The Influence of OFDI on the Industrial Structure of Guangdong Province: An Application of the Grey Incidence Theory

Jaime Ortiz, Jingwen Xia, Haibo Wang, and Junqi Cao

***Abstract*—Adjustments in industrial structure are a necessary condition to maintain sustainable economic growth. Outward foreign direct investment (OFDI) is a strategy that the P.R. China was slow to pursue but developed quickly once initiated. This article analyzes the relationship between OFDI and the adjustment in industrial structure of Guangdong Province. The absolute, relative, and comprehensive degrees of the Grey incidence are calculated and compared with their equivalents for the P.R. China. The results show that adjustments in industrial structure are closely related to OFDI since OFDI in fact drives this optimization and upgrading. These impacts are far more evident at the provincial than the national level, with implications for P.R. China's future economic growth.**

***Index Terms*—OFDI, grey system, industrial structure.**

I. Introduction

Industrial structure and capital flows are closely interrelated. As the main form of capital flow, outward foreign direct investment (OFDI) exerts a pivotal influence on the industrial structure of a country [1]. In 1979 the P.R. China initiated a series of profound economic and political reforms to promote the establishment of special economic zones along the coastline. Guangdong Province, located on the eastern coast of P. R. China adjacent to Hong Kong S.A.R. and to Macao, implemented a number of these reforms. Its positive economic growth has depended heavily on its privileged geographical location, which has allowed it to welcome an unusually high amount of OFDI in the form of industrial facilities, public services, and housing centers designed to produce exportable goods [2]. In 2012, the total value of its OFDI stock reached $25.2 billion, representing 4.7 percent of the national OFDI stock.

After the 1979 reforms, OFDI in P.R. China initially developed slowly, with correspondingly modest adjustments in the country's industrial structure. Since then studies have been scarce and have generally concentrated on inward foreign direct investment (FDI). An early article by [3] found that, at least in theory, OFDI promoted the optimization and upgrading of the domestic industrial structure. Using a Granger causality analysis, [4] concluded that OFDI promoted upgrading of the industrial structure from reliance on primary industries to greater development of secondary and tertiary industries. [5] calculated the Grey correlation between the sectoral amount of OFDI and industrial structure in P.R. China between 2003 and 2006. Their results showed that OFDI in the mining and manufacturing sectors contributed to reshaping their overall industrial structures.

More recently, an accelerated flow of OFDI into P.R. China has lent new urgency to study the effect of OFDI on the structure of Chinese industry. This article analyzes the relationship between OFDI and the optimization of industrial structure in Guangdong Province compared with P.R. China as a whole. It uncovers the factors of OFDI that influence industrial structure based on OFDI data between 2007 and 2012.

The Grey relational analysis is suitable for use with a small data sample like the one in this study. Originally proposed by [6], the Grey relational analysis is based on the dynamic correlation established around the geometrical similarities among a set of predetermined sequences between multiple factors and variables. The more similar the shape of the parametric curves, the greater the degree of correlation between the corresponding sequences.

In the next section we discuss the literature on the relationship between OFDI and industrial structure in the P.R. China. We then present the theoretical framework around the Grey relation to demonstrate its suitability for analyzing the attributes of various plausible explanations to identify the presence of such a relationship. The subsequent section describes the data collection process and how the variable sequences were constructed. The empirical results reflecting the impact of OFDI on the optimization and upgrading of the industrial structure are then presented along with concluding remarks.

II. Literature Review

There are basically two views on the relationship between OFDI and the organization of industry. [7] believe that FDI can transfer an industry overseas in its existing form, thereby reallocating resources toward host industries that enjoy a global competitive advantage and also readjusting the trade structure to allow leading foreign technologies to spread throughout the domestic industry. Therefore, according to [7]

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OFDI does play an important role in promoting and optimizing the industrial structure of a country. In contrast, [8] believe that OFDI may not only hinder competition among similar industries located in the home and host countries but also may lead to an industrial decline. Thus, the optimization of the industrial structure in the home country due to OFDI would not only discourage, but would actually be harmful to, industry in the host country.

Ref. [9] introduced the concept of marginal expansion, in which a country transfers those industries that suffer competitive disadvantages to a host country that has just begun to develop those industries, in order to recoup its investments. According to [10], industries with comparative advantages are then compelled to promote the optimization and upgrading of the industrial structure in the home country. With regard to technology transfer and technical innovation, [11] argue that a country should provide the learning and managerial factors for developing high-tech industries in the form of OFDI, then trigger adoption of those technologies. At the level of individual companies, [12] and [13] have researched the OFDI in South Korea and Slovenia, respectively. Their results unequivocally show that OFDI adjusts and optimizes the regional and national industrial structures but to varying degrees.

In contrast, [14] believe that OFDI has no optimization effects on the industrial structure of U.S. subsidiaries. As [15] indicates, despite some gains in employment and increases in the capital stock, the U.S. domestic production capacity has not substantially improved. In fact, the U.S. industrial structure may have achieved neither optimization nor upgrading. [16] studied the FDI made by Japanese multinational companies between 1981 and 1995. They found that FDI was conducive to the expansion of those companies but produced a hollowing effect on the Japanese industrial sector.

According to [17], OFDI-produced technology spillovers inevitably penetrate countries regardless of those countries' levels of industrial development. At the same time, labor cost differentials deepen global production networks due to the value chain that is created, the continuous process of technical change, and the political behavior and motivations behind OFDI [18]. These conditions reflect the inadequacy of conventional FDI theories for explaining OFDI behaviors among countries. More recently, new theories with higher power for explaining the practice of FDI have emerged. These new theories support the view that OFDI is positively related to the optimization and upgrading of the industrial structure in a receiving country [19].

Ref. [20] proposed the imbalance theory to explain the unconventional behavior of firms in terms of backward and forward OFDI. They proved OFDI was significant in the creation of competitive advantages and product upgrades in terms of balancing a firm-specific portfolio of assets. Similarly, [21] pointed out that a firm with a weak set of competitive advantages might choose to move abroad to bypass domestic competition and seek complementarities that would enhance both its asset portfolio and competitiveness. In such a situation, to increase OFDI would be an equally effective way to improve the competitiveness of an enterprise in a relatively inferior position as to upgrade backward and forward industries in the home country [22].

For multinational companies located in the Asian Pacific Rim, [23] proposes the Linkage-Leverage-Learning (LLL) framework to explain perfectly mobile resources. The LLL framework considers multinational companies based in newly industrialized economies as latecomers and therefore OFDI offers them relatively greater competitive advantages and optimization and upgrading of the domestic industrial structure through processes of "resource linkage," "leverage effect," and "learning by doing."

[24] and subsequently [25] suggest that exports of Japanese manufactured goods are positively related to employment in Japanese subsidiaries. Hence, a host country could enhance the competitiveness of its domestic enterprises and promote the optimization and upgrading of its domestic industry via OFDI. Using data for 22 multinational companies between 1970 and 1995, [26] concluded that trade and OFDI were both sources of economic growth and that newly industrializing economies experienced a positive structural change during their industrialization process.

In the case of Ireland, [7] also found that multinational corporations' demand for intermediate inputs is partially met by the investment landscape of the host country, which provokes changes in its industrial structure. [11] analyzed the relationship between home-country exports and employment and production at the subsidiary level. He concluded that by shifting labor-intensive industries to developing countries and focusing on the development of capital-intensive alternatives, a country can optimize and upgrade its industrial structure.

III. Theoretical Model

Grey relational analysis enables the identification of a relationship between two given variables, more specifically it yields a quantitative index for uncovering trends within a dynamic process. If these variables change synchronously over time, the Grey correlation degree between them improves and a relationship can be established. The Grey correlation degree is used here as a dimensionless method with respect to the observed raw data in order to calculate the relevance of the correlation coefficients, correlation degrees, and evaluation indexes.

The Grey correlation degree is calculated in both absolute and relative terms. The relative correlation degree is analyzed using the initial point zero method when the analyzed variables are intrinsically different, their dimension is inconsistent, and it is difficult to get reasonable results through the absolute correlation degree. Alternatively, discrete sets of data may be used in order to make up for the deficiencies of the absolute correlation degree. Hence, the results are related to the rate of change of the sequence with respect to the initial point not to the magnitude of the data.

The Grey correlation degree is determined by examining the reference and comparison sequences. The absolute and relative correlation degrees are first calculated, then the comprehensive correlation degree is obtained by calculating the weighted average of the absolute and the relative correlation degrees. The goal is to verify the existence of a correlation between the reference sequence and comparison sequence using the comprehensive correlation degree as an index. The comprehensive Grey correlation degree assumes that the total value index or sub-value index of the industrial structure is as follows:

$$X_0 = (x_0(1), x_0(2), x_0(3), x_0(4), x_0(5), x_0(6))$$

The lack of reliable data on OFDI across firms in Guangdong Province prevented any extrapolation at the industry level. There are two independent variable sequences. One is provincial OFDI calculated as a proportion of Guangdong Province's GDP; the other is the national OFDI calculated as a proportion of P.R. China's GDP. The index values of the comparison sequences are assumed as follows:

$$X_1 = (x_1(1), x_1(2), x_1(3), x_1(4), x_1(5), x_1(6))$$

A. Calculation of the Absolute Grey Correlation Degree

The absolute Grey correlation degree represents the similarity between the reference sequence, X_0, and the comparison sequence, X_1. The higher the similarity between these two sequences, the greater the absolute correlation between them, and vice versa. First,

$$= (x_i(1) - x_i(1), x_i(2) - x_i(1), \dots, x_i(6) - x_i(1))$$
$$= \left(x_i^0(1), x_i^0(2), x_i^0(3), x_i^0(4), x_i^0(5), x_i^0(6)\right), i = 0,1$$

Once the new sequences X_0^0 and X_1^0 are made, the starting point of the original sequences equal to zero, then:

$$|s_i| = \left|\sum_{k=2}^{5} x_i^0(k) + \frac{1}{2}x_i^0(6)\right|, i = 0,1$$
$$|s_1 - s_0| = |\sum_{k=2}^{5}\left(x_1^0(k) - x_0^0(k)\right) + \frac{1}{2}\left(x_1^0(6) - x_0^0(6)\right)|$$

The absolute Grey correlation degree between these two sequences is obtained as:

$$\varepsilon_{01} = \frac{1 + |s_0| + |s_1|}{1 + |s_0| + |s_1| + |s_1 - s_0|}$$

B. Calculation of Relative Grey Correlation Degree

The relative Grey correlation degree captures the rate of change of the reference sequence, X_0, and the comparison sequence, X_1, from their starting points. If the rate of change of these two sequences is similar, their relative correlation degree is also high, and vice versa. First,

$$X_i' = \left(\frac{x_i(1)}{x_i(1)}, \frac{x_i(2)}{x_i(1)}, \dots, \frac{x_i(6)}{x_i(1)}\right) = \left(x_i'(1), x_i'(2), \dots, x_i'(6)\right)\ i = 0, 1$$

Second, the sequences that make the starting point of the original sequences equal to zero are:

$$X_i'^0 = (x_i'(1) - x_i'(1), x_i'(2) - x_i'(1), \dots, x_i'(6) - x_i'(1))$$
$$= \left(x_i'^0(1), x_i'^0(2), \dots, x_i'^0(6)\right)\ i = 0,1$$

and third,

$$|s_i'| = \left|\sum_{k=2}^{5} x_i'^0(k) - \frac{1}{2}x_i'^0(6)\right|\ i = 0,1$$

$$|s_1' - s_0'| = |\sum_{k=2}^{5}(x_1'^0(k) - x_0'^0(k)) - \frac{1}{2}(x_1'^0(6) - x_0'^0(6))|$$

The relative Grey correlation degree between the two sequences is calculated as:

$$\rho_{01} = \frac{1+|s_0'|+|s_1'|}{1+|s_0'|+|s_1'|+|s_1'-s_0'|}$$

C. Calculation of the Comprehensive Grey Correlation Degree

The comprehensive Grey correlation degree captures all the merits of absolute and relative indexes. The relationship between these sequences can be measured as:

$$\gamma_{01} = \theta\varepsilon_{01} + (1 - \theta)\rho_{01}$$

where θ expresses the weight given to the absolute Grey correlation degree versus the relative Grey correlation degree. A value of 0.5 gives equal weight to the two indexes. The closer to 1 the γ_{01} value is, the stronger the correlation between the two factors. The closer to 0 γ_{01} is, the weaker the correlation is.

IV. Data Selection

An efficient industrial structure should facilitate a smooth transfer of inputs into products and services to meet market demand. Optimization of the industrial structure requires enhancing its resource transformation ability through sophistication and rationalization. The sophistication of the industrial structure addresses the development process by which the structure moves to a higher level. According to [27], industrial structure advancement can be indexed by the Hoffman coefficient. This is basically the ratio (M) of the net values of consumer goods over capital goods from the same economic sector. The lower the index the higher the degree of sophistication of the industrial structure.

Rationalization of the industrial structure, on the other hand, concerns the quality and efficiency attained by related industries [28]. The ratio (S) for secondary to tertiary industrial outputs is used here to represent a rationalization pattern. The lower the S index, the more adequate the industrial structure is. Finally, the arithmetic average of S and M represents the index of industrial structure optimization expressed as $E = 0.5\ (S + M)$. Thus, a smaller value of E represents a faster speed of industrial structural adjustment.

Data for OFDI were obtained from the Statistical Bulletin of P.R. China's Outward Foreign Direct Investment and industrial output values from the P.R. China Statistical Yearbook, the P.R. China Industry Economy Statistical Yearbook, and the P.R. China Industry Yearbook. Data for the indexes on light and heavy industrial output were gathered from the Industrial Output Value - P.R. China Industry Economy Statistical Yearbook, and the Industrial Sales Value - P.R. China Industry Statistical Yearbook, respectively. Secondary and tertiary industrial output values, and light and heavy industrial output values, for the Guangdong Province were obtained from the relevant volumes of the Guangdong Statistical Yearbook. For all measures, data were obtained for the six-year span from 2007 to 2012.

V. Results

Table I and Table II show the indexes for industrial structure rationalization (*S*) and industrial structure sophistication (*M*), along with the comprehensive index of industrial structure optimization for the P.R. China and Guangdong Province.

TABLE I: Indexes of Industrial Optimization Structure for P.R. China ($100 Million)

	Year					
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Rationalization						
Secondary Industry	17,034	21,752	23,148	28,297	33,345	37,626
Tertiary Industry	15,074	19,174	21,738	26,215	31,044	37,111
***S* index**	1.130	1.135	1.065	1.079	1.074	1.014
Sophistication						
Light Industry	16,196	21,231	23,715	30,213	35,961	41,770
Heavy Industry	38,653	52,826	56,801	75,282	91,765	10,3797
***M* index**	0.419	0.402	0.418	0.401	0.392	0.402
Comprehensive						
***E* = 0.5 (*S* + *M*)**	0.775	0.768	0.741	0.740	0.733	0.708

TABLE II: Indexes of Industrial Optimization Structure for Guangdong Province ($100 Million)

	Year					
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Rationalization						
Secondary Industry	2,167	2,701	2,852	3,475	4,001	4,432
Tertiary Industry	1,910	2,383	2,651	3,128	3,646	4,243
***S* index**	1.137	1.134	1.076	1.111	1.098	1.045
Sophistication						
Light Industry	2,873	3,655	3,919	4,963	5,4471	5,731
Heavy industry	4,607	5,896	6,107	7,997	8,90.5	9,566
***M* index**	0.624	0.620	0.642	0.621	0.618	0.599
Comprehensive						
$E = 0.5\,(S + M)$	0.880	0.877	0.859	0.866	0.855	0.822

The OFDI stock was used over the OFDI flow because of data availability. The comparison sequence is the ratio of the OFDI stock to GDP. This measure was chosen to take into consideration the difference among various units of output, inflationary factors, and price variability in order to better understand how OFDI actually influenced industrial development at the provincial and national levels.

The empirical analysis is divided into two parts. One examines the impact of P.R. China's OFDI on the optimization of the national industrial structure and the other examines the same effect on the provincial industrial structure. If the comprehensive Grey correlation degree between the reference sequence and the comparison sequence is close to 1, this indicates a strong correlation between the reference sequence and the comparison sequence; or, in other words, that OFDI accelerates the optimization and upgrading of the industrial structure.

As Table III shows, the comprehensive Grey correlation degree between the national OFDI stock and the index of domestic industrial structure for P.R. China is above 0.7, and the comprehensive Grey correlation degree between the provincial OFDI stock and the index of industrial structure for Guangdong Province is above 0.9. In addition, the comprehensive Grey correlation degree between P.R. China's OFDI and the comprehensive index of domestic industrial structure optimization is 0.7256, which is 23.5 percent below the equivalent index of 0.9483 for Guangdong Province.

TABLE III: Grey Correlation Results in Terms of OFDI

Comparison Sequence	Absolute	Relative	Comprehensive
P.R. China			
Rationalization Index	0.8064	0.6111	0.7097
Sophistication index	0.8805	0.6094	0.7449
Comprehensive Index	0.8406	0.6106	0.7256
Guangdong Province			
Rationalization Index	0.8646	0.9884	0.9265
Sophistication index	0.9785	0.9317	0.9551
Comprehensive Index	0.9139	0.9826	0.9483

TABLE IV: Ratios of Output to GDP for Main Industries P.R. China and Guangdong Province

	Year					
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
P.R. China						
Primary Industries	0.1077	0.1073	0.1033	0.1010	0.1004	0.1008
Secondary industries	0.4734	0.4745	0.4624	0.4667	0.4659	0.4527
Tertiary Industries	0.4189	0.4182	0.4343	0.4324	0.4337	0.4465
Guangdong Province						
Primary Industries	0.0534	0.0536	0.0509	0.0497	0.0501	0.0499
Secondary industries	0.5037	0.5028	0.4919	0.5002	0.4970	0.4854
Tertiary Industries	0.4430	0.4436	0.4572	0.4501	0.4529	0.4647

Table IV reveals no large differences between Guangdong Province and the P.R. China in terms of employment generation and production value in the structure of tertiary industries. However, industrial outputs and employment rates for both primary and secondary industries are higher for Guangdong province than for P.R. China. These findings are consistent with the findings for developed countries that are absorbing the benefits of OFDI (i.e., a wide resource base) in order to gain competitive advantages and attain dominant market positions. Moreover, countries with this profile are able to capture and return home the technology spillover effects caused by OFDI.

The impact of OFDI on the industrial structure of the P.R. China is related to the prevalent managerial and technical levels in the home countries. Specifically, highly developed countries tend to fully absorb the benefits of OFDI because their multinational corporations are able to gain competitive advantages by maintaining a dominant market position, obtaining strategic resources, and capturing technology spillover effects.

Table V shows the composition of employment in the P.R. China versus Guangdong Province by three industry strata. The composition of employment in P.R. China has clearly changed over time. The rate of employment in primary industry decreased by roughly 7 percent while the rates of employment in secondary and tertiary industries both increased, by approximately 3 and 4 percent, respectively. Guangdong Province experienced a similar pattern. The rate of employment in primary industry decreased by almost 6 percent while the rates of employment in secondary and tertiary industries both increased by roughly 3 percent each. These figures confirm that optimization and upgrading of the industrial structure has occurred in both P.R. China and Guangdong Province.

TABLE V: COMPOSITION OF EMPLOYMENT (%)

Years	2007	2008	2009	2010	2011	2012
P.R. China						
Primary Industry	40.8	39.6	38.1	36.7	34.8	33.6
Secondary industry	26.8	27.2	27.8	28.7	29.5	30.3
Tertiary Industry	32.4	33.2	34.1	34.6	35.7	36.1
Guangdong Province						
Primary Industry	29.3	28.8	26.6	24.5	24.0	23.8
Secondary industry	39.0	39.0	40.3	42.4	42.4	42.1
Tertiary Industry	31.6	32.3	33.1	33.2	33.7	34.2

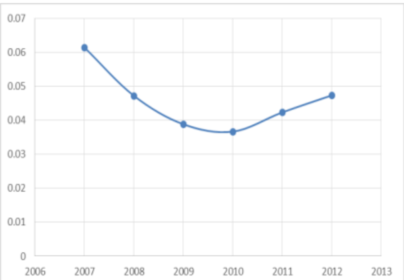

Fig. 1. Guangdong OFDI as a proportion of P.R. China OFDI.

Fig. 1 shows the annual change from 2007 to 2012 in the ratio of OFDI for Guangdong Province to OFDI for P.R. China. In Guangdong Province OFDI developed relatively slowly between 2007 and 2010, then gradually accelerated afterwards. Development of OFDI for the P.R. China outpaced that for Guangdong Province until 2010, after which the reverse occurred. Although OFDI flows for both P.R. China and Guangdong Province increased during those years, the flow of OFDI to P.R. China gradually plateaued and was insufficient to sustain overall economic growth. In contrast, OFDI for Guangdong Province continued increasing annually, reflecting government efforts to achieve its growth potential.

Fig. 2 shows the comprehensive Grey index of Guangdong Province industrial structure optimization in Guangdong Province for the same years. The smaller the index value, the faster the adjustment toward a more advanced industrial structure. The gradual decline in OFDI in 2009–10 explains the slowdown in the speed of industrial adjustment in that period. The index of industrial structure optimization accelerated again once OFDI rebounded after 2010. Hence, the impact of OFDI on the optimization and upgrading of industrial structure grew as a result of an increase in the level of economic activity.

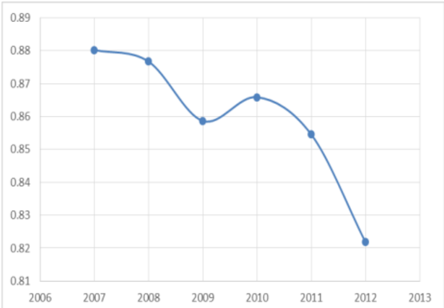

Fig. 2. Comprehensive grey index of industrial structure optimization for guangdong province

VI. CONCLUSIONS

Economic growth has accelerated in both the P.R. China and Guangdong Province. The comprehensive Grey index unveils a significant positive correlation between OFDI and the degree of optimization and upgrading of the industrial structure at both provincial and national levels. However, the extent of OFDI development potential and speed of industrial structure optimization that the P.R. China has accomplished pales in comparison to the achievements of Guangdong Province. The remainder of the P.R. China will be compelled to increase OFDI rapidly and significantly in order to incorporate advanced technologies at levels comparable with developed nations and maintain the rates of economic growth it has experienced in recent decades.

The results presented in this article are consistent with the existing theory of OFDI and confirm that the technology spillovers caused by OFDI greatly affect the optimization and upgrading of industrial structure in the host country. The speed of OFDI growth determines how rapidly the industrial structure is optimized and upgraded and the extent to which this promotes economic growth. Calculation of the various measures of the Grey correlation coefficients, comparison of output ratios, and composition of employment across industry strata for Guangdong Province all underscore that region's important contribution to overall economic growth in the P.R. China.

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