Artificial Intelligence, Medical Engineering and Education
Z. Hu et al. (Eds.)

doi:10.3233/ATDE250107

Exploring the Dynamic Correlation Between External Opening Up and Regional Economic Growth Through Crawling Technology

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Abstract. Crawler technology is a kind of technology that can automatically collect data from a large amount of web pages and data resources (such as videos, pictures, texts, etc.) on the Internet without manual intervention, and according to the automatic program or script technology, the relevant information scattered in different websites is summarized together for real-time monitoring. It can get information such as policy changes, demand changes, price fluctuations and other content changes in a short time. At present, in response to the changes in the domestic and foreign economic situation, China is promoting the construction of free trade pilot zones, the construction of the Belt and Road as the fulcrum, reshaping the pattern of opening up. This paper takes Jiangsu Province as a case to discuss the dynamic correlation between external opening up and regional economic growth, which can effectively help the government to have a real-time, accurate and comprehensive understanding of the dynamic correlation between external opening up and regional economic growth, hoping to provide a strong basis for the government to make relevant enterprise strategies and government decisions, and promote the prosperity and development of regional economy.

Keywords. Crawler technology; Dynamic correlation; External opening.

1. Introduction

Crawler technology is a kind of technology that can automatically collect data from a large amount of web pages and data resources (such as videos, pictures, texts, etc.) on the Internet without manual intervention, and according to the automatic program or script technology, the relevant information scattered in different websites is summarized together for real-time monitoring. It can get information such as policy changes, demand changes, price fluctuations and other content changes in a short time. At present, in response to the changes in the domestic and foreign economic situation, China is promoting the construction of free trade pilot zones, the construction of the Belt and Road as the fulcrum, reshaping the pattern of opening up. Various localities have conducted studies to explore how to seize historic opportunities, expand the depth and breadth of opening-up, and promote local economic growth. Opening to the outside world covers many aspects such as technology exchange, investment, trade and capital flow. How each region achieves its own economic acceleration through technology

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exchange, investment, trade and capital flow is the focus of this paper. Over the past 30 years of reform and opening up, Jiangsu Province has been at the forefront of China's reform and opening up with its unique geographical advantages and good economic foundation. This paper takes Jiangsu Province as a case study to explore the dynamic relationship between foreign opening and regional economic growth. Traditional research methods are often faced with many limitations in obtaining and analyzing relevant data, while crawler technology automatically collects data from a large amount of web pages and data resources (such as videos, pictures, texts, etc.) on the Internet without human intervention. In addition, according to the automatic program or script technology, the relevant information scattered in different websites is summarized together for real-time monitoring, and the content changes such as policy changes, trade data, demand changes, economic indicators, price fluctuations can be obtained in a short time. Therefore, exploring the dynamic correlation between opening up and regional economic growth based on crawler technology has important practical value, which can effectively help the government to understand the dynamic correlation between opening up and regional economic growth in a real-time, accurate and comprehensive manner, hoping to provide a strong basis for the government to formulate relevant enterprise strategies and government decisions. Promoting regional economic prosperity and development.

2. Related Works

Although opening to the outside world has made great contributions to China's economic growth in the transition period, and is one of the most vivid cases of opening up to achieve economic growth, based on the international perspective, whether theoretical analysis or empirical research, there are still many differences in their conclusions. The theoretical research of opening to the outside world and economic growth mainly falls on the relationship between foreign trade, foreign direct investment and economic growth. The initial discussion is from the perspective of foreign trade, and the views are relatively consistent: the absolute benefit theory and the comparative benefit theory in classical economic theory believe that trade openness can promote economic growth by improving labor efficiency and promoting the exchange of surplus products; According to Keynes theory, trade surplus can stimulate employment and increase output; Later, although the new classical trade theory and the new trade theory have different mechanisms on the relationship between opening to the outside world and economic growth, the mainstream trade theory undoubtedly affirms the contribution of trade opening to economic growth. Previous research has extensively explored the endogenous growth theory fully affirms the contribution of foreign direct investment to the economic growth of the host country [1]. There are two sides to the effect of foreign direct investment on economic growth, which can produce positive effects such as scale economy and negative effects such as inhibiting domestic capital Previous empirical studies on opening to the outside world and economic growth are mainly divided into two categories: one is to directly study the relationship between foreign trade, foreign direct investment and economic growth; The other studies the relationship between the indicators of opening to the outside world and economic growth [2]. The literature of the first type of research is very rich, and the research conclusions are also different. Some results affirm the contribution of foreign trade and foreign direct investment to economic growth and believe that they are the causes of economic growth. Wang Previous research

has extensively explored the relationship between trade volume and economic growth is verified by using trade volume and trade barrier as indicators of freedom and openness respectively [3]. The conclusion shows that both are positively correlated with economic growth, indicating that the relationship between trade volume and economic growth is consistent while the relationship between trade barrier and economic growth is contrary to traditional trade theory. Fu L., Longzong W., Lianfeng Previous research has extensively explored the total amount of import and export and the actual foreign direct investment, a comprehensive index of openness is constructed to study the relationship between China's openness and economic growth [4]. From the perspective of regional research, this paper constructs the index of opening degree to study the relationship between opening degree and regional GDP of provinces. The results show that there is a strong positive relationship between opening degree and regional GDP of most provinces. Luo Previous research has taken Yunnan Province as the research object, the index of openness to the outside world is constructed based on foreign trade, foreign investment, foreign contracted projects, labor service cooperation and international tourism, and the conclusion is also obtained that the regional openness to the outside world is positively correlated with economic growth [5].Asif R, Xiaodong Previous research has extensively explored the foreign trade dependence and foreign capital dependence as indicators of opening to the outside world, this paper studies the relationship between opening to the outside world and regional economic growth in southern Jiangsu Province, Central Jiangsu Province and Northern Jiangsu Province [6]. The results show that foreign trade dependence has a high correlation with regional per capita GDP, while foreign capital dependence has a high negative correlation with per capita GDP in southern Jiangsu Province and a weak correlation with other regions. The comprehensive opening index of the two structures has a significant promoting effect on regional economic growth. Hu Previous research has extensively explored the different countries and regions are at different stages of development, their internal and external economic structures are different, and their attitudes towards opening up and the direction and extent of the impact of opening up on regional economy are bound to be different [7].

3. Crawler technology explores the dynamic correlation between external opening and regional economic growth

This paper conforms to the new situation of opening up, including foreign investment into the construction of opening degree index; The crawler technology is used to expand the comparison area from southern Jiangsu, Central Jiangsu and Northern Jiangsu to 13 cities in Jiangsu Province [8]. Replacing regional division with administrative division is more conducive to the positioning of each city's openness and policy response. The analysis of this paper mainly focuses on the following four aspects: first, compare the foreign economic development of 13 cities in Jiangsu; Second, compare the opening efficiency of 13 cities in Jiangsu; Third, examine the influence of opening to the outside world on regional economic growth; Fourth, examine which forms of opening up have contributed the most to economic growth.

3.1. Crawler technology analyze the indicators of the degree of opening up to the outside world

The degree of opening to the outside world is a measure of a country's (region's)

participation in international economic activities and dependence on the external economic environment in the process of international economic and trade exchanges, and is an important representation of the development of a country's (region's) open economy [9]. Although many scholars at home and abroad have basically reached a consensus on the meaning of openness to the outside world, they still hold different opinions on the measurement methods and the selection of indicators of openness to the outside world. With the continuous development of the opening up field, China's opening up to the outside world, which is dominated by export and introduction of foreign capital, has entered a new situation of equal emphasis on import, export, introduction of foreign capital and foreign investment. Nowadays, transnational capital flows not only show the ability of a country (region) to control the global distribution of capital to a certain extent, but also show the degree of integration of a country (region) into the development of the global economy. The measurement of a country's level of opening to the outside world should not only consider foreign trade and external capital inflow, but also consider capital outflow. Therefore, this paper will increase the consideration of foreign investment indicators on the basis of the commonly used foreign trade dependence and foreign capital dependence, and use the ratio of the total trade flow and capital flow to the gross domestic product (GDP) as the measurement standard of regional opening degree [10]. The specific formula is as follows:

$$OD = EXD + IMD + IFDID + OFDID \tag{1}$$

Where, (opening degree) is the degree of opening to the outside world, (export dependence) is the degree of export dependence, = export value/gross regional product; (import dependence) is the proportion of import to gross regional product, which is called import dependence in this paper. The formula is expressed as = import amount/gross regional product; inflow foreign direct investment dependence = inflow foreign direct investment/Gross regional product; outflow foreign direct investment dependence refers to the proportion of outward direct investment to GDP, which is called outward investment dependence, and the formula is expressed as = outward direct investment/ GDP.

3.2. Crawler technology describe and analysis of opening index of Jiangsu region

As mentioned above, trade flow and capital flow constitute the main manifestations of opening to the outside world. Limited by the availability of data, the import and export dependence, foreign capital dependence and foreign investment dependence of 6 cities in Jiangsu in the past five years were first calculated. The average monthly exchange rate of the average exchange rate calculated by the People's Bank of China was used as the annual exchange rate data. The remaining data are from Jiangsu Statistical Yearbook and statistical Bulletin. For details, see Table 1 export dependency and import dependency percentage, Table 2 Foreign capital dependency and foreign investment dependency percentage, Table 3 Opening degree percentage.

Table 1 shows that most of the export dependence and import dependence of the five cities in Jiangsu show a downward trend, but the amplitude of decline is quite different. Generally, the higher the degree of dependence, the more obvious the decline is. For example, Suzhou has the highest degree of import and export dependence. In 2020, the import and export dependence of various regions generally showed signs of reversal, but

the subsequent trend was greatly differentiated, and the regions with high dependence of Suzhou, Wuxi, Nanjing and Changzhou returned to the decline channel; Suqian with low dependence has been showing an upward trend. The rest of the region fell slightly or remained relatively flat in the volatility [11]. It can be seen that the ranking of export dependence has the regularity of the regional division. However, the regularity of the ranking of import dependence in regional distribution has been greatly weakened.

Table 1. Export dependency and import dependency percentage

Regional	index	2019	2020	2021	2022	2023
Nanjing	export dependence	29.81	32.83	32.45	27.96	24.95
	import dependence	24.68	27.33	27.84	20.45	18.17
Wuxi	export dependence	35.56	42.38	39.74	34.46	31.59
	import dependence	24.54	29.16	28.32	24.57	22.44
Xuzhou	export dependence	4.33	6.05	7.57	9.88	6.84
	import dependence	2.24	3.52	3.91	3.20	1.94
Changzhou	export dependence	29.44	34.59	34.93	31.74	28.95
	import dependence	11.42	14.94	16.73	14.42	12.56
Suzhou	export dependence	100.69	112.31	100.83	91.80	83.64
	import dependence	77.10	88.73	80.57	68.84	63.61

Table 2. Foreign capital dependency and foreign investment dependency percentage

Regional	index	2019	2020	2021	2022	2023
Nanjing	Inflow foreign direct invest dependence	3.86	3.72	3.75	3.62	3.12
	outflow foreign direct invest dependence	0.24	0.45	0.62	0.80	0.78
Wuxi	Inflow foreign direct invest dependence	4.38	3.86	3.29	3.34	2.56
	outflow foreign direct invest dependence	0.24	0.41	0.61	0.77	0.92
Xuzhou	Inflow foreign direct invest dependence	1.99	2.33	2.67	2.67	2.10
	outflow foreign direct invest dependence	0.15	0.04	0.22	0.96	0.28
Changzhou	Inflow foreign direct invest dependence	7.00	5.94	5.51	5.34	5.02
	outflow foreign direct invest dependence	0.30	0.76	0.80	0.40	0.61
Suzhou	Inflow foreign direct invest dependence	7.26	6.26	5.44	4.82	4.14
	outflow foreign direct invest dependence	0.28	0.35	0.42	0.64	0.77

Table 2 shows that the dependence on foreign investment in the five cities of Jiangsu shows a downward trend, while the dependence on foreign investment shows an upward trend. In comparison, the gap of foreign capital dependence among Jiangsu cities tends to shrink continuously, and the ratio of the highest value to the lowest value decreases continuously. However, the gap of dependence on foreign investment tends to widen continuously. Compared with import and export dependence, the regional distribution of foreign capital dependence and foreign investment dependence is less obvious, and the average foreign capital dependence is highest in Suzhou. Nantong has the highest average dependence on foreign investment.

As mentioned above, the opening-up degree of Jiangsu region is described by the

sum of import, export, foreign capital and foreign investment dependence (see Table 3). From 2019 to 2023, the openness of Jiangsu cities can be roughly divided into three levels: Suzhou's openness is the highest, far exceeding that of other regions, which is the first level; Next, Wuxi and Nanjing belong to the second level, which opened a significant gap with the other regions, among which Nanjing fell faster and showed a trend of overlapping with Changzhou; Xuzhou is in the fourth level, and the trend of opening degree of each city also overlaps each other. Based on Table 1-3, it is not difficult to conclude that the degree of openness to the outside world is most affected by the degree of export dependence, and the level division of the degree of export dependence has a high degree of agreement. From the perspective of development trend, during the sample period, the gap of opening degree of the five Jiangsu cities has been narrowing, and Suzhou, which is in the first level, has dropped sharply [12-14]. The openness of the region in the second level experienced a decline in 2019, and began to show a slight decline in 2022 after a correction in 2020. The regions in the third tier basically maintained an upward trend except for a slight decline in 2023.

Table 3. Opening degree percentage

Regional	index	2019	2020	2021	2022	2023
Nanjing	Opening degree percentage	3.86	3.72	3.75	3.62	3.12
	Opening degree percentage	0.24	0.45	0.62	0.80	0.78
Wuxi	Opening degree percentage	4.38	3.86	3.29	3.34	2.56
	Opening degree percentage	0.24	0.41	0.61	0.77	0.92
Xuzhou	Opening degree percentage	1.99	2.33	2.67	2.67	2.10
	Opening degree percentage	0.15	0.04	0.22	0.96	0.28
Changzhou	Opening degree percentage	7.00	5.94	5.51	5.34	5.02
	Opening degree percentage	0.30	0.76	0.80	0.40	0.61
Suzhou	Opening degree percentage	7.26	6.26	5.44	4.82	4.14
	Opening degree percentage	0.28	0.35	0.42	0.64	0.77

3.3. Crawler Technology Compare the Economic Growth Effect of Opening Index in Jiangsu Region

The above analysis shows that in addition to the dependence on foreign investment, the differences in other indicators of opening up in the five cities of Jiangsu have a decreasing trend, but the differentiation between regions is still very obvious [15]. So what is the difference in the impact of different degrees of opening-up on regional economic growth? Regional economic growth is the result of various means of production and various conditions of development. Only by eliminating the interference of other factors can we understand the exact impact of regional opening to the outside world on economic growth. Therefore, this paper builds an econometric model to further explore the relationship between opening to the outside world and economic growth in Jiangsu region: first, compare the heterogeneity of the effect of opening to the outside world on regional economic growth; The second is to compare the impact of opening to the outside world index and other variables on regional economy; The third is to compare the difference of the impact of opening to the outside world indicators on regional economy.

Further expanding on the base of Cobb-Douglas production function, this paper assumes that economic growth is a nonlinear function of technological progress, capital input, labor input and opening to the outside world. The logarithm of both sides of the nonlinear function is calculated in the following econometric model form:

$$\ln Y_{it} = C + \alpha \ln A_{it} + \beta \ln K_{it} + \chi \ln L_{it} + \delta \ln OD_{it} + \varepsilon_{it} \quad (2)$$

In formula A is a relevant indicator representing technological progress, K is a relevant indicator representing capital input, L is a relevant indicator representing labor input, and OD is a relevant indicator representing openness to the outside world. According to the characteristics of the data in this paper, panel data is suitable for analysis. The analysis steps are as follows: First, four test methods, LLC, IPS Fisher-ADF and Fisher-PP, are used for panel unit root test. The results show that the first-order difference of all variables can reject the null hypothesis of the existence of unit root at the significance level of 5%, which is a first-order single integral variable. Secondly, the test method is used to test whether there is a long-term stable relationship between the variables. The test results show that except the Group RHO-Statistic statistic, which rejects the null hypothesis without cointegration relationship at the significance level of 10%, all the other statistics can reject the null hypothesis at the significance level of 5%. Therefore, it is believed that the stable relationship between variables can be found through panel regression [16,17]. Subsequently, by the Hausman test, the statistic of 31.00 rejects the null hypothesis of random effects at 1% significance level. Finally, auxiliary analysis software EVIEWS7.2 was used to estimate the fixed effect variable intercept model, and the results were shown in Regression 1 in Table 4. In view of the purpose of this paper is to compare and analyze the difference of the effect of opening to the outside world on economic growth among cities in Jiangsu, and also to compare the estimation effect of the model and examine the robustness of the results, the fixed effect variable coefficient model is further estimated. Due to the large number of explanatory variables, this paper adopts the method of controlling some variables and only allows the coefficient of the variable of openness to the outside world to change. The estimated results are shown in regression 2 in Table 4, and the output elasticity of openness to the outside world in Jiangsu is shown in Table 4.

Table 4. For the output elasticity of openness degree in Jiangsu

variable	Regression I	Regression II
constant term	0.34(3.56) ***	0.32（3.12）***
capital input	0.60（5.83）***	0.60（4.37）***
technological progress	0.05（2.05）**	0.06（1.79）*
labor input	-0.07（0.45）	-0.07（1.18）
opening degree	0.14（2.95）**	NJ 0.16(2.96)*** WX 0.19(3.34)*** XZ 0.14(1.89)* CZ 0.16(3.07)*** SZ 0.14(2.46)**
goodness of fit	R^2=0.9，F= 596.39***	R^2=0.97， F= 774.89 ***

The empirical results show that openness, technological progress and capital input are all positively correlated with the GDP of Jiangsu region. Compared with result 1 and result 2, although the estimation methods are different, the symbols of the parameter estimates are the same and the absolute values are relatively stable. In order to further

investigate the robustness of the results, this paper re-estimates by removing one year's data, and the results show that the coefficient sign remains unchanged, and the change of absolute value can be basically ignored. As can be seen from Table 4, the output elasticity of openness degree in Jiangsu is 0.14, indicating that 1% increase in openness degree and 0.14% increase in regional GDP, which is higher than the impact of technological progress on economy, but less than the effect of capital on economic growth. The results of 5% significance test in Regression II are all positive, indicating that the improvement of opening to the outside world can promote the economic growth of each city, which is similar to the conclusions of most literatures [18]. Compared with the estimated results of 10% significance test, the elastic values of Wuxi, Changzhou and Xuzhou are successively from largest to smallest. From the perspective of the output elasticity ranking of the openness of each city, there is no obvious regularity in geographical location, which further explains the necessity of using administrative division instead of regional division for research.

4. Results and Discussion

his paper takes Jiangsu Province as a case to discuss the dynamic correlation between external opening up and regional economic growth, which can effectively help the government to have a real-time, accurate and comprehensive understanding of the dynamic correlation between external opening up and regional economic growth, hoping to provide a strong basis for the government to make relevant enterprise strategies and government decisions, and promote the prosperity and development of regional economy.

4.1. Case Discussion

Some scholars study 13 cities in Jiangsu instead of 5 cities in Jiangsu，the hierarchical structure of open economy development in 13 cities of Jiangsu is quietly changing, and the gap between the indicators of opening to the outside world tends to narrow, which shows the influence and drive of the developed areas of Jiangsu on the less developed areas. The rapid development of open economy in Central and northern Jiangsu has increasingly become an important engine to promote regional economic growth. In recent years, with the rapid economic growth in central Jiangsu, the GDP of Nantong City ranks the fourth in Jiangsu Province, and the GDP of Yangzhou and Taizhou also exceeds that of Zhenjiang. The economic development of Central Jiangsu is closely related to accelerating the pace of opening, actively docking the development of international industries and actively undertaking the industrial transfer from Shanghai and southern Jiangsu. Taking Nantong as an example, the average dependence on foreign investment during the sample period exceeded that of Wuxi and Nanjing, and the average dependence on foreign investment ranked first in the province. In recent years, Nantong has continuously promoted the development strategy of "connecting with Shanghai and promoting cross-river cooperation", and has built 12 cooperation parks with Shanghai, Suzhou and Wuxi successively, including Sutong Science and Technology Industrial Park and Xitong Science and Technology Industrial Park, which not only deepens the pace of Nantong's opening to the outside world, but also deepens the cooperation between Nantong and Shanghai, Suzhou, Wuxi and other southern Jiangsu regions. Through the radiation of Shanghai and southern Jiangsu, the integration and development

of the region are accelerated. Although limited by geographical location, development basis and other factors, the economic development of northern Jiangsu is far behind that of southern Jiangsu and Central Jiangsu. However, in recent years, the economic growth rate of northern Jiangsu has accelerated significantly, and Suqian, Lianyungang and Huaian are among the top three in the province. The economic growth of northern Jiangsu is also attributable to its open economy. During the sample period, trade and investment in northern Jiangsu increased significantly, especially the inflow of foreign capital was more rapid. The average annual growth rates of actual used foreign capital in Suqian, Huaian and Xuzhou were *44.12%, 35.24% and 24.24% r*espectively, ranking first in the province. The inflow of foreign capital has effectively promoted the local export trade, for example, Xuzhou City has successfully established provincial export bases and national demonstration bases such as construction machinery, plate, garlic, etc., which has driven the development of local economy.

4.2. Results

Through the analysis, it is not difficult to see that improving the openness of Jiangsu region, strengthening capital investment and promoting technological upgrading can promote the further growth of regional economy. Under the opportunity of a new round of opening, this paper puts forward the following countermeasures and suggestions for Jiangsu region to deepen opening up and promote economic growth based on the above analysis conclusions: we should prevent the dependence on foreign trade and foreign investment from falling too fast and speed up the pace of going global. In recent years, due to weak external demand, high production costs, manufacturing relocation and other factors, the growth rate of Jiangsu region, whether it is import, export trade or foreign direct, has generally shown signs of decline, and the foreign trade dependence and foreign capital dependence of Jiangsu five cities have mostly shown a downward trend. Although with the development of economy and the gradual adjustment of industrial structure, the dependence on foreign trade has decreased, the dependence on foreign capital has decreased, and the increase of capital outflow is in line with the general law of economic development, now economic growth has entered the "shift period", while the optimization and upgrading of industrial structure still takes time, outbound investment is still at a low level, and there is no strong driving force for growth. At this time, we cannot ignore the driving role of foreign trade and foreign capital on economic growth. Therefore, on the one hand, we should speed up the pace of going global, build new engines of economic growth, and promote the diversification of economic growth drivers. On the other hand, the structure of foreign trade and foreign investment should be upgraded in an orderly manner to prevent the dependence on foreign trade and foreign investment from falling too fast.

5. Conclusion

This paper takes Jiangsu Province as a case to discuss the dynamic correlation between external opening up and regional economic growth, which can effectively help the government to have a real-time, accurate and comprehensive understanding of the dynamic correlation between external opening up and regional economic growth,and promote the prosperity and development of regional economy.strengthen regional cooperation, improve the efficiency of opening up, and promote the balanced

development of Jiangsu economy. The results of this paper show that the opening to the outside world is one of the main sources of economic growth in Jiangsu region, and the promotion of opening to the outside world has no clear law of geographical location and great difference in quantity. Comparatively speaking, the opening degree of the less developed areas in Jiangsu has great room for improvement, and some areas have already shown their huge development potential. Therefore, increasing the opening up of the less developed areas can effectively drive the economic growth of these areas and promote the balanced economic development of Jiangsu.

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