Research on the Influence of Green Patents on Regional Green Economy Development Level -- Based on An Entropy-Tobit Model

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Abstract. The primary goal of today's high-quality economic development is to achieve the growth of green economic, and green patents play an important role in this. Based on panel data of 30 Chinese provinces from 2010 to 2019, this study constructed a framework of green economy development level indicators and used an entropy-Tobit model to empirically examine the impact of green patents on the green economy. The results show that (1) the level of green economy development in each province of China shows a time-series characteristic of rising, then retracting and finally stabilizing during the sample examination period. The cross-sectional gaps between regions are significant, with the eastern region having the highest level of development. (2) The green technology innovation represented by green patents has a significant contribution to the green economy. In addition, the technology market level, the R&D human input and the high-tech enterprises development level all have a positive impact on the development of green economy.

Keywords: Green patent, green economy, Entropy method, Tobit regression.

1. Introduction

Since the reform and opening up, China's economy has been growing rapidly, but its extensive growth model has led to the over-exploitation of resources and environmental pollution [1]. In order to change this situation, the Chinese government has put forward the "carbon peak and carbon neutral" target in 2020 and the "accelerated green transformation of development" plan in the 20th National Congress, aiming to promote green economic development.

The concept of the green economy was first introduced by Pearce as a sustainable economic development model that human society and natural resources can sustain [2]. The United Nations Environment Programme believes that the growth of a green economy can significantly reduce environmental risks and ecological scarcity while improving human well-being and social equity. Since the outbreak of various problems [3] such as the financial crisis, global warming, and pandemic influenza at the beginning of the 21st century, the pursuit of a green economy with synergistic economic, social and ecological development has become a consensus among scholars in various countries [4]. And many counties have introduced policies to promote the green economy.

Green technology refers to technology that helps to save resources, prevent and control pollution, reduce carbon emission levels and achieve sustainable development [5]. In the current situation, green technology innovation has become a driving force to promote green economic growth [6]. The number of green patents has been used by many scholars as an important indicator of green technological innovation due to the natural advantage of patents in measuring technological innovation [7].

The following studies have been related to green economic growth: Wang et al.[8] found that the degree of marketisation can effectively improve energy efficiency and reduce environmental pollution in economic development through the innovation development effect; Li et al.[9] found that the factors of industrial agglomeration, scientific and technological progress contribute significantly to the regional green economies; Kang et al. [10] suggested that both education and research and development (R&D) have a positive impact on the green economy.

The quantity of studies on the impact of green patents on the green economy is relatively small, while scholars have different views on the impact of patents [11], and it is impossible to judge whether the impact is positive on the green economy. Therefore, this study firstly constructed an evaluation system for the development level of green economy and used the entropy method to measure the development level of green economy in 30 provinces in China, finally constructed a panel Tobit model to empirically explore the effect of green patents and other factors on green economy. The results of the study can provide reference for the further development of green economy research.

2. Entropy-Tobit model

The research method is an entropy-Tobit model consists of entropy method and Tobit progression.

2.1. Entropy method

The entropy method is an objective assignment method that calculates information entropies based on the degree of change in the observed value of each indicator. The entropy method is more operable and can maximize the characteristics of the panel data of index values. Drawing on the method of Tian [12] to calculate the green economic development index, the specific steps are as follows:

Standardize the values of indicators:

$$\overset{*}{X}_{aij} = \begin{cases} \dfrac{X_{aij} - \min(X_{ai1}, X_{ai2}, \cdots X_{aim})}{\max(X_{ai1}, X_{ai2}, \cdots X_{aim}) - \min(X_{ai1}, X_{ai2}, \cdots X_{aim})} & if\ X_{aij}\ is\ positive \\ \dfrac{\max(X_{ai1}, X_{ai2}, \cdots X_{aim}) - X_{ij}}{\max(X_{ai1}, X_{ai2}, \cdots X_{aim}) - \min(X_{ai1}, X_{ai2}, \cdots X_{aim})} & if\ X_{aij}\ is\ negative \end{cases} \quad (1)$$

$$\overset{*}{X}_{aij} = \overset{*}{X}_{aij} + 0.001 \qquad if\ \overset{*}{X}_{aij} = 0$$

Calculate indicator information entropies and the weights of indicators:

$$P_{aij} = \frac{\overset{*}{X}_{aij}}{\sum_{a=1}^{k}\sum_{i=1}^{m}\overset{*}{X}_{aij}} \qquad Ej = \sum_{a=1}^{k}\sum_{i=1}^{m} P_{aij} \cdot \ln P_{aij} \cdot \left(-\frac{1}{\ln(km)}\right)$$

$$g_j = 1 - Ej \qquad W_j = \frac{g_j}{\sum_{j=1}^{n} g_j} \quad (2)$$

Calculate green economic development indexes:

$$GEDI_{ai} = \sum_{j=1}^{n} \overset{*}{X}_{aij} \cdot W_j$$

$$a = 2010,\ 2011, \cdots, 2019;\ i = 1, 2, \cdots, 30;\ j = 1, 2, \cdots, 12 \quad (3)$$

Where $GEDI$ is the Green Economy Development Index (GEDI), $\overset{*}{X}_{aij}$ is the standardized value of the indicator, W_j is the weight of the indicator, a is the year, i is the provincial administrative unit and j is the indicator. The higher the index, the higher the level of green economy development, and vice versa, the lower the level of green economy development.

2.2. Tobit regression

The panel data passed the stationarity test since the HT test is qualitied (p = 0.000). The entropy-method-based GEDIs for the 30 Chinese provinces range from 0 to 1. And they show a cut-off feature that is eligible for a Tobit regression model with a restricted dependent variable. Using the GEDIs for each province as the values of the explanatory variable (Y_{ia}), the model was set up as follows:

$$Y_{ia}{}' = \alpha_0 + \beta_k Z_{ia} + \varepsilon_{ia} \begin{cases} if\ Y_{ia}{}' > 0,\ Y_{ia} = Y_{ia}{}' \\ if\ Y_{ia}{}' \leqslant 0,\ Y_{ia} = 0 \end{cases} \tag{4}$$

$$i = 1, 2, \cdots, 30;\ t = 2010, 2011, \cdots, 2019;\ k = 1, 2, \cdots, 5$$

Where i is the provincial administrative unit, a is the year, Z is the core explanatory and control variables, α_0, β_k are the parameters to be estimated, and ε_{it} is the random disturbance term. To reduce errors in the analysis results and to increase the smoothness of the data [13], each variable in Z is logarithmically treated. The equation can also be expressed as:

$$Y_{ia} = \alpha_0 + \beta_1 Lnngpa_{it} + \beta_2 Lntml_{it} + \beta_3 Lnsrdi_{it} + \beta_4 Lnrdhs_{it} + \beta_5 Lnhedl_{it} + \varepsilon_{it} \tag{5}$$

3. Explanation of variables

The variables used in this study consist of two parts: the level of green economy and its explanatory variables. And the level of green economy is measured by 12 indicators.

3.1. The framework of green economy development level indicators

Existing studies on measuring the level of green economy have not yet formed systematic conclusions. Zhang et al [14] established a high-quality green development evaluation index system based on the DPSIR model, Lin et al [15] constructed a green development index from the definition of the connotation of green development, and Zhang Wei [16] summarized the high-frequency indicators about green economy that appeared in relevant literature at home and abroad. In addition, some authoritative institutions such as the China Development and Reform Commission have also constructed green economy-related indicators [17]. Existing studies have different definitions and understandings of green economy, but green economic development should essentially reflect the harmonious relationship between ecological development, economic development, and social development. Based on this concept, this study evaluated the level of green economic from three aspects: socio-economic development, resource and environmental sustainability and green transformation drive, and selects 12 evaluation indicators to establish a green economic development evaluation system. The process followed the principles of science, systematization, feasibility, and representativeness. The system is shown in Table 1.

Table 1. Green economy development level evaluation system

Target layer	Criteria Layer	Indicator Layer	unit
The Level of Green Economic Development	The Level of Social and Economic Development Z1	Per capita disposal income X1	yuan per capita
		Per capita education expenditure X2	yuan per capita
		Per capita growth rate of GDP X3	%
		Proportion of tertiary industry in GDP of all industries X4	%
	The Level of Sustainable Resources and Environment Z2	Forest coverage rate X5	%
		Per capita water resources quantity X6	cubic meter per capita
		Utilization of industrial solid waste X7	ton
		Household garbage disposal rate X8	%
	The Level of Green Transformation Drive Z3	Per capita carbon dioxide emissions X9	ton per capita
		Proportion of total investment in industrial pollution control to GDP X10	%
		Proportion of total Investment in urban environmental infrastructure to GDP X11	%
		Expenditure on new product development of industrial enterprises X12	ten thousand yuan

3.2. Explanatory variable

3.2.1. Core explanatory variable

Number of green patents: green patents include utility model patents and invention patents. The IPC range provided by WIPO is used to classify green patents and non-green patents, and the number of patent applications (NGPA) is chosen as a measurement indicator. This is because the number of applications reflects the level of expectation and awareness of protection of patent assets owned by innovation agents, and can dynamically reflect the active level of innovation [13].

3.2.2. Control variables

Technology market level (TML): The technology market is an important production factor market as an important component of the modern market system and innovation system. Its development status can show the degree of technology marketisation and reform of the technology system in a region, so it is chosen as an important control variable. It is expressed in terms of the total amount of contracted projects in the technology market in the region (million yuan).

The scale of R&D industry (SRDI): The scale of R&D activities is usually adopted internationally to reflect the technological strength and innovation competitiveness of a region, so it is used as one of the control variables. The variable is expressed in terms of the number of enterprises conducting R&D activities (in units) that can effectively reflect the scale of activities in the region.

R&D human resource (RDHR): Talent is the first productive force and the source of promoting scientific and technological innovation. Therefore, the average annual number of personnel engaged in R&D industry (per capita) is used to reflect the human resource in R&D activities.

High-tech enterprises development level (HEDL): High-tech enterprises are those that produce high-tech products using contemporary cutting-edge technology, with high investment in innovation. Enterprises are the bearers of the birth and landing of innovative technologies in a region. Therefore, it is used as a control variable in this study and is expressed as the sum of the main revenue of high-tech enterprises (billion yuan).

3.3. Data sources

The panel data on green economic development of 30 Chinese provinces (excluding Hong Kong, Macao, Taiwan and Tibet) from 2010-2019 were used as the sample. The raw data for the indicators measuring the level of green economic development were obtained from the *China Social Statistics Yearbook 2010-2020*, the RESSET database and the CSMAR database, and the data of the explanatory variables were from CnOpenData. All missing data were processed by interpolation.

4. Analysis and results

4.1. Descriptive analysis: overall and regional analysis

The overall and regional averages of the Green Economy Development Index (GEDI) for each of the 30 provinces in China were measured by **Stata** and shown in Fig.1.

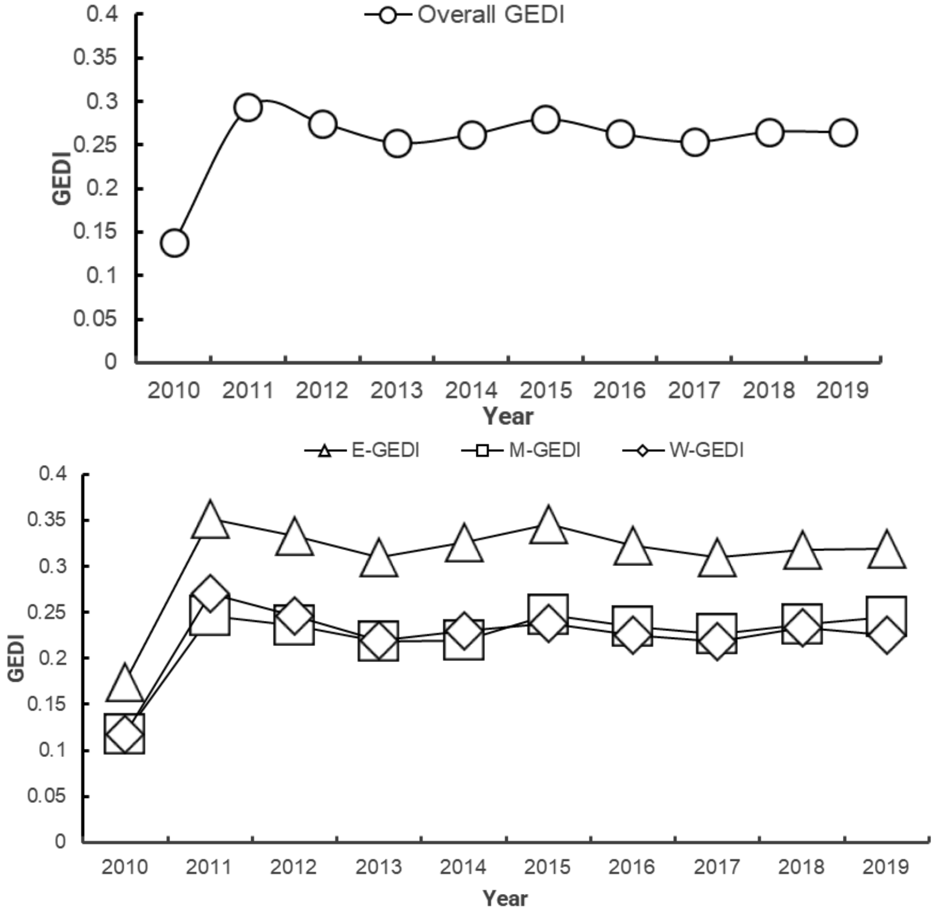

Figure 1. The overall and regional averages of the GEDIs

As shown in Fig.1, the overall green economy of the 30 Chinese provinces from 2010 to 2019 reveals a time series of rising, then shrinking and finally stabilizing. The lowest value of the GEDIs occurred in 2010 at 0.138 and the highest value occurred in 2011 at 0.293. From 2010 to 2011, the level of green economy increased by 112.83%. The reason for this significant growth rate may be [18] that China has just survived the "most difficult" year of economic and social development under the aftershocks of the financial crisis, 2009, and quickly achieved a V-shaped reversal, with GDP growth rising rapidly from 6.4% to 12.2%; Meanwhile, China government conducted its first national survey of pollution sources in 2010, and exceeded its energy conservation target for ecological protection. From 2011 to 2019, the green economy contracted and then levelled off, fluctuating at around 0.268 with a small standard deviation of 0.013. This may be closely related to the fact that China's economy entered a long downward cycle after 2011[18]. Meanwhile, the excessive pollution emissions accumulated led to sharp environmental degradation.

At the regional level, the eastern region has a significantly higher level of green economy development, while there is not a large gap between the central and western regions. From 2010-2011, the GEDI for the eastern region increased from 0.174 to 0.352, with a faster growth rate than the central and western regions, probably since the eastern region has a larger economic scale and stronger government administration which can bring access to more rapid economic and policy feedback. Based on the broader context of changes in green economic across the country, the regional indices for 2011-2019 also underwent a simultaneous process of contraction and levelling off. In the meanwhile, the GEDI in the eastern region tends to 0.326, while the index in the central and western regions tends to 0.234. The difference between them is 0.092, an increase of 61.40% from 0.057 in 2010, indicating that the imbalance in green economic level between regions is further widening.

4.2. Analysis of regression results

The regression results of Tobit are shown in Table II. Where model (1) is the regression result with only the core explanatory variable and model (2) is the regression result with the control variables.

Table 2. Tobit regression results

GEDI	Tobit	
	(1)	(2)
(ln)NGPA	0.0259*** (0.0039)	0.0132** (0.0064)
(ln)TML		0.0105**(0.0045)
(ln)SRDI		-0.1298***(0.0182)
(ln)RDHS		0.0725***(0.0206)
(ln)HEDL		0.0347***(0.0133)
constant	0.0520(0.0322)	-0.3240**(0.1552)
sigma_u	0.05312***(0.0074)	0.0691***(0.0103)
sigma_e	0.04831***(0.0021)	0.0426***(0.0019)
LR	159.85***	207.95***

From Model (1) (2), the coefficient of influence of the number of green patent applications on the development of local green economy is positive and significant at the 1% and 5% levels respectively. It can be shown that the increase in the number of green patents significantly contributes to the improvement of the level of regional green economy. On the one hand, an increase in the number of applications represents an increase in investment in green technology research and development and a favorable government policy on patent funding, both of which can create new economic demand and thus promote the local economy. On the other hand, when green patents are applied for, the green technologies covered by them are often already being used in local industries to contribute to areas such as environmental management and energy conservation, and generate economic effects.

Model (2) shows that technology market level has a significantly positive relationship with the local green economy at the 5% level. A higher level of technology market indicates a better local science and technology system, and it can promote the capitalization and industrialization of scientific and technological achievements. Therefore, they can not only provide strong support for technological innovation but has a positive impact on the local economy and industrial structure.

The influence coefficient of the scale of R&D activities on the local green economy is negative at 1% level. It shows that excessive R&D activities will hinder the development of green economy. The increase in R&D activities is naturally beneficial to technological innovation, but at the same time, the resources like materials and venues needed to hold the activities, as well as the experimental pollution like carbon dioxide and noise generated during the activities, will also have a negative impact on the environment and the surrounding residents.

R&D human resource is significantly and positively correlated with the local green economy at the 1% level. The increase in human resource provides more incentive for technological innovation, which not only helps local enterprises to absorb new knowledge, but also enhances the efficiency of technological output.

High-tech enterprises development level is also positively correlated with the local green economy at the 1% level. High-tech enterprises are the creators of technological achievements and social wealth, as well as the drivers of economic and social development. The development of high-tech enterprises and the growth of the green economy are interdependent and mutually reinforcing.

4.3. Robustness Test

To further test the robustness of the estimation results, this study draws on existing research by changing the core explanatory variables and re-running Tobit regressions [12]. Since patents granted through substantive examination are usually of higher quality and have a more direct impact on economic growth, the number of green patent applications is replaced by the number of green patents granted (NGPG). The results of Model (3) show that all variables except technology market level passed the significance test and remained stable, with the core explanatory variables showing a more significant positive relationship in the baseline regression. Thus, the above regression results are robust.

Table 3. Tobit regression results of the number of green patents granted

GEDI	(ln)NGPG	(ln)TML	(ln)SRDI	(ln)RDHS	(ln)HEDL	constant	sigma_u	sigma_e	LR
Tobit (3)	0.0204***	0.007	-0.133***	0.0790***	0.0280**	-0.3322**	0.0693***	0.0423***	210.17***
Std. Err.	(0.0077)	(0.0049)	(0.0182)	(0.0208)	(0.0138)	(0.1549)	(0.0103)	(0.0018)	-

5. Conclusions and recommendations

Conclusions: (1) Overall, the development of China's green economy showed a change of rising, then retreating, finally stabilizing and falling into a "stagnation" trap. From a regional perspective, there are differences in the green economy in different regions: the eastern region is always developing faster, with the largest increase in the first period, while the central and western regions are developing at a similar pace and with a smaller increase. In the later period, the volatility of the green economy in the three major regions became less and tended to stabilize, while the development imbalance between the eastern and central and western regions increased. (2) From the empirical results, the number of green patents significantly contributes to the improvement of the green economy. Among the control variables, the scale of R&D activities has a significant inhibiting effect on the green economy, while technology market level, the R&D human resource and high-tech enterprises development level all have a significant promoting effect on the green economy.

Recommendations: Considering the above conclusions, the following recommendations are made to further improve China's green economy: (1) The central government should vigorously promote green technology innovation and development to help the green economy escape the "stagnation" trap. It should increase policy support and resources for the central and western regions in terms of economic construction and ecological management, so as to narrow the gap between them and the eastern regions in terms of green economy development. (2) Local governments at the provincial level should co-ordinate resources, expand the fiscal expenditure, and construct science and technology plans with local characteristics to promote the continuous increase of patent output. The governments should also formulate financial reform programs (special projects, funds, etc.) for local science and technology to promote quality of patent output. (3) Improve the management system of the technology market so that the technology market can develop smoothly and well. Adjust and optimize the scale of R&D activities so that they are more eco-friendly and more market-oriented. In addition, emphasize on the training of technological personnel and support for their innovative activities, while enterprises should increase investment in R&D human resource. Local governments can also develop incentive policies such as tax incentives, R&D cost reductions and patent incentives to encourage the development of high-tech enterprises. Also, the industry-university-research cooperation among enterprises, universities and research institutes should be strengthened to create a system chain with outstanding core technology capability, strong integrated innovation capability.

References

[1] Wu, Yufeng, et al. "Review of Soil Heavy Metal Pollution in China: Spatial Distribution, Primary Sources, and Remediation Alternatives." *Resources, Conservation and Recycling*, vol. 181, 2022, p. 106261., https://doi.org/10.1016/j.resconrec.2022.106261.

[2] Zheng, Defeng, et al. "Review of green economy, green development and green transformation." *Ecological Economy*, vol. 02, 2015, p. 64 - 68.

[3] Avissa, Shila. "Neo-Liberalism and Post-Crisis Recovery: A Review of Literature on 2008 Crisis and Covid-19 Pandemic Recovery." *Intersectionalities: A Global Journal of Social Work Analysis, Research, Polity, and Practice*, https://journals.library.mun.ca/ojs/index.php/IJ/article/view/2283.

[4] Zhao, Xin, et al. "Green Economic Growth and Its Inherent Driving Factors in Chinese Cities: Based on the Metafrontier-Global-SBM Super-Efficiency DEA Model." *Gondwana Research*, vol. 106, 2022, pp. 315 – 328., https://doi.org/10.1016/j.gr.2022.01.013.

[5] Doğan, Buhari, et al. "The Mitigating Effects of Economic Complexity and Renewable Energy on Carbon Emissions in Developed Countries." *Sustainable Development*, vol. 29, no. 1, 2020, pp. 1 – 12., https://doi.org/10.1002/sd.2125.

[6] Mohd Suki, Norazah, et al. "How Does Green Technology Innovation Affect Green Growth in ASEAN-6 Countries? Evidence from Advance Panel Estimations." *Gondwana Research*, vol. 111, 2022, pp. 165 – 173., https://doi.org/10.1016/j.gr.2022.06.019.

[7] Zhou, Yi and Chen. "Impact of Foreign Direct Investment on Green Patent Output: Empirical Analysis Based on Provincial Panel Data in China." *Science and Management*, vol. 42, no. 1, 2020, pp. 34 - 42.

[8] Wang, Shuai, et al. "Green Total Factor Productivity Growth: Policy-Guided or Market-Driven?" *International Journal of Environmental Research and Public Health*, vol. 19, no. 17, 2022, p. 10471., https://doi.org/10.3390/ijerph191710471.

[9] Li, Zhiyu, et al. "Research on Influencing Factors of Regional Economic Green Growth under Carbon Emissions Constraint." *IOP Conference Series: Earth and Environmental Science*, vol. 615, no. 1, 2020, p. 012019., https://doi.org/10.1088/1755 - 1315/615/1/012019.

[10] Kang, Dongliang, et al. "How to Promote the Development of a Green Economy: Talent or Technology? —Evidence from China's High-Speed Rail." *Frontiers in Psychology*, vol. 13, 2022, https://doi.org/10.3389/fpsyg.2022.953506.

[11] Weng and Zhang. "Patent, Technological Innovation and Economic Growth: A Review." *East China Economic Management*, vol. 33, no. 8, 2019, pp. 152-160., https://doi.org/10.19629/j.cnki.34-1014/f.180919007.

[12] Tian, Tong and Li. "Fiscal Expenditure, Government Competition and Medical and Healthcare Service Level: An Empirical Analysis Based on Provincial Panel Entropy Tobit Model." *Journal of Yunnan University of Finance and Economics*, vol. 38, no. 8, 2022, pp. 19-36., https://doi.org/10.16537/j.cnki.jynufe.000807.

[13] Mao, Yi, et al. "Can Chinese Innovation Get Rid of the 'Utility Model Patent System Use Trap'?" *China Industrial Economics*, vol. 03, 2018, pp.98-115., https://doi.org/10.19581/j.cnki.ciejournal.2018.03.006.

[14] Zhang, Wei and Yuan. "Evaluation and evolution of high-quality green development in China's provinces." *Economic Geography*, vol. 40, no. 2, 2020, pp. 108-116., https://doi.org/10.15957/j.cnki.jjdl.2020.02.012.

[15] Lin, Su and Zhang. "Research on Measurement of Green Development Level." *Study & Exploration*, vol. 11, 2019, pp. 106 - 113+2.

[16] Zhang Wei. "Construction and demonstration of green Economy evaluation index system in China." *Statistics & Decision*, vol. 37, no. 16, 2021, pp. 126-129., https://doi.org/10.13546/j.cnki.tjyjc.2021.16.028.

[17] Green development indicator system. 22 Dec. 2016, http://www.gov.cn/xinwen/2016-12/22/5151575/files/72d0685c67a74e2b844629917707e652.pdf.

[18] Yan, Xiang, and Zhan, Di. Follow The Path of Value: 1990~2020 The Review of The Chinese Stock Market. *Economic Science Press*, 2021.