Research on Influencing Factors of National Innovation Efficiency from The Perspective of Digital Trade Barriers

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Abstract—The rapid development of digital trade is reshaping the current trade pattern, but at the same time, various forms of trade protection measures are constantly strengthening the restrictions on digital trade. Therefore, this paper uses the three-stage DEA model to measure the innovation efficiency of 25 countries and uses TOBIT regression to analyze its influencing factors. The following conclusions are drawn: pure technical efficiency has a great impact on comprehensive technical efficiency; The impact of three environmental variables, namely intellectual property protection, government effectiveness and industry-university-research cooperation, on national innovation efficiency is different, and the national innovation efficiency is divided into three types: stable, developmental and improved. Digital trade barriers are further subdivided into two types, in which tariff barriers are significantly negatively correlated with innovation efficiency, and non-tariff barriers are significantly positively correlated with innovation efficiency, which has a negative effect on innovation.

Keywords-Digital barriers to trade; National innovation efficiency; Three-stage DEA-TOBIT model

1. Introduction

Against the backdrop of the spread of COVID-19, traditional trade, which relies on cross-border movement of people, has been restricted, while digital trade has bucked the trend and shown strong vitality and resilience. Data from China's Digital Trade Development Report showed that China's digital trade volume in 2020 was $294.76 billion, up nearly 48 percent compared with 2015, accounting for 44.5 percent of service trade. Digital trade has rewritten the traditional way of Commodity Exchange, reducing the cost and time of trade; The emergence of new traded products has expanded the scale and scope of international trade and expanded the boundaries of traded products. However, studies have found that digital trade barriers have been strengthened in the past five years [1], which may be caused by the following two reasons: first, in order to maintain their comparative advantages in international trade, countries set up relevant regulations to promote high-tech investment and production within their own borders, so as to enhance market competitiveness; Second, a large part of the data in the development of digital economy and trade is related to basic national information, which may pose a threat to national security if it is not restricted. In the era of digital transformation of the global economy, excessive digital protection will miss the new opportunities provided by digital trade. Therefore, it is of great practical significance to reduce all kinds of protection policies in international trade and

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extensively carry out scientific and technological cooperation to improve national innovation capacity.

2. Figures and tables

Innovation efficiency is the input-output ratio of innovation resources, which reflects the level of comprehensive innovation ability. Global innovation index, according to a report in recent years our country innovation efficiency of the former member of the global rankings, to some extent, can explain with limited investment in our country, obtained good economic output results, independent research and development and absorb foreign scientific and technological achievements to effectively combine [2], but policymakers should not separate the pursuit of innovation efficiency indicators of high and low, Instead, it should be synchronized with the innovation capability indicators. The influencing factors of national innovation capability are the focus of the academic community. Nieves Arranz et al., using the social network analysis method, added two dimensions of international cooperation and non-profit organizations to the traditional university-industry-government triple helix model to study its impact on national innovation [3]. Jie Wu et al. divided 80 countries into three categories: leading innovation countries, emerging innovation countries and backward innovation countries, and analyzed the relationship between high-tech international trade and foreign technology investment and innovation in different categories of countries [4]. Tao Qiuyan believes that ICT public infrastructure construction can improve national information level and sensitivity to information [5]. Zhang Yongan used the quantified scientific and technological innovation policy data to establish a three-dimensional spatial quantification system and found that there was a dynamic mutually promoting relationship between scientific and technological innovation policy and national innovation capability [6]. Zhang Yang found that creating a good environment for scientific research and innovation, strengthening the protection of intellectual property rights and carrying out multilateral scientific and technological cooperation are conducive to improving the national innovation level [7].

The characteristic of multi-input and multi-output of innovation activities determines that the evaluation model of innovation efficiency needs to highly integrate all aspects of innovation factors, and DEA model just meets this requirement. However, the traditional DEA model does not eliminate the influence of external factors on innovation. Therefore, this paper chooses the three-stage DEA model to measure the innovation efficiency value of 25 countries. The efficiency value calculated according to DEA model is distributed between 0-1, which has obvious restricted interval as the dependent variable. TOBIT model can better handle the data of restricted dependent variable, so this model is selected to analyze the influence degree of different factors on national innovation efficiency.

3. Study design

3.1 Introduction to the three-stage DEA model

The first stage: traditional DEA model. In this paper, the input-oriented BCC model is used to calculate the initial efficiency value of the innovation input and output data of 25 countries. The formula is as follows:

$$\text{Min}\theta - \varepsilon(e^T S^- + e^T S^+) \quad (1)$$

$$\text{s.t.}\begin{cases} \sum_{i=1}^{n} X_i\lambda_i + S^- = \theta X \\ \sum_{i=1}^{n} Y_i\lambda_i + S^+ = Y \\ \lambda_i \geq 0, \ S^-, \ S^+ \geq 0 \end{cases} \quad (2)$$

Among them， I = 1,2... P represents decision making unit (DUM), X and Y are input variables and output variables respectively, and S represents slack variables.

The second stage: eliminate external influencing factors by SFA regression. With the help of SFA regression, the slack variables can be decomposed into environmental factors, management inefficiency and statistical noise, and all decision making units are placed in the same external environment, according to which the input variables can be adjusted. The adjustment formula is as follows:

$$X_{it}^* = X_{it} + \{\max[f(Z_i;\beta_t)] - f(Z_i;\beta_t)\} + [\max(v_{it}) - v_{it}] \quad (3)$$

Where Xit* and Xit represent the modified input value and the original input value respectively; $\max[f(Z_i;\beta_t)] - f(Z_i;\beta_t)$is adjusted for environmental variables; $\max(v_{it}) - v_{it}$is adjusted for random disturbances.

The third stage: DEA model after adjustment. When the revised input and original output are brought into DEAP2.1 software again, the efficiency value has eliminated the influence of external factors, which is relatively real and effective.

3.2 Three-stage DEA model variables and data sources

Through combing innovation efficiency related literature known impact on innovation is the basic element of labor and capital, considering the colleges and universities, enterprises, government, research institutes and other innovative main body, under the interaction of this article from three aspects as innovation input and output, environmental building innovation efficiency measurement index, index interpretation and data sources are shown in table 1.

This paper measures and ranks the innovation capabilities of more than 120 countries in the world. In order to better analyze the gap between China and countries with high innovation capabilities, this paper takes the top 30 countries in the 2020 Innovation Index as samples, and only 25 countries are retained due to missing data of some countries. For TOBIT regression of national innovation influencing factors, data on digital trade barriers are derived from the Global Digital Trade Restrictions Index report.

3.3 Tobit model and its variables

The efficiency values calculated by the DEA model are distributed within the restricted interval of 0-1. If the general regression model is used, the results may be biased. Therefore, TOBIT regression is selected to analyze the influencing factors of innovation efficiency in 25 countries. The explained variable is the national innovation efficiency value (EFF) after removing environmental variables and random disturbances. Explanatory variable: The degree of industrial cluster development (ICD) is represented by the prevalence of complete industrial clusters. Digital Barriers to Trade (DTRI) is represented by the global digital trade restrictions index, which ranges from 0 to 1, with a larger index indicating a higher degree of restrictions. Information

Technology application (NBLP) is expressed as the share of information and communication technology investment in GDP. Economic freedom (IEF) is expressed as an index of economic freedom, with higher scores indicating less government intervention in the market. Industrial structure (ST) is expressed by the proportion of added value of the tertiary industry in GDP. Foreign investment (FDI) is expressed as the proportion of net foreign investment inflow to GDP. Gross domestic product (GDP) is expressed as the final income of a country's production and business activities in a specified period. The data comes from the World Economic Forum, World Bank and WTO databases. The model is constructed as follows:

$$EFFit=\beta 0+\beta 1\ ICD\ it+\ \beta 2DTRIit\ +\beta 3\ NBLPit\ +\beta 4\ IEF\ it+\beta 5\ STit\ +\beta 6\ FDI\ IT\ +\beta 7\ GDPit+\varepsilon it \quad (4)$$

Here, EFFit represents the innovation efficiency of country i in year t, β0 is a constant term, β is a coefficient, and ε is a random error.

4. Empirical results

4.1 Calculation results of three-stage DEA efficiency

4.1.1 Analysis of traditional DAE model results in the first stage

The 5-year average values of technical efficiency, pure technical efficiency and scale efficiency in 25 countries were 0.728, 0.815 and 0.894, respectively, indicating that the scale factor was dominant and the technology factor was second among the factors affecting the technical efficiency. Without considering the influence of external factors, China and Cyprus

are at the forefront of efficiency, and their three efficiency values are all up to 1, indicating that the resource allocation and technology management of these two countries are relatively effective. The technical efficiency of nearly half of the countries (13 countries) is lower than the average value, which is due to the low pure technical efficiency, leading to the low overall technological level. Therefore, the improvement of technology, management and other factors has an important impact on improving the overall innovation efficiency of the country.

Table 1 National innovation efficiency measurement index system

Dimensions	elements	indicators	data sources
The innovation	Money into	R&D spending as a share of GDP	The world bank
	Human input	Researchers/million people	
Innovation output	Scientific and technological achievements	International patent application	World Economic Forum
		Scientific Publications	Global Innovation Index

	Economic benefits	High-tech exports minus re-exports as a share of total trade	Global Innovation Index
The environment variable	Level of legal protection	Intellectual Property protection	World Economic Forum
	Level of government administration	The government effectiveness	
	Level of industrial cooperation	Intensity of industry-university-research cooperation	

Table 2 National innovation efficiency in the first and third stages

countries	Technical efficiency		pure technical efficiency		scale efficiency	
	Before the adjustment	After the adjustment	Before the adjustment	After the adjustment	Before the adjustment	After the adjustment
Austria	0.729	0.816	0.753	0.9	0.954	0.937
Belgium	0.594	0.661	0.656	0.743	0.9	0.886
Canada	0.648	0.638	0.670	0.709	0.969	0.889
China	1	0.951	1	0.956	1	0.994
The Danish	0.664	0.684	1	0.939	0.664	0.745
Finland	0.813	0.832	0.977	1	0.836	0.832
The French	0.603	0.637	0.629	0.691	0.959	0.934
Germany	0.768	0.773	0.779	0.784	0.984	0.978
The Greek	0.738	0.705	0.746	0.720	0.986	0.973
Italy	0.863	0.940	0.889	0.955	0.970	0.983
Japan	0.816	0.748	0.823	0.761	0.986	0.955
Luxembourg	0.710	0.696	0.804	0.771	0.831	0.818
New Zealand	0.907	0.846	0.962	0.966	0.938	0.866
Portugal	0.517	0.634	0.902	0.895	0.586	0.702
Russia	0.462	0.536	0.569	0.711	0.788	0.691
Spain	0.600	0.721	0.612	0.730	0.979	0.983
The Swedish	0.755	0.772	0.875	0.892	0.819	0.822
Britain	0.777	0.797	0.899	0.964	0.865	0.830
The United States	0.721	0.753	0.741	0.771	0.971	0.958

South Korea	0.522	0.633	0.532	0.666	0.977	0.908
The Norwegian	0.665	0.572	0.693	0.601	0.957	0.963
Czech Republic	0.691	0.642	0.896	0.839	0.765	0.791
Estonia	0.705	0.757	1	1	0.705	0.757
Malta	0.936	0.731	0.960	0.842	0.973	0.844
Cyprus	1	1	1	1	1	1
The mean	0.728	0.739	0.815	0.830	0.894	0.882

4.1.2 Stage 2: empirical results of SFA model

The SFA model takes slack variables of R&D personnel and R&D expenditure as explained variables, and intellectual property protection, government effectiveness and industry-university-research cooperation as explanatory variables. Frontier4.1 is used for regression measurement, and the results are shown in Table 3. As can be seen from Table 3, the LR likelihood ratio reaches the significance level of 1%, indicating that the efficiency value is affected by three environmental factors, and it is necessary to carry out SFA regression. The value of 2 is very large, and γ is close to 1, indicating that management inefficiency accounts for a large proportion of the influencing factors of input slack. Specific analysis is as follows:

Intellectual property protection is negatively correlated with the two input slack variables, and it is significant at 1% and 5% levels, respectively. This indicates that intellectual property protection can reduce the number of R&D personnel and the redundancy of R&D expenditure, and promote the full utilization of resources. Proper property rights protection can protect the innovation rights and interests of innovation subjects, stimulate their R&D motivation, and thus improve the overall innovation efficiency of the country. The government effectiveness is negatively correlated with the two input slack variables, and all of them are significant at the 1% level. That is, the government administrative level can not only promote the improvement of innovation efficiency, but also reduce the amount of innovation input. Industry-university-research cooperation is positively correlated with the two input slack variables, both of which are significant at the 1% level. Description of the cooperation between colleges and universities, institutions, will attract more R&D investment, but the government personnel shall be considered for investment projects, and only for the country will have conditions, the accumulation of basic research, and is suitable for increasing investment through financial channels, otherwise it may cause waste of R&D funds, joint training of personnel with similar skills, talents idle.

Table 3 Second stage SFA regression analysis

Variables	the slack variable of the number of R&D personnel	the slack variable of R&D expenditure
Intellectual Property protection	-183.724*** (-5.427)	-1.637** (-2.143)
The government effectiveness	-236.957*** (-6.387)	-2.528*** (-2.996)
Industry-university-research cooperation	391.783*** (10.220)	4.322*** (5.122)
Constant term	127.600*** (9.667)	-0.893 (-0.902)
σ^2	0.515E+07*** (0.515E+07)	136.277*** (137.182)
γ	0.999*** (0.138E+06)	0.999*** (0.517+04)
Log Likelihood	-209.408	-77.534
LR value	15.305***	15.539***

Note: ***, ** and * are significant at 1%, 5% and 10% levels respectively (same as the following table).

4.1.3 Stage 3: empirical results of DEA model after adjustment

As can be seen from Table 2, the technical efficiency of Cyprus remains at the optimal efficiency level, indicating that environmental variables have no impact on the innovation efficiency of this country. China's technical efficiency dropped from 1 to 0.951, which still leaves room for technological improvement, but its score close to efficiency and effectiveness means that China has innovations that are beneficial to the economy. The technical efficiency of 15 countries increased, and 13 of them were influenced by the improvement of pure technical efficiency, which again confirmed the important influence of national technology and management on innovation. The technical efficiency of the remaining countries has decreased to varying degrees, indicating that the relatively favorable environment of these countries has caused their high technical efficiency.

4.2 Tobit regression analysis

According to the TOBIT regression results of influencing factors of national innovation in Table 4, information technology application, foreign investment inflow and GDP are all negatively correlated with innovation efficiency. Foreign investment, there is no significant impact on innovation efficiency, the reason for this may be as follows, domestic enterprises have more favourable conditions to enter the market, foreign companies to enter the market, must have a cost and production efficiency and other advantages, so the foreign investment is the main channel to transfer advanced technology to developing countries, but the research object of this article for more developed countries, the impact is not obvious. At the same time, when technology diffusion and talent allocation exceed the corresponding value, the impact of ICT capital accumulation on economic development changes from promoting effect to inhibiting effect. The degree of industrial cluster development, economic freedom, digital trade barriers and industrial structure are positively correlated with national innovation efficiency. The innovation ability of developed countries is relatively high. Although digital trade barriers will have a negative impact on innovation in the long run, they will maintain their innovation advantages to a certain extent in the short term. The optimization and upgrading of industrial structure can promote the transfer of production factors to high-efficiency sectors, affect the input factors of innovation, and then affect the efficiency of innovation. The higher the economic freedom, the less the government's intervention in the market, and the full play of the self-adjustment of the market. Free market competition is conducive to improving the overall innovation efficiency.

Table 4 TOBIT regression results of influencing factors of national innovation

Influencing factors	regression coefficient	standard deviation
Degree of industrial cluster development	0.004**	0.002
Digital Barriers to Trade	0.564**	0.214
Information technology application	-0.010***	0.002
Economic freedom	0.012**	0.005
The industrial structure	0.008*	0.004
The foreign investment	-0.003	0.002
Gross domestic product	-0.19E-04***	4.41E-06

Digital trade barriers can also be divided into tariff barriers and non-tariff barriers. Tariff and non-tariff barriers are taken as explanatory variables to analyze the impact of digital trade barriers on innovation efficiency, and the regression results are shown in Table 5. Tariff barriers are significantly negatively correlated with national innovation efficiency, while non-tariff barriers are significantly positively correlated with national innovation efficiency.

Table 5 TOBIT regression results of digital trade barriers

Variable	regression coefficient	standard deviation
Tariff barriers	-0.037**	0.013
Non-tariff barrier	0.456E-03***	0.484E-04

5. Conclusions and suggestions

In this paper, three-stage DEA model is used to measure innovation efficiency in 25 countries, and TOBIT regression is used to analyze the influencing factors of innovation efficiency. The research conclusions are as follows:

First, due to the low pure technical efficiency, the comprehensive technical level is low. Therefore, the improvement of technology, management and other factors has an important impact on improving the overall innovation efficiency of a country.

Second, environmental factors have a great impact on national innovation efficiency. The level of industry-university-research cooperation will attract more R&D personnel and R&D funds, but it does not improve national innovation efficiency, resulting in investment redundancy.

Government administration level and intellectual property protection can reduce the redundancy of investment.

Third, by comparing the efficiency value of the first stage and the third stage, it can be found that the technical efficiency of each country is stable, rising and declining. Therefore, according to the change of efficiency value, countries can be divided into three types: stable, developmental and improved. A stable country indicates that the country has a high management efficiency, and external factors have no influence on its efficiency value. Improving countries indicate that these countries show high efficiency values due to their good external environmental factors, so they should improve their own management efficiency, make better use of innovation input resources, and increase output. Development-oriented countries indicate that external factors reduce the overall innovation efficiency, so these countries should provide corresponding policy support for enterprises and provide better environmental conditions for efficiency improvement.

Fourthly, the degree of industrial cluster development, economic freedom and industrial structure have a significant positive impact on national innovation efficiency, while the application of information technology has a significant negative impact. Tariff barriers are significantly negatively correlated with national innovation efficiency, while non-tariff barriers are significantly positively correlated with national innovation efficiency.

In view of this, the text makes the following recommendations:

First, create a favorable environment for innovation. In the process of promoting innovation, the government should pay more attention to the legal and regulatory system, establish a sound intellectual property protection system, stimulate the innovation vitality of individuals, and create a fair and open market competition environment.

Second, we need to improve input factors for innovation. The government needs to increase investment in basic research, improve basic research facilities, pay attention to personnel training and talent introduction, and make more "zero-to-one" breakthroughs in innovation to provide strong support for economic development. At the same time, we should optimize the allocation of innovation resources, solve the problem of scattered and inefficient utilization of innovation resources, and make resources serve the creative work of R&D personnel in a more appropriate way.

Third, the implementation of a diversified foreign trade strategy. Strengthen the cooperation with other countries and regions, explore the international market in an all-round way, expand the road of cooperation on the basis of maintaining trade contacts with leading countries, especially pay attention to international cooperation with emerging countries, establish friendly international relations, eliminate barriers, and make trade smooth.

Fourth, delve into digital trading standards. First of all, it is necessary to understand the trade requirements of each country, so that export enterprises can produce products in accordance with international standards. Meanwhile, the government can provide corresponding legal and policy support, so that the overall innovation level of the country can be improved in the process of constantly breaking through various forms of trade barriers.

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References

[1] Zhao Jin.(2021) Policy Trends of Digital Trade Barriers and Digital Transformation: An analysis based on the European and OECD Digital Trade Restrictions Index [J]. International Trade, (02):72-81.

[2] Li Zhe. (2019)Discussion on Innovation Efficiency -- Based on the analysis of Global Innovation Index data [J]. Science and Technology China, (08):13-16.

[3] Nieves Arranz, Marta F. Arroyabe, Martin Schumann.(2020) The role of NPOs and international actors in the national innovation system: A network-based approach mixes J I.Technological Forecasting and Social Change, 159.

[4] Jie Wu, Zhenzhong Ma, Shuaihe Zhuo.(2017) Enhancing national innovative capacity: The impact on inward foreign direct investment of high-tech international trade and inward foreign direct investment[J]. International Business Review, 26(3) : 502-514.

[5] Tao Qiuyan, high take-off. The influence path of information and communication technology on national innovation capability [J]. Science and Technology Management Research,2019,39(13):46-52.

[6] Zhang Yang, Tang Lingbing, Jin Peizhen.(2015) Measurement and influencing factors of innovation capacity of BRICS countries[J]. China Soft Science, (06):148-157.

[7] Charnes, W.W.Cooper, E.(1978) Rodes. Measuring the efficiency of decision making units[J].European Journal of Operational Research, 2(6): Pages 429-444.

[8] Pei Yunlong, Guo Jue, Xiang Xiyao. (2016)search and Development Personnel Cooperation Network, Scientific research and Technological Innovation [J]. Research in Science of Science, 34(07):1054-1064.

[9] OUYANG, Chen Qi.(2014)luation of technical efficiency and single factor Efficiency of Innovation System in BRICS countries: A comparison with the experience of developed countries [J]. Great Country Economic Research, (00):106-124.

[10] Zhao Yun, Zhou Yuan, Fu Shichan, Chen Luyi.(2019,)alysis on the evolution of national innovation efficiency and its influencing factors from the perspective of open economy [J]. Industrial Technical Economics, 38(06):44-54.

[11] Jiancheng Guan, Kaihua Chen.(2012)odeling the relative efficiency of national innovation systems[J].Research Policy, 41 (1) : 102-115.

[12] Zang Lei Zhen. (2019)How Government Governance Effectiveness Promotes National Innovation Capability: An Empirical analysis of Global Panel data [J]. Chinese Public Administration,01:121-127.

[13] Li Houjian, Zhang Zongyi.(2014) Financial Development, Intellectual Property Protection and Technological Innovation Efficiency: The Role of Financial Marketization [J]. Science Research Management,35(12):160-167.