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Particle Physics and the Decomposition of Economic Growth Sources

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Abstract

Economic growth is similar to the formation of the universe. In order to measure the source of economic growth and explore the relationship between economic growth and physics, this paper uses data envelopment analysis (DEA) to decompose China's economic growth from 1978 to 2017 into total factor productivity and input effects. The conclusion is: China's overall economic growth rate from 1978 to 2017 was 10.71%, of which the growth rate of total factor productivity (TFP) and technical efficiency have been negative for a long time. Economic growth mainly depends on input factors, especially capital input. Linking physical indicators with economic variables, the economic growth Kinetic energy in 2017 was 1599.59J, and the economic promotion force between Guangdong Province and Jiangxi Province was 2.24N.

Keywords

Economic growth; data envelopment analysis; total factor productivity; classical Newtonian mechanics.

1. INTRODUCTION

To a certain extent, the development history of human society is equal to the history of economic growth, and economic growth is an important issue of human society. In the continuous growth of enterprises, countries and regions, the economic level of human society has improved again and again. Innovation is the source of human progress. Technological progress in modern times has completely changed the long and arduous state of human existence in the past. Every technological revolution in history has had a profound impact on the transformation of the world's political and economic structure. It can be said that technological progress determines the future and destiny of each country and nation.

The history of economic growth is familiar to us. Because it is similar to the evolution of life and the origin of the universe. Life forms evolved from single-celled organisms to multi-celled organisms, from invertebrate to spine, from water to land, and from ape to human. This evolution is continuous and does not happen suddenly. Uncertainty may lead to fatal danger, or amazing progress may occur. Although there are huge changes caused by cyclical fluctuations and uncertain factors, economic growth is continuous too. Both the economy and life are like particles in physics, and economic growth and biological evolution are like the energy transition of particles. Nowadays, the most widely accepted theory of the origin of the universe is the Big Bang. The theory holds that the universe was born in a big bang, and the universe we live in now is formed by continuous expansion after this big bang. At the beginning of the explosion, there were only a few particles in the universe. The charge and magnetic field of the particles constitute a quantum field, and the particles are constantly moving, colliding, condensing and annihilating, giving birth to nebulae. Energy collisions also occur inside the nebula, giving birth to beautiful galaxies and planets.

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The formation of the universe requires energy and matters, and biological evolution requires opportunities and coincidences. What about the sources of economic growth? Different from microeconomics and macroeconomics, this paper analyzes the economic growth from the universe level. Defined as cosmo-economics. Considering the ingenious similarities between the economic growth process and the formation of the universe, and in order to explore the source of economic growth, this paper transfers physics and astronomy theories to economic research, and uses data envelopment analysis to decompose economic growth into total factor productivity and input factors.

The rest of the paper is arranged as follows. The second part is methodology. The third part is and data and empirical study. The last part is the conclusion and summary.

2. METHODOLOGY

Total factor productivity analysis is one of the important research fields of economic growth. The traditional economic growth theory is represented by Solow [1]. Although this approach is simple, it does not consider the impact of other factors, overestimates the share of technological progress, and is completely based on the assumptions of neoclassical economics. Another method of total factor productivity analysis is data envelopment analysis [2]. Malmquist productivity index is based on DEA, which decomposes TFP into changes in technical efficiency and technological progress [3]. The Luenberger indicator of additive structure has many good performances in empirical research [4]. The Malmquist index overestimates productivity [5]. The Luenberger index can more accurately describe the logical relationship between overall performance and internal element performance [6]. In the extensive research of scholars, for different research samples, different model methods are used, and different results are obtained regarding the source of economic growth and TFP growth [7-9].

This study uses the DEA method to construct an additive Luenberger productivity index, decomposing the sources of China's economic growth into three parts: inputs, technical efficiency and technological progress.

According to previous research, assuming that there are n production decision-making units (DMU) for time t=1,...,T, the production technology can be expressed as:

$$P^t = (L^t, K^t, Y^t): z_n^t \overline{Y}_n^t \geq Y^t;\ z_n^t \overline{L}_n^t \leq L^t;\ z_n^t \overline{K}_n^t \leq K^t$$
$$\sum_{n=1}^{N} z_n^t = 1;\ z_n^t \geq 0;\ n = 1, \dots, N \tag{1}$$

L and K are two input variables, labor and capital respectively, and Y is output. z_n^t is the weight assigned to each observation value to construct the production frontier. When the weight is non-negative, the production technology is the constant return to scale (CRS).

The output directional distance function is set as:

$$\vec{D}_o^t(L^t, K^t, Y^t; g^t) = \sup\{\beta: Y^t + \beta g^t \in P^t\} \tag{2}$$

The above formula represents the maximum multiple β that the output can expand along the direction vector g=(y,−b) under a given input. The smaller the value, the closer the production is to the production frontier and the more efficient it is.

Similar to the form in which the Malmquist index is expressed as the geometric average of two periods, the Luenberger index is expressed as the arithmetic average of the two periods. The Luenberger index from period t to period t+1 is:

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$$L_t^{t+1} = \frac{1}{2}\left\{ \begin{array}{c} \left[\vec{D}_o^t(x^t, y^t; g^t) - \vec{D}_o^t(x^{t+1}, y^{t+1}; g^{t+1})\right] + \\ \left[\vec{D}_o^{t+1}(x^t, y^t; g^t) - \vec{D}_o^{t+1}(x^{t+1}, y^{t+1}; g^{t+1})\right] \end{array} \right\} \quad (3)$$

Which can be decomposed into:

$$L_t^{t+1} = \left[\vec{D}_o^t(x^t, y^t; g^t) - \vec{D}_o^{t+1}(x^{t+1}, y^{t+1}; g^{t+1})\right] + \frac{1}{2}\left\{ \begin{array}{c} \left[\vec{D}_o^{t+1}(x^t, y^t; g^t) - \vec{D}_o^t(x^t, y^t; g^t)\right] + \\ \left[\vec{D}_o^{t+1}(x^{t+1}, y^{t+1}; g^{t+1}) - \vec{D}_o^t(x^{t+1}, y^{t+1}; g^{t+1})\right] \end{array} \right\} = EFF+TC \quad (4)$$

$$EFF=\left[\vec{D}_o^t(x^t, y^t; g^t) - \vec{D}_o^{t+1}(x^{t+1}, y^{t+1}; g^{t+1})\right] \quad (5)$$

$$TC=\frac{1}{2}\left\{ \begin{array}{c} \left[\vec{D}_o^{t+1}(x^t, y^t; g^t) - \vec{D}_o^t(x^t, y^t; g^t)\right] + \\ \left[\vec{D}_o^{t+1}(x^{t+1}, y^{t+1}; g^{t+1}) - \vec{D}_o^t(x^{t+1}, y^{t+1}; g^{t+1})\right] \end{array} \right\} \quad (6)$$

EFF means technological efficiency change, TC means technological progress. EFF greater than (less than) 0 indicates improvement in technical efficiency (decay), TC greater than (less than) 0 indicates technological progress (regression).

$Y^{t+1} - Y^t$ is the economic growth from period t to period t+1 which expressed as:

$$Y^{t+1} - Y^t = \left[\vec{D}_o^t(L^t, K^t, Y^t; g^t) - \vec{D}_o^{t+1}(L^{t+1}, K^{t+1}, Y^{t+1}; g^{t+1})\right] + \left\{\left[Y^{t+1} + \vec{D}_o^{t+1}(L^{t+1}, K^{t+1}, Y^{t+1}; g^{t+1})\right] - \left[Y^t + \vec{D}_o^t(L^t, K^t, Y^t; g^t)\right]\right\} \quad (7)$$

Therefore, economic growth can be divided into technical efficiency changes (EFF), technological changes (TC), and factor contributions. Factor contributions are further divided into two parts: labor economic growth contribution (LE) and capital economic growth contribution (KE).

3. EMPIRICAL STUDY

3.1. Input and Output Indicators

According to the availability of data, 29 provinces in China, excluding Tibet, were selected as the research objects, and the study period was selected from 1978 to 2017. The statistical data mainly comes from the China Statistical Yearbook, the National Bureau of Statistics and the provincial statistical yearbooks.

Labor input. Since data on labor time and labor remuneration are not available, the number of employees in each province over the years is selected as a measure of labor input.

Physical capital investment. Use the perpetual inventory method to calculate the stock of physical capital [10]. The actual investment is the total fixed capital formation, and the fixed asset investment price index in the early years is calculated by the method of calculating the implicit price index using the fixed capital formation index. Different provinces have different depreciation rates [11]. The initial capital stock is calculated according to the following formula [12].

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$$K_0 = \frac{I_0}{g+\delta} \tag{8}$$

Output. The output indicator selects the GDP of each province and region based on the expenditure method at constant prices in 1978. The data before 1993 is supplemented by the "Compilation of Statistical Data for 60 Years of New China" or statistical yearbooks of various provinces. In the end, we get the GRP of each province's current price from 1978 to 2017. As the revision of the GDP deflator may be controversial [13], the GDP deflator published in the statistical yearbooks of each province is directly used to deflate GDP.

According to the above data processing method, Table 1 shows the descriptive statistics of each input-output variable. GDP and physical capital are both at constant prices in 1978. The average GDP is 4803.378 billion yuan, and the average labor force and physical capital are 630,723,500 yuan and 13,192.36 billion yuan respectively. Among them, GDP increased from 340.949.7 billion yuan in 1978 to 179980 billion yuan in 2017, and labor input and material capital investment increased from 3.8686605 million to 82.875 million, and from 540.534 billion to 62,753.16 billion. Figure 1 shows the change trend of labor force, material capital and GDP over the years. It can be seen that the growth trend of GDP and the growth trend of material capital are relatively similar, while the growth trend of labor force is relatively flat. GDP and physical capital have experienced rapid growth since the 21st century.

Table 1. Summary statistics of various variables (1978-2017)

Variable	Mean	Std. Dev	Min	Max
GDP (100 million yuan)	48033.78	52482.60	3409.50	179980.00
Labor (10,000 people)	63072.35	13616.67	38686.05	82987.50
Capital (100 million yuan)	131923.60	172864.80	5405.34	627531.60

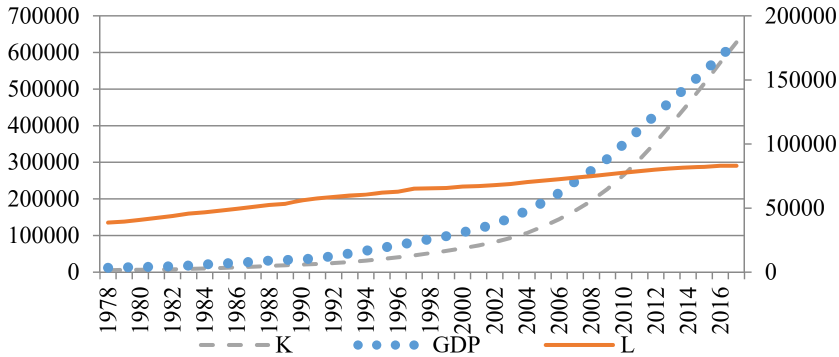

Figure 1. Labor, capital and GDP over 1978-2017

3.2. Results and Discussion

Use GAMS software to construct an additive Luenberger productivity index to decompose economic growth. Table 2 shows the results of China's economic growth and the average annual growth rate of its components from 1978 to 2017. It can be seen from the table that from 1978 to 2017, China's overall economic growth rate was 10.71%, TFP growth rate was -6.54%, technical efficiency growth rate was -7.25%, technological progress growth rate was 0.16%, and labor growth rate was 1%. The capital growth rate was 16.17%. The third line of Table 2 shows the contribution share of each component to China's economic growth from 1978 to 2017. It can be seen from this that due to the decline of technical efficiency and small technological progress, the contribution of TFP is negative, and economic growth mainly depends on the input of factors, of which capital contributes greatly to economic growth.

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Table 2. The average growth rate of Economic growth (1978-2017)

Index	Y	TFP	EFFCH	TC	LE	KE
Average growth rate	0.107059	-0.06539	-0.07247	0.001587	0.009982	0.161702
Contribution	100.00%	-61.08%	-67.70%	1.48%	9.32%	151.04%

Table 3. Economic growth rate over the years (1978-2017)

Time	Y	TFP	EFFCH	TC	LE	KE
1978-1979	0.0833	-0.1668	0.0322	-0.1990	0.0149	0.2352
1979-1980	0.0882	-0.1474	0.0134	-0.1608	0.0201	0.2155
1980-1981	0.0592	-0.1240	0.0523	-0.1763	0.0121	0.1711
1981-1982	0.0972	-0.1095	0.0490	-0.1586	0.0103	0.1964
1982-1983	0.1092	-0.0974	0.0549	-0.1523	0.0210	0.1856
1983-1984	0.1527	-0.0532	0.0161	-0.0694	0.0067	0.1993
1984-1985	0.1353	-0.0825	-0.0141	-0.0684	0.0044	0.2134
1985-1986	0.0744	-0.1168	0.0272	-0.1440	0.0038	0.1874
1986-1987	0.1131	-0.0607	0.0116	-0.0724	0.0038	0.1701
1987-1988	0.1173	-0.0400	-0.0786	0.0386	0.0039	0.1534
1988-1989	0.0418	-0.0716	-0.0418	-0.0298	0.0032	0.1102
1989-1990	0.0551	-0.0639	-0.0986	0.0346	0.0150	0.1040
1990-1991	0.0947	-0.0258	-0.1482	0.1224	0.0105	0.1100
1991-1992	0.1561	0.0213	-0.1494	0.1707	0.0083	0.1265
1992-1993	0.1637	0.0224	-0.1564	0.1788	0.0064	0.1348
1993-1994	0.1432	-0.0169	-0.1412	0.1242	0.0091	0.1509
1994-1995	0.1288	-0.0469	-0.1062	0.0592	0.0146	0.1611
1995-1996	0.1174	-0.0506	-0.0552	0.0047	0.0060	0.1619
1996-1997	0.1106	-0.0455	-0.0892	0.0438	0.0024	0.1538
1997-1998	0.0981	-0.0535	-0.0784	0.0249	-0.0046	0.1562
1998-1999	0.0915	-0.0544	-0.0831	0.0288	-0.0010	0.1469
1999-2000	0.0989	-0.0524	-0.0922	0.0398	0.0071	0.1442
2000-2001	0.0971	-0.0447	-0.0973	0.0525	0.0026	0.1392
2001-2002	0.1094	-0.0486	-0.1092	0.0606	0.0136	0.1443
2002-2003	0.1237	-0.0452	-0.1094	0.0643	0.0118	0.1571
2003-2004	0.1375	-0.0571	-0.1150	0.0580	0.0304	0.1641
2004-2005	0.1316	-0.0592	-0.1009	0.0417	0.0142	0.1766
2005-2006	0.1351	-0.0577	-0.1258	0.0681	0.0153	0.1776
2006-2007	0.1464	-0.0490	-0.1465	0.0975	0.0171	0.1782
2007-2008	0.1190	-0.0624	-0.0975	0.0351	0.0137	0.1678
2008-2009	0.1159	-0.0816	-0.0778	-0.0037	0.0156	0.1819
2009-2010	0.1302	-0.0732	-0.1225	0.0493	0.0147	0.1887
2010-2011	0.1164	-0.0852	-0.1127	0.0275	0.0155	0.1861
2011-2012	0.1015	-0.0895	-0.1056	0.0161	0.0114	0.1797
2012-2013	0.0936	-0.0904	-0.1099	0.0193	0.0131	0.1710
2013-2014	0.0817	-0.0812	-0.0310	-0.0501	0.0131	0.1498
2014-2015	0.0772	-0.0596	-0.0862	0.0266	0.0038	0.1330
2015-2016	0.0721	-0.0627	-0.0734	0.0107	0.0079	0.1269
2016-2017	0.0714	-0.0385	-0.0546	0.0162	-0.0016	0.1115

Table 3 shows the historical growth rates of China's economic growth and its components from 1978 to 2017. It can be seen from the third column that from 1978 to 2017, most years of China’s TFP growth rate were negative. In earlier years, technical efficiency was positive, while

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technological progress was negative. In most subsequent years, Technical efficiency is negative, while technological progress is positive. In all years, capital maintained a large growth rate.

Figure 2 shows the trend of China's economic growth and its components over the years from 1978 to 2017. It can be seen intuitively from the figure that the growth rate of TFP, technical efficiency, and labor input is kept at a low level, and the growth rate of technological progress and material capital is relatively high. Under the combined effect, the overall growth rate of economic growth is maintained at 10 % Fluctuates up and down.

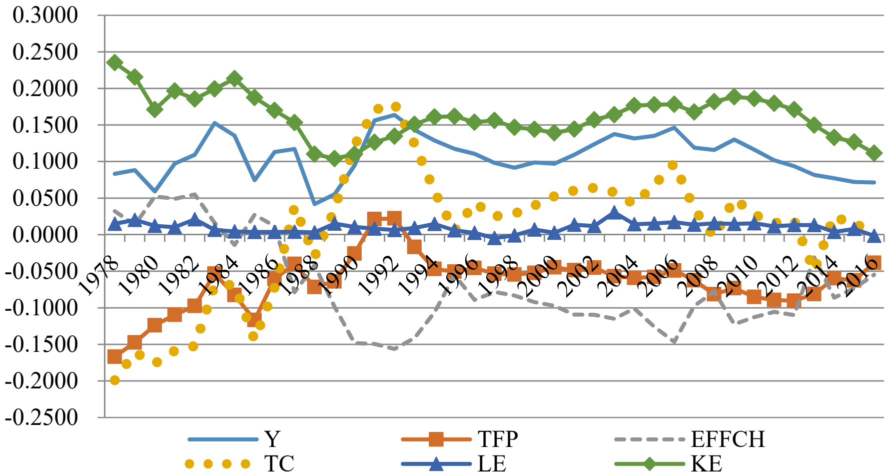

Figure 2. The change trend of economic growth and its components over the years

3.3. Quantum Economic Growth

Regarding the economy as a particle, and comparing economic growth factors with the physical properties of particles, the following assumptions are made: The material quality m is equivalent to the resource endowment and factor input of the economy itself. The more input, the greater the quality; The speed of material movement v is equal to the economic growth rate, which is used to measure the speed of economic growth; The acceleration of economic growth a is the rate of change of the economic growth rate. According to Newton's third law F=ma, Redefine the pulling force on a material as the growth force experienced by an economy. Therefore, the growth force experienced by an economy is determined by the rate of change of resource endowment and economic growth rate of the economy, that is, the product of the sum of resource endowment and factor input and the rate of change of economic growth. Economic growth shows different directions. Similar to material movement, economic variables are a vector. According to the momentum formula p=mv, p is the momentum of the economy, which represents the trend of the economy to achieve economic growth in a specific direction, that is, the product of the sum of resource endowments and factor inputs and the economic growth rate. According to the kinetic energy formula $\mathrm{E_k} = \frac{1}{2}\mathrm{mv}^2$, The growth kinetic energy of the economy is E_k. There is also a transformation between potential energy and kinetic energy in the process of economic growth. TFP can be regarded as growth potential. Economic growth can do work and has power. The function of the economy is used to measure the spatial accumulation effect of economic growth. According to W=sF, s is the ranking distance of each economy. Under the influence of F growth power, s is the ranking of progress, and its value is a natural number. Power $\mathrm{P} = \frac{\mathrm{W}}{\mathrm{t}}$ is the speed of work.

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Table 4. Comparison table of basic economic variables and basic physical variables

Economy	Expression	Physics	Expression
Input	m	Quality	m
Economic growth rate	v	Speed	v
Economic acceleration	a	Acceleration	a
Growth force	F=ma	Pulling force	F=ma
Growth trend	P=mv	Momentum	P=mv
Growth energy	$E_k = \frac{1}{2}mv^2$	Kinetic energy	$E_k = \frac{1}{2}mv^2$
Growth work	W=sF	Work	W=sF
Growth power	$P = \frac{W}{t}$	Power	$P = \frac{W}{t}$

According to the above basic formula, the problem of economic growth can be further expanded. According to the formula of universal gravitation, the interaction force between different economies is defined as $G=\frac{m_1 m_2}{\triangle GDP^2}$, $m_1$and m_2 are the resource endowments and factor inputs of two different economies. △ GDP is the difference between the two GDPs, indicating the gap between the two economic levels. G is used to measure the economic promotion force between two economies. The greater the product of resource endowments and factor inputs, the greater the gap between economic levels and the greater the impact on each other. At the same time, G can also be used to measure economic growth between different years. $m_1$and m_2 are resource endowments and factor inputs in different years. △ GDP is the difference in GDP between two years. There is also a gravity model that uses the formula of universal gravitation for economic analysis. It is used to measure the spatial connection of finance and economic trade between cities. The numerator is the population of the city, and the denominator is the geographic distance between cities.

Table 5. Comparison table of economic variables and quantum mechanical variables

Economy	Expression	Physics	Expression
Economic promotion force	$G=\frac{m_1 m_2}{\triangle GDP^2}$	Gravity	$G=\frac{m_1 m_2}{r^2}$
Economic growth wave	$\lambda = \frac{h}{p}$	De Broglie wave	$\lambda = \frac{h}{p}$
Economic energy	$E=mv^2$	Energy	$E=mc^2$

The above is the particle nature of the economy. Since the economy is regarded as a particle, the economy not only has a particle property, but also has a wave-particle duality. Therefore, de Broglie wave can be extended to the economic field. $\lambda=\frac{h}{p}=\frac{h}{mv}$, λ is the wavelength, h is the Planck constant, and p is the momentum. This formula is used to reflect the relationship between the economic cycle of an economy and the momentum of economic growth. At the same time, according to the mass-energy equation $E=mc^2$,The energy of the economy can be expressed as $E=mv^2$, Therefore, $E=\frac{hc}{\lambda}=vp$.

According to the above formula and economic growth accounting data, the corresponding physical variables of the economy can be calculated. Take 2017 as an example. In 2017, China's labor input was 829,875 million people, and the capital input was 62,753.160 billion yuan.

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According to Table 4, the economic growth rate from 2016 to 2017 was 7.14%. According to $E_k = \frac{1}{2}mv^2$, The economic growth kinetic energy in 2017 is the sum of the growth kinetic energy of labor input and the growth kinetic energy of material capital input, which is $\frac{1}{2}Lv^2 + \frac{1}{2}Kv^2$. Substituting the data, the economic growth kinetic energy in 2017 is 1599.59 J.

According to $G=\frac{m_1 m_2}{\triangle GDP^2}$, It is also possible to calculate the economic promotion forces between different cities. Taking Guangdong Province and Jiangxi Province as an example. In 2017, the labor force and capital investment of Guangdong Province in 2017 were 63,407,900 and 283.2077 billion yuan respectively. And the labor force and capital investment of Jiangxi Province in 2017 were 26.456 million people and 19.08235 billion yuan respectively. Therefore, the economic promotion force between Guangdong Province and Jiangxi Province in 2017 is:

$$G=\frac{L_1 L_2}{\triangle GDP^2}+\frac{K_1 K_2}{\triangle GDP^2}=\frac{0.634079\times 0.26456}{(19464.76-3944.735)^2}+\frac{28320.77\times 19082.35}{(19464.76-3944.735)^2}=2.24N.$$

4. CONCLUSION

This article analyzes the economic growth by decomposing and calculating, combined with physical theory. The main conclusions are as follows: Firstly, China's overall economic growth rate from 1978 to 2017 was 10.71%, TFP growth rate and technical efficiency were negative for a long time, and economic growth mainly relied on factor input, especially material capital input. Secondly, the economic growth kinetic energy in 2017 was 1599.59J. Thirdly, the economic promotion force between Guangdong Province and Jiangxi Province in 2017 was 2.24N.

The continuity and transition of economic growth embodies the beauty of quantum theory. Innovation and uncertainty play a huge role in the process of economic growth. Uncertainty is also one of the mysterious and unpredictable basic laws of the quantum world. In the research of physics and astronomy, string theory has gradually come into people's field of vision, and there may be string theory in economic research. The reason why we build bridges between completely different disciplines is because we can find interest and more possibilities in the process of thinking transfer to things of different nature.

Human's understanding of things develops with the continuous progress of society. In natural sciences, people's understanding has undergone a shift from geocentric theory to heliocentric theory, from quantum mechanics to superstring theory. In the social sciences, people have shifted from the study of production, division of labor and efficiency to the exploration of economic growth. In the development of theory, interdisciplinary and interdisciplinary research has attracted more and more attention from scholars. The blending and collision of different disciplines brings interest and inspiration to scientific research. Natural science and social science are not completely separated. Sometimes we fall into the fog of thinking and it is difficult to distinguish the boundaries between physics, philosophy and social science. It is this fascinating way of thinking that allows us to confront the rules of theoretical research. It's like a Frankenstein who accidentally went to the wrong laboratory. He is accustomed to face completely different things. The end result is surprises, disasters, or nothing happened, but it is difficult for us to evaluate this.

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