, Guangxi and Chongqing, a total of 12 provinces (municipalities, autonomous regions).

$$\rho^* = min \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{S_{io,t}^-}{X_{io,t}}}{1 + \frac{1}{s_1+s_2}\left(\sum_{\tau=1}^{S_1}\frac{S_{\tau,t}^{good}}{Y_{\tau o,t}^{good}} + \sum_{\tau=1}^{S_2}\frac{S_{\tau,t}^{bad}}{Y_{\tau o,t}^{bad}}\right)}$$

$$s.t.\ X_{o,t} = X\lambda + S_{o,t}^-$$

$$Y_{o,t}^{good} = Y\lambda - S_{o,t}^{good} \quad (1)$$

$$Y_{o,t}^{bad} = Y\lambda - S_{o,t}^{bad}$$

$$L \leq e\lambda \leq U$$

$$S_{o,t}^-,\ S_{o,t}^{good},\ S_{o,t}^{bad},\ \lambda \geq 0$$

2.4. Measurement Model Setting

In Equation 1, ρ^* represents the measured health care resource allocation efficiency values; λ represents the weight vector representing the decision unit; $X_{o,t}$, $Y_{o,t}^{good}$, $Y_{o,t}^{bad}$, $S_{o,t}^-$, $S_{o,t}^{good}$ and $S_{o,t}^{bad}$ respectively represent the input vector group, the desirable output vector group, the undesirable output vector group, the slack vector group of the input vector group, the residual vector group of the desirable output vector group, and the slack vector group of the undesirable output vector group in the t-th period of the o-th province (municipality directly under the Central Government and autonomous region).

3. RESULTS

3.1. Efficiency Measurement Results

This study uses the global undesirable output DEA-SBM model to measure the health care resource allocation efficiency in China. The results are presented in Table 2; only the national and three regional health care resource allocation efficiency levels are shown due to the space limitation, and its spatial and temporal evolution has the following characteristics.

Firstly, the overall effectiveness of health care resource allocation efficiency in China from 2011 to 2019 is relatively weak, with a mean value of only 0.756, but there is a large difference among regions. Specifically, the eastern region performs relatively effectively overall, with an efficiency mean value of 0.814, the western region is second with an efficiency mean value of 0.757, and the central region is the weakest, with an efficiency mean value of only 0.674.

Table 2. Efficiency measurement results.

Testing strategy	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average
Eastern region	0.880	0.821	0.817	0.799	0.777	0.814	0.817	0.778	0.821	0.814
Central region	0.650	0.676	0.669	0.672	0.621	0.652	0.711	0.720	0.691	0.674
Western region	0.852	0.863	0.803	0.756	0.691	0.726	0.691	0.683	0.752	0.757
Nationwide	0.810	0.800	0.773	0.750	0.703	0.738	0.741	0.726	0.761	0.756

Secondly, the health care resource allocation efficiency in the eastern, middle and western regions of China all show a U-shaped trend, and the inflection point of the efficiency trend in each region is in 2015, but there are obvious differences among regions. Specifically, the allocation efficiency in the eastern region declined from 0.880 in 2011 to 0.777 in 2015, and has since fluctuated and reached 0.821 in 2019. The allocation efficiency in the central region fluctuated from 0.650 in 2011 to 0.621 in 2015 and has since fluctuated up to 0.691 in 2019. The allocation efficiency in the western region experienced a brief increase from 2011 to 2012, then continued to decline to 0.691 in 2015 and has since fluctuated up to 0.752 in 2019. In summary, although the overall health care resource allocation efficiency effectiveness in China is relatively weak and all regions have experienced different degrees of decline in efficiency, all regions have shown different degrees of upward trend since 2015. So, has health care expenditure contributed to this process? How strong is the contribution? These questions can be answered with further testing through convergence analysis.

3.2. Convergence Analysis

3.2.1. Absolute Β-Convergence Analysis

3.2.1.1. Convergence Model Selecting

To better control for endogenous factors, this study selects a fixed effects panel regression model as the benchmark for absolute β-convergence analysis. The results of the cross-section F-test and the period F-test in Table 3 show that both individual and time fixed effects should be controlled for in the convergence analysis for nationwide and the western region, individual fixed effects should be controlled for in the convergence analysis for the eastern region, and no fixed effects are required for the convergence analysis for the central region.

Table 3. Fixed effects selection test.

Testing strategy	Cross-section F	Period F	Conclusion
Nationwide	3.498***	2.132**	Both individual and time fixed effects should be controlled
Eastern region	9.939***	0.708	Individual fixed effects should be controlled
Central region	1.603	1.260	No fixed effects are required
Western region	2.575***	1.913*	Both individual and time fixed effects should be controlled

Note: *** represents p < 0.01; ** represents p < 0.05; * represents p < 0.1.

3.2.1.2. Convergence Model Setting

Based on the absolute β-convergence analysis model and combined with the test results of the model selection in the previous section, the regression model for nationwide and the western region is set as follows:

$$LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}} = \alpha_1 + \beta_1 LNMRAE_{i,t} + \lambda_t + \mu_i + \varepsilon_{i,t} \qquad (2)$$

The regression model for the eastern region is set as follows:

$$LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}} = \alpha_2 + \beta_2 LNMRAE_{i,t} + \mu_i + \omega_{i,t} \qquad (3)$$

The regression model for the central region is set as follows:

$$LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}} = \alpha_3 + \beta_3 LNMRAE_{i,t} + \varphi_{i,t} \qquad (4)$$

In Equations 2, 3 and 4, $LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}}$ represents the growth rate of health care resource allocation efficiency in the i-th province (municipality, autonomous region) in the t-th period; $LNMRAE_{i,t}$ represents the logarithmic health care resource allocation efficiency of the i-th province (municipality, autonomous region) in the t-th period; λ_t represents the time effects that do not change with the individual; μ_i represents the individual effects that do not change with the time; α_1, α_2 and α_3 represent the constant terms; β_1, β_2 and β_3 represent the coefficients to be estimated; and $\varepsilon_{i,t}$, $\omega_{i,t}$ and $\varphi_{i,t}$ represent the error terms.

3.2.1.3. Cointegration Test

The results of Pedroni (augmented Dickey–Fuller) test in Table 4 show that there is a long-term stable cointegration relationship between $LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}}$ and $LNMRAE_{i,t}$ for both nationwide and the different regions. The absolute β-convergence analysis can be performed directly using the above variables.

Table 4. Cointegration test.

Testing objective	Nationwide	Eastern region	Central region	Western region
Pedroni (ADF) test	-5.753***	-5.133***	-1.880***	-2.017***

Note: *** represents p < 0.01.

3.2.1.4. Convergence Model Analysis

Columns 2, 3, 4 and 5 in Table 5 report the results of the absolute β-convergence analysis of health care resource allocation efficiency nationally and by region, respectively, and the results show that the β coefficients of health care resource allocation efficiency (LNMRAE) nationally and by region are significantly negative at the 1% level. Therefore, there is an absolute β-convergence trend of health care resource allocation efficiency nationwide and in each region. This indicates that the nationwide health care resource allocation efficiency is converging to the same steady-state level with a convergence rate of 0.900 without considering other factors, and there is a strong linkage effect among regions. However, it should be noted that there is a significant difference in the convergence rate within each region. Specifically, the convergence speed in the eastern region is the fastest, with a speed of 2.645, much higher than the nationwide average, and there is a strong linkage effect within the eastern region. The western region is the second fastest, with a speed of 0.692, slightly lower than the nationwide average, and there is a certain degree of linkage within the western region. The central region is the slowest, with a speed of 0.038, much lower than the nationwide average, and the linkage effect within the central region is very weak.

Table 5. Absolute β-convergence analysis.

Variable	Nationwide	Eastern region	Central region	Western region
LNMRAE	-0.593*** (0.066)	-0.929*** (0.069)	-0.037*** (0.003)	-0.500*** (0.121)
Constant	-0.219*** (0.024)	-0.249*** (0.019)	-0.011*** (0.003)	-0.197*** (0.045)
Individual fixed effects	Controlled	Controlled	Controlled	Controlled
Time fixed effects	Controlled	Controlled	Controlled	Controlled
R^2	38.43%	72.14%	64.85%	37.04%
Convergence or not	Convergence	Convergence	Convergence	Convergence
Convergence speed	0.900	2.645	0.038	0.692

Note: *** represents p < 0.01. Numbers in parentheses are standard errors.

3.2.2. Conditional Β-Convergence Analysis

3.2.2.1. Convergence Model Selecting

After controlling the condition of health care expenditure, the cross-section F-test and the period F-test are conducted on the benchmark model, and the results are presented in Table 6. In the convergence analysis for nationwide and the western region, both individual and time fixed effects should be controlled. In the convergence analysis for the eastern region, individual fixed effects should be controlled. In the convergence analysis for the central region, fixed effects need not be controlled.

Table 6. Fixed effects selection test.

Testing strategy	Cross-section F	Period F	Conclusion
Nationwide	3.740***	2.645***	Both individual and time fixed effects should be controlled
Eastern region	10.492***	1.580	Individual fixed effects should be controlled
Central region	1.231	1.297	No fixed effects are required
Western region	3.011***	2.358**	Both individual and time fixed effects should be controlled

Note: *** represents p < 0.01; ** represents p < 0.05.

3.2.2.2. Convergence Model Setting

Based on the conditional β-convergence analysis model and combined with the test results of model selection in the previous section, the regression model for the nationwide and the western region is set as follows:

$$LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}} = \alpha_1 + \beta_1 LNMRAE_{i,t} + \beta_2 LNPCMFE_{i,t} + \lambda_t + \mu_i + \varepsilon_{i,t} \quad (5)$$

The regression model for the eastern region is set as follows:

$$LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}} = \alpha_2 + \beta_3 LNMRAE_{i,t} + \beta_4 LNPCMFE_{i,t} + \mu_i + \omega_{i,t} \quad (6)$$

The regression model for the central region is set as follows:

$$LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}} = \alpha_3 + \beta_5 LNMRAE_{i,t} + \beta_6 LNPCMFE_{i,t} + \varphi_{i,t} \quad (7)$$

In Equations 5, 6 and 7, $LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}}$ represents the growth rate of health care resource allocation efficiency of the i-th province (municipality, autonomous region) in the t-th period; $LNMRAE_{i,t}$ represents the logarithmic health care resource allocation efficiency of the i-th province (municipality, autonomous region) in the t-th period; $LNPCMFE_{i,t}$ represents the logarithmic per capita health care expenditure of the i-th province (municipality, autonomous region) in the t-th period; λ_t represents the time effects that do not change with the individual; μ_i represents the individual effects that do not change with the time; α_1, α_2 and α_3 represent the constant terms; β_1, β_2, β_3, β_4, β_5 and β_6 represent the coefficients to be estimated; and $\varepsilon_{i,t}$, $\omega_{i,t}$ and $\varphi_{i,t}$ represent the error terms.

3.2.2.3. Cointegration Test

The results of the Pedroni (ADF) test in Table 7 show that there is a long-term stable cointegration relationship between $LN\frac{MRAE_{i,t+1}}{MRAE_{i,t}}$ and $LNMRAE_{i,t}$ for both nationwide and the different regions. The conditional β-convergence analysis can be performed directly using the above variables.

Table 7. Cointegration test.

Testing objective	Nationwide	Eastern region	Central region	Western region
Pedroni (ADF) test	-4.635***	-3.263***	-2.760***	-1.976**

Note: *** represents $p < 0.01$; ** represents $p < 0.05$.

3.2.2.4. Convergence Model Analysis

Columns 2, 3, 4 and 5 in Table 8 report the results of the conditional β-convergence analysis of health care resource allocation efficiency nationally and by region, respectively, and the results show that after controlling the condition of health care expenditure, it was found that the convergence rates nationwide and in the eastern and western regions show different levels of increase, while the convergence rate in the central region shows a small decrease.

Table 8. Conditional β-convergence analysis.

Variable	Nationwide	Eastern region	Central region	Western region
LNMRAE	-0.641*** (0.068)	-0.966*** (0.078)	-0.033** (0.013)	-0.625*** (0.128)
LNPCMFE	-0.358** (0.157)	-0.026 (0.035)	-0.038*** (0.007)	-0.733** (0.302)
Constant	-1.125*** (0.373)	-0.323*** (0.097)	-0.109*** (0.018)	-1.977*** (0.734)
Individual fixed effects	Controlled	Controlled	Controlled	Controlled
Time fixed effects	Controlled	Controlled	Controlled	Controlled
R^2	40.14%	73.96%	37.93%	41.64%
Convergence or not	Convergence	Convergence	Convergence	Convergence
Convergence speed	1.025	3.378	0.034	0.981

Note: *** represents $p < 0.01$; ** represents $p < 0.05$. Numbers in parentheses are standard errors.

Specifically, health care fiscal expenditure increased the convergence rate of national health care resource allocation efficiency from 0.900 to 1.025, increased the convergence rate in the eastern region from 2.645 to 3.378, decreased the convergence rate in the central region from 0.038 to 0.034, and increased the convergence rate in the western region from 0.692 to 0.981 that is, health care expenditure promotes the convergence of health care resource allocation efficiency in China as a whole and in the eastern and western regions, but has a divergence effect in the central region.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the global undesirable output DEA-SBM model, this study measures the health care resource allocation efficiency of 31 provinces (municipalities directly under the Central Government and autonomous regions) in China from 2011 to 2019 and explores the trends of health care resource allocation efficiency and its differences nationwide and in each region. By introducing the concept of economic convergence, an absolute β-convergence analysis is conducted on the health care resource allocation efficiency of China as a whole and each region. By controlling for the health care expenditure condition, the influence of health care expenditure on the convergence consistency of health care resource allocation efficiency in China as a whole and in each region is investigated. The results show that, firstly, the overall health care resource allocation efficiency in China is relatively weak, and there are obvious differences among regions, with the highest efficiency in the eastern region followed by the western region, and the lowest is in the central region. In terms of the trend, health care resource allocation efficiency nationwide and in each region shows a U-shaped trend, and since 2015 has shown different degrees of upward momentum, and the overall performance is positive. Secondly, at the national level, there is an obvious absolute convergence of health care resource allocation efficiency in China. At the regional level, there are obvious signs of absolute convergence within the eastern, central and western regions. Specifically, the convergence rate in the eastern region is faster than that in the western and central regions, and the convergence rate in the eastern region is much faster than the national average. The convergence rate in the western region is slightly lower than the national average, and the convergence rate in the central region is much lower than the national average. Thirdly, health care expenditure accelerates the convergence rate of health care resource allocation efficiency nationwide, but there are obvious regional differences. After controlling for the condition of health care expenditure, the convergence rate of health care resource allocation efficiency nationwide and in the eastern and western regions has increased to different degrees, while the convergence rate in the central region shows a small decrease.

The above findings have obvious policy implications, thus it is suggested that the eastern and western regions should increase health care expenditure to promote the convergence of health care resource allocation efficiency, while the central region should improve the efficiency of health care expenditure usage to avoid the dispersion effect caused by ineffective health care expenditure.

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