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Influence of mainland China's industrial structure evolution on the development of Cross-Strait trade: the grey relational analysis (2011–2020)

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ABSTRACT

Because of the complex and special political relationship between Mainland China and Taiwan. Cross-Strait trade is influenced by many variables, there has been a view that trade relations between Mainland China and Taiwan are more influenced by political factors. However, between the Cross-Strait, the trade volume has generally shown an upward development trend, especially since 2001. Therefore, the political factors can hardly explain the facts, and economic factors, especially industrial structure factors in Mainland China play an important role in Cross-Strait trade. Based on the small sample data since 2001, this study employed Grey Relational Analysis (GRA) method to verify the evolution of Mainland China's industrial structure and Cross-Strait trade. Based on the results show that the evolution of Mainland China's industrial structure strongly impacts the development of Cross-Strait trade. The tertiary industry has the strongest correlation with Cross-Strait trade, followed by the secondary and primary industries. Furthermore, the evolution of the mainland's industrial structure will expand as well as accelerate the imbalance of Cross-Strait trade.

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1. Introduction

Over the past 40 years of reform and opening up and the steady economic development of Mainland China and advancement of Cross-Strait relations, economic and trade relations between the two sides of the Strait have continuously improved. In 2020, the Cross-Strait trade volume was US$260.81, and industrial products dominated trade. Additionally, in terms of absorbing Taiwanese capital, as of December 2020, Mainland China has approved 117,186 Taiwanese-funded projects, accounting for 11.2% of the total amount of overseas investment actually absorbed by Mainland China. At present, Mainland China is Taiwan's largest trading partner, investment

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destination, and export destination, and second-largest import destination. Given the Cross-Strait exchange principle of 'business first and then politics', economic and trade exchanges are the main components of current exchanges, and the development of Cross-Strait trade is the core consideration.

Relevant empirical research suggests that changes in Mainland China's industrial structure have impacted Cross-Strait trade (Lin, 1997). Siyue et al. (2021) examined Taiwanese investment in Mainland China as it is an important part of Cross-strait economic cooperation. Kun et al. (2009) applied a computable general equilibrium model to investigate the potential economic effects of trade liberalization across the Taiwan Strait. The results reveal that Cross-Strait trade liberalization will have significant positive impacts on external trade, domestic investment and real GDP for the economies in this area in general and in Taiwan in particular. Broadly speaking, that the upgrading of industrial structure will promote trade liberalization. Evidence reveals that the unusually large amount of Hong Kong–Taiwan direct investment (HKTDI) cannot be fully appreciated without understanding China's location characteristics and differences between HKTDI and the Triad FDI. Four determinants of the dominant HKTDI in China are identified: China's export-promotion FDI strategy, its large pool of cheap labor, HKT's specific advantages in export-oriented FDI, and their unique links with China (the Chinese connections). Empirical results suggest that HKTDI was primarily motivated by low labor costs while FDI from the Triad was market-oriented (Kevin, 2005). Cheap labor is an important indicator of the low level of industrial structure development (Patricia, 2005).

Many factors affect the development of Cross-Strait trade. Existing research predicts that the impact of the evolution of Mainland China's industrial structure on Cross-Strait trade is worth discussing. To this end, this study uses statistical data on China's industrial structure and Cross-Strait trade from 2001 to 2020 and uses the grey relational analysis (GRA) to clarify the degree of this impact and its specific manifestations.

2. Literature review

Over the past years, more and more literatures on the relationship between trade and industry (Beylis et al., 2020; Xu & Wang, 2021; Michail, 2020; Yazdani & Pirpour, 2020; Li & Wu, 2019; Dwesar & Kesharwani, 2019), but there are relatively few studies on how the industry development affects inter-regional trade. Marianne and Michael (20032019) analyzed the extent to which the composition of a country's production and trade differs among its trade partners. Based on the findings, that industrialized countries have low dispersion for both output and trade. That is, an industrialized country's production structure tends to be similar to that of the rest of the world, and her export and import baskets are similar among all trading partners. Developing countries, by contrast, show high dispersion in production and trade. Aliaa (2017) analyzed the impact of the development level of industrial technology on intra industry trade. According to the research results, it is found that the higher the development level of industrial technology, the more obvious the promotion effect on the development of intra industry trade, while the lower the development level of industrial technology, the

weaker the promotion effect on intra industry trade Jiaochen (2016) found that the positive impacts of trade shocks on industry entry are enhanced by industry relatedness. This suggests trade shock-induced industrial branching is also path dependent and can be influenced by the pre-existing industry structure of a region.

In this study, we mainly focus on Mainland China's industrial structure on Cross-Strait trade, it is necessary to briefly review the relevant literature. Mainland China promoted a large number of economic policy to facilitate the CrossTaiwan Strait economic integration in the past decades. This informs some critical political-economic ways of thinking that have driven the economic development (Zheng, 2021). Also, Mainland China markets have more influence on Taiwan by showing that Mainland China macroeconomic variables have a significant impact on Taiwanese macroeconomic variables, but the same cannot be said for the reverse. By continuing the trend of gradually reducing restrictions in sectors outside the service industry, Taiwan and Mainland China show great potential for increasing not only Cross-Strait economic interdependence but also peaceful prosperity in the future (Chiang, 2017). Taiwan was the first place to adopt an export-oriented trade strategy, with Mainland China as the main factor (Douglas, 2021). Taiwan and Mainland China are nevertheless antagonistic in the political arena (Chien, 2003). Taiwan has had discriminatory trade and investment policies towards Mainland China, severely limiting economic engagement (Shiro, 2013). However, Cross-Strait trade is rising rapidly in the context of industrial upgrading in Mainland China.

According to the existing literature, it can be found that the change of regional industrial structure has a direct impact on the trade between regions, but there is no microscopic analysis of the specific impact of primary, secondary and tertiary industries on inter-regional trade. This study adopts the GRA method to judge whether the relationship is close, based on the similarity of the curve geometry between the system feature sequence and the observed system sample sequence. The closer the curve geometry, the greater the correlation degree; if the relationship is small, the connection is not close. In essence, the GRA is a quantitative description and comparison method for dynamic development. The basic task is to analyse and determine the degree of influence between factors based on the microscopic or macroscopic geometric closeness of the behavioural factor sequence.

For the analysis, Cross-Strait trade is regarded as a grey system based on the sample data of the industrial structure, and the correlation degree is used to describe the strength, size, and order of the relationship between the two factors. Compared with traditional multi-factor analysis methods (correlation, regression, etc.), this can determine the law reflecting the evolution of the system according to its disordered time sequence with a small amount of data and does not require a typical distribution and computational workload Small is a systematic analysis method worthy of promotion and application.

3. Methods

3.1. The GRA model

The GRA is among the main components of the grey system theory (Hongtao & Ruisi, 2021). It constructs a reference series and comparison series and, thereafter,

compares the similarity of the geometric shapes of the two series to determine whether the connection is close. The closer the curve, the greater the degree of correlation between the sequences.

First, it is necessary to construct a reference sequence set as: $x_0(j)$

$$x_0(j) = \{x_0(1), x_0(2), x_0(3), \ \ldots \ x_0(m)\} \tag{1}$$

$j = 1, 2, \ldots, m,$ respectively indicate different moments. As statistical data from 2001 to 2020 are used here, for a total of 20 years, so this reference series set can be defined by the following formula:

$$x_0(j) = \{x_0(1), x_0(2), x_0(3), \ \ldots \ x_0(20)\} \tag{2}$$

$x_0(j), = 1, 2, \ldots, 20,$ represent the total value of Cross-Strait trade from 2001 to 2020.

Second, in the GRA, it is necessary to construct a sub-series which is compared with the reference series, it is called the comparative series $x_i(j)$. To illustrate the impact of the evolution of China's mainland industrial structure on Cross-Strait trade and examine whether industry is an important factor affecting Cross-Strait trade, that is, whether there is a correlation between them, and the industrial value is used here as the gross domestic product (GDP) to represent, then the first comparison sequence set to be constructed is denoted as $x_g(j)$.

Additionally, for illustrating the relationship between the three industries in the industrial structure and Cross-Strait trade, there are three other sets of comparative series that need to be defined here, which are respectively denoted as $x_1(j)$ (primary industry), $x_2(j)$ (secondary industry), $x_3(j)$ (tertiary industry). Then the equations can be expressed as:

$$x_g(j) = \{x_g(1), x_g(2), \ x_g(3), \ \ldots \ x_g(20)\} \tag{3}$$

$$x_1(j) = \{x_1(1), x_1(2), x_1(3), \ \ldots \ x_1(20)\} \tag{4}$$

$$x_2(j) = \{x_2(1), x_2(2), x_2(3), \ \ldots x_2(20) \tag{5}$$

$$x_3(j) = \{x_3(1), x_3(2), x_3(3), \ \ldots \ x_3(20)\} \tag{6}$$

Thirdly, it is necessary to initialize each evaluation index. Due to the different meanings and purposes of each indicator, each indicator usually has a different dimension and order of magnitude. In order to facilitate comparison, it is often necessary to perform non-dimensional processing on the quantity set of each indicator according to the following formula to reduce the possibility The random interference factors:

$$x_i = \left\{ \frac{x_i(1)}{x_i(1)}, \ \frac{x_i(2)}{x_i(1)}, \ \ldots \ \frac{x_i(3)}{x_i(1)}, \ \frac{x_i(n)}{x_i(1)} \right\} \tag{7}$$

$\frac{x_i(n)}{x_i(1)}$ Indicates that the statistical value of each statistical indicator is compared with the first statistical value.

Finally, it is necessary to calculate the correlation coefficient of the comprehensive evaluation. According to the grey system theory, we define the comparison sequence $x_i(j)$, and series $x_0(j)$ in indicators $x_i(j)$, the correlation coefficient is:

$$\xi_{0i}(j) = \frac{\min_i \min_j |x_0(j) - x_i(j)| + p \bullet \max_i \max_j |x_0(j) - x_i(j)|}{|x_0(j) - x_i(j)| + p \bullet \max_i \max_j |x_0(j) - x_i(j)|} \tag{8}$$

p distinguishes between the coefficients and weakens the distortion of the absolute difference value which is too large, so as to improve the significance of the difference between the correlation coefficients. It is a given coefficient, that generally takes a value between 0and1, that is, $p = 0.5$.

As the correlation coefficient is for the comparison series and the reference series at the moment j of relative difference, so it is more than one, then the information is too scattered and it is not convenient to compare as a whole. Therefore, it is necessary to concentrate the correlation coefficients at each moment into one value, that is, to find the average value and express it as the number of correlation degrees. The degree of association is recorded as r_{0i}, and its expression is:

$$r_{0i} = \frac{1}{N} \sum_{j=1}^{n} \xi_0(j) \tag{9}$$

r_{0i} is the relevance of the series to the reference series $(0 < r_{0i} < 1)$, the closer r_{0i} is closer to 1, the greater the degree of relevance. In the formula, N is the number of data points in the comparison sequence.

3.2. Index of industrial structure evolution

The regularity of the evolution trend of the industrial structure is a process of transition from low to high levels as well as a process of positive development of history and logical sequence. This process of transformation and evolution is termed industrial structure supererogation.

Industrial structure supererogation is an important indicator of the optimization of the industrial structure. It refers to the dynamic development process of the transition of the industrial structure. Analyzed from the perspective of the evolution of industrial structures, the heightened industrial structure is embodied in the sequential evolution of the entire industrial structure from the Primary industry to the tertiary industries. Assuming that an industrial structure system consists of n industrial sectors, h_i represents the value of i industrial sector, and p_i is the proportion of the i industrial sector in the output of the entire industrial structure system(GDP). The industrial structure supererogation index H is:

$$H = \sum_{i}^{n} p_i h_i \qquad n = 1, 2, \cdots n \tag{10}$$

Table 1. Total Cross-Strait trade, GDP and three industry indicators in each year after initial value.

Year	Total Cross-Strait trade	GDP	Primary industry output value	Secondary industry output value	Tertiary industry output value
2001	1.00	1.00	1.00	1.00	1.00
2002	1.38	1.10	1.05	1.09	1.12
2003	1.80	1.24	1.10	1.26	1.26
2004	2.42	1.46	1.36	1.49	1.46
2005	2.82	1.69	1.42	1.77	1.69
2006	3.33	1.98	1.52	2.09	2.00
2007	3.85	2.44	1.81	2.54	2.51
2008	4.00	2.88	2.14	3.01	2.96
2009	3.28	3.14	2.23	3.18	3.34
2010	4.50	3.72	2.57	3.78	3.91
2011	4.95	4.40	3.01	4.45	4.63
2012	5.22	4.86	3.32	4.75	5.23
2013	6.10	5.35	3.61	5.04	5.91
2014	6.13	5.78	3.70	5.49	6.89
2015	5.83	6.19	3.86	5.70	7.80
2016	5.55	6.68	4.03	5.99	8.64
2017	6.17	7.40	3.94	6.72	9.60
2018	7.00	8.12	4.10	7.37	11.04
2019	7.05	8.90	4.47	7.69	12.07
2020	8.06	9.16	4.93	7.76	12.49

Source: The Cross-Strait trade statistics in table 1 are taken from the General Administration of Customs of China: http://guangzhou.customs.gov.cn/customs/302249/zfxxgk/2799825/302274/index.html and the industry statistics are taken from the respective years' statistical yearbooks (2001-2020).: http://www.stats.gov.cn/tjsj/ndsj/?ref=bukesci.com
Note: All the figures are normalized.

Here we assign h_i, the industrial value of the primary, secondary, and tertiary industries as 1, 2, and 3 according to the characteristics of the industrial structure's advancement process, and calculate values from 2001 to 2020 according to the formula. The results are shown in the Table 4. The table can partially reflect to a certain extent the development status of the country's advanced industrial structure.

4. Data source and statistical description

The data in this article are divided into two parts: the Cross-Strait trade data are derived from the General Administration of Customs of China, and the Mainland China industry statistics are from the '2020 China Statistical Yearbook'. Data selection is based on the availability and convenience of operation, and the GRA has relatively low data requirements, such as requiring a large amount of data or requiring data to be linear, exponential, or following a typical distribution. Therefore, the scope of the analysis data defined in the study is from 2001 to 2020. For effective analysis, the data are first initialised, as shown in Table 1.

5. Results and analysis

To explain the impact of the evolution of Mainland China's industrial structure on Cross-Strait trade, it is necessary to calculate the correlation coefficients of the GDP and the primary, secondary, and tertiary industries with Cross-Strait trade through models. The specific calculation results are shown in Table 2.

Table 2. Correlation coefficients of annual GDP and the three industries with Cross-Strait trade.

Year	GDP	Primary industry output value	Secondary industry output value	Tertiary industry output value
2001	1.00	1.00	1.00	1.00
2002	1.10	1.05	1.09	1.12
2003	1.24	1.10	1.26	1.26
2004	1.46	1.36	1.49	1.46
2005	1.69	1.42	1.77	1.69
2006	1.98	1.52	2.09	2.00
2007	2.44	1.81	2.54	2.51
2008	2.88	2.14	3.01	2.96
2009	3.14	2.23	3.18	3.34
2010	3.72	2.57	3.78	3.91
2011	4.40	3.01	4.45	4.63
2012	4.86	3.32	4.75	5.23
2013	5.35	3.61	5.04	5.91
2014	5.78	3.70	5.49	6.89
2015	6.19	3.86	5.70	7.80
2016	6.68	4.03	5.99	8.64
2017	7.40	3.94	6.72	9.60
2018	8.12	4.10	7.37	11.04
2019	8.90	4.47	7.69	12.07
2020	9.16	4.93	7.76	12.49

Source: The Cross-Strait trade statistics in table 2 are taken from the General Administration of Customs of China: http://guangzhou.customs.gov.cn/customs/302249/zfxxgk/2799825/302274/index.html and the industry statistics are taken from the respective years' statistical yearbooks (2001-2020): http://www.stats.gov.cn/tjsj/ndsj/?ref=bukesci.com
Note: The data processing in the table is assigned as $p = 0.5$.

According to the annual correlation coefficients of the three industries calculated in Table 2, the correlation of the GDP and each industry with Cross-Strait trade can be calculated according to the correlation formula (Table 3).

The correlation between GDP and Cross-Strait trade is $r_{0g} = 0.57$; The correlation between the primary industry and Cross-Strait trade is $r_{01} = 0.50$; that between the secondary industry and Cross-Strait trade is $r_{02} = 0.56$; and that between the tertiary industry and Cross-Strait trade is $r_{03} = 0.70, > r_{02} > r_{01}$.

Based on the above analysis, the following results can be drawn:

5.1. Mainland china's industries have a strong correlation with Cross-Strait trade(result 1)

Regarding the degree of correlation between Mainland China's industries and Cross-Strait trade, the GDP (the gross value of the three industries) is used to calculate the degree of correlation between the two. First of all, from Figure 1, it can be intuitively found that the GDP after initial value processing is basically the same as the growth trend of Cross-Strait trade, which also shows that there may be a correlation between the two. In order to test this conclusion, the correlation model is calculated as $r_{0g} = 0.57$, This verifies the correlation between Mainland China's industries and Cross-Strait trade, Simultaneously, based on experience, when $p = 0.5$, the correlation between the two factors is greater than 0.6, and the correlation is considered significant Based on this, we can see that the development of Cross-Strait trade and Mainland China's industry is an important influencing factor. Cross-Strait trade received an impetus after Taiwan allowed visits to relatives in Mainland China in the late 1980s; in 2013, the total Cross-Strait trade was worth approximately US$200

Table 3. The correlation between GDP, and industry, and Cross-Strait trade.

GDP and Cross-Strait trade	r_{0g}	0.57
The primary industry and Cross-Strait trade	r_{01}	0.50
The secondary industry and Cross-Strait trade	r_{02}	0.56
The tertiary industry and Cross-Strait trade	r_{03}	0.70

Source: The Cross-Strait trade statistics in table 3 are taken from the General Administration of Customs of China: http://guangzhou.customs.gov.cn/customs/302249/zfxxgk/2799825/302274/index.html and the industry statistics are taken from the respective years' statistical yearbooks (2001-2020).: http://www.stats.gov.cn/tjsj/ndsj/?ref=bukesci.com.
Note: The correlation is calculated by the equation (8).

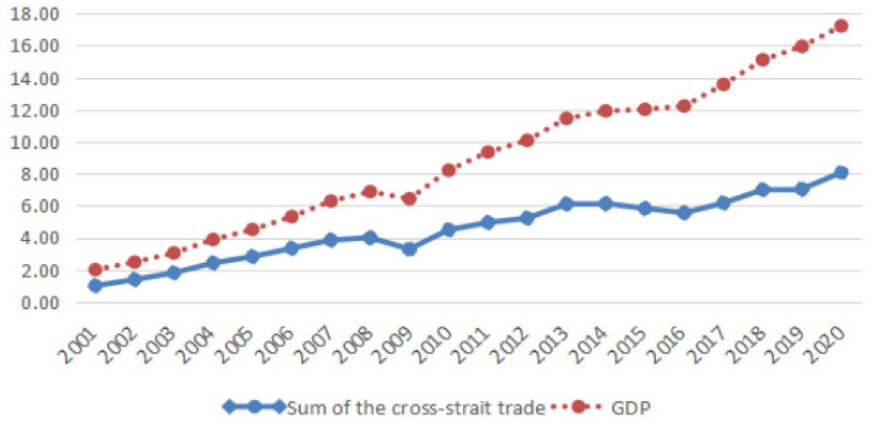

Figure 1. The trend of GDP and Cross-Strait trade.
Source: The Cross-Strait trade statistics in figure 1 are taken from the General Administration of Customs of China: http://guangzhou.customs.gov.cn/customs/302249/zfxxgk/2799825/302274/index.html and the industry statistics are taken from the respective years' statistical yearbooks (2001-2020).: http://www.stats.gov.cn/tjsj/ndsj/?ref=bukesci.com.
Note: All the figures are normalized and demonstrated.

billion. The scale of Cross-Strait trade is expected to expand mainly because of the continuous optimisation of the industrial structure and investment environment in Mainland China, which has triggered the free flow of products and production factors aCross the Strait, driven by large-scale 'landing' investments of Taiwanese businessmen.

5.2. Following the evolution of China's Mainland industrial structure, the tertiary industry has the largest correlation with Cross-Strait trade, followed by the secondary and primary industries (result 2)

In Figure 2, the trend of change of the total Cross-Strait trade after initial value processing is closest to that of the tertiary industry, followed by the secondary and primary industries. Based on the geometric meaning of the GRA, this trend chart shows the largest correlation between Cross-Strait trade and the tertiary industry, followed by the secondary and primary industries. This result is consistent with the result after the calculation and verification of the correlation formula $(r_{03}>r_{02}>r_{01}$. Additionally, according to this result, it can be inferred that in the process of optimisation of the industrial structure of Mainland China, as the proportion of the tertiary industry increases, the degree of its influence on Cross-Strait trade will also increase. This impact will be embodied in the rapid development of the tertiary

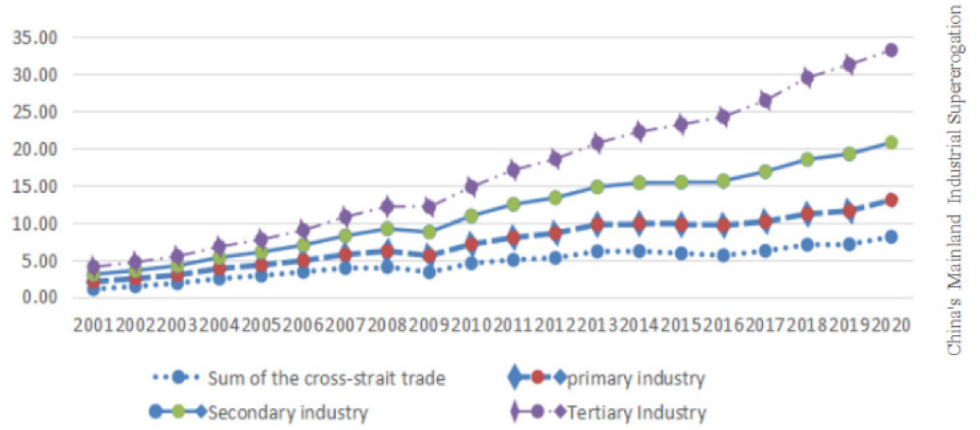

Figure 2. The trend of the output value of the three industries and the Cross-Strait trade.
Source: The Cross-Strait trade statistics in figure 2 are taken from the General Administration of Customs of China: http://guangzhou.customs.gov.cn/customs/302249/zfxxgk/2799825/302274/index.html and the industry statistics are taken from the respective years' statistical yearbooks (2001-2020).: http://www.stats.gov.cn/tjsj/ndsj/?ref=bukesci.com.
Note: All the figures are normalized and demonstrated.

Table 4. Statistics on the proportions of Cross-Strait trade, industry, and GDP.

year	Sum of the Cross-Strait trade	Export to Taiwan	Import from Taiwan	Trade deficit of Cross-Strait	Primary industry	Secondary industry	Tertiary industry	H
2001	323.4	50.0	273.4	−223.4	14.0	44.8	41.2	2.27
2002	446.7	65.9	380.8	−314.9	13.3	44.5	42.2	2.29
2003	583.6	90.0	493.6	−403.6	12.3	45.6	42.0	2.30
2004	783.2	135.5	647.8	−512.3	12.9	45.9	41.2	2.28
2005	912.3	165.5	746.8	−581.3	11.6	47.0	41.3	2.30
2006	1078.4	207.4	871.1	−663.7	10.6	47.6	41.8	2.31
2007	1244.8	234.6	1010.2	−775.6	10.2	46.9	42.9	2.33
2008	1292.2	258.8	1033.4	−774.6	10.2	47.0	42.9	2.33
2009	1062.3	205.1	857.2	−652.1	9.6	46.0	44.4	2.35
2010	1453.7	296.8	1156.9	−860.1	9.3	46.5	44.2	2.35
2011	1600.3	351.1	1249.2	−898.1	9.2	46.5	44.3	2.35
2012	1689.6	367.8	1321.8	−954	9.1	45.4	45.5	2.36
2013	1972.8	406.4	1566.4	−1159.93	8.9	44.2	46.9	2.38
2014	1983.1	462.8	1520.3	−1057.5	8.6	43.1	48.3	2.40
2015	1885.6	449.0	1436.6	−987.6	8.4	40.8	50.8	2.42
2016	1796.0	403.7	1392.3	−988.6	8.1	39.6	52.4	2.45
2017	1993.9	439.9	1554.0	−1114.1	7.5	39.9	52.7	2.45
2018	2262.4	486.5	1776.0	−1289.51	7.0	39.7	53.3	2.46
2019	2280.8	550.8	1730.0	−1179.2	7.1	39.0	53.9	2.47
2020	2608.1	601.4	2006.6	−1405.2	7.7	37.8	54.5	2.47

Source: The Cross-Strait trade statistics in table 4 are taken from the General Administration of Customs of China: http://guangzhou.customs.gov.cn/customs/302249/zfxxgk/2799825/302274/index.html and the industry statistics are taken from the respective years' statistical yearbooks (2001-2020).: http://www.stats.gov.cn/tjsj/ndsj/?ref=bukesci.com.
Note: H is the index of industrial supererogation, calculated by equation(10).

industry in Mainland China, which will force the development of the secondary industry to seek more import substitution methods, especially to accelerate the import of Taiwan's industrial manufacturing products. Similarly, the development level of the tertiary industry on both sides of the strait is quite different, and the complementary effects of the advantages are obvious. The rapid development of the tertiary industry in Mainland China will also drive the import of Taiwan's modern service industry

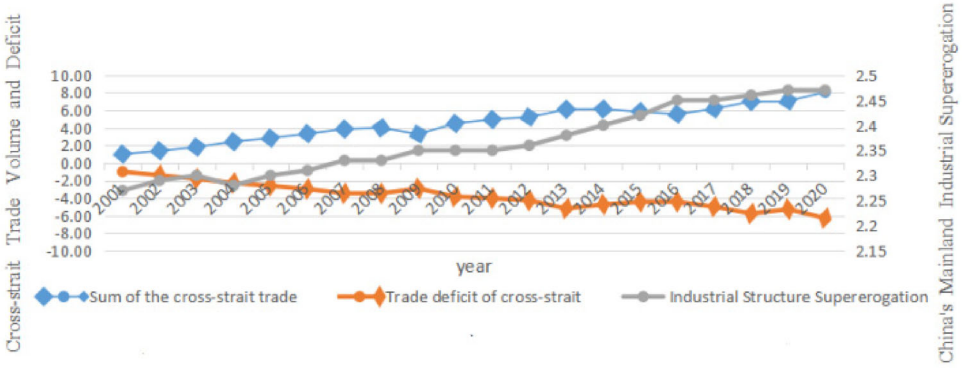

Figure 3. China's Mainland industrial structure supererogation and Cross-Strait trade volume and deficit trends (2001–2020).
Source: The Cross-Strait trade statistics in figure 3 are taken from the General Administration of Customs of China: http://guangzhou.customs.gov.cn/customs/302249/zfxxgk/2799825/302274/index.html and the industry statistics are taken from the respective years' statistical yearbooks (2001-2020).: http://www.stats.gov.cn/tjsj/ndsj/?ref=bukesci.com
Note: H is the index of industrial supererogation, calculated by equation (10), Cross-Strait trade volume and deficit is normalized.

products and further expand the scale of Cross-Strait trade. According to the planning requirements of China's economic development strategy, the development of the primary and secondary industries is more in the direction of optimising the structure, and their proportion of the overall social and economic development will continue to be maintained at a stable development level. Consequently, the sensitivity and relevance of the primary and secondary industries to the development of Cross-Strait trade are slightly lower than those of the tertiary industry.

5.3. The evolution of China's Mainland industrial structure will accelerate the trade imbalance between the two sides of the Strait, simultaneously expanding the scale of trade between the two sides (result 3)

For many years, China's Mainland has experienced a Cross-Strait trade deficit, whereas Taiwan has experienced a surplus; this trade imbalance is accelerating (Table 4) because of several factors. The restrictive economic and trade policies of the Taiwanese authorities implemented by the China's Mainland are mainly responsible for this huge trade deficit. Taiwanese authorities have adopted an unreasonable policy of 'lean export and strict import' in Cross-Strait trade, strictly restricting the import of products from Mainland China, especially large imports of agricultural and industrial raw materials, electromechanical ships, and household appliances produced in Mainland China. Certain commodities, such as supplies and high-value-added products, enter the island, which directly affects Mainland China's exports to Taiwan. In addition to the policy factors, industrial structure also affects Cross-Strait trade. Conclusion 2 also states that the evolution (advanced) of China's industrial structure has accelerated the imbalance of Cross-Strait trade. From a long-term perspective, the evolution of the trade structure will inevitably be accompanied by the evolution of the industrial structure and the development of industry. Alternatively, the evolution of the trade structure is the inevitable result of the evolution of the industrial structure. In this sense, the industrial structure of a country/region has a decisive influence

on its trade structure. Based on the case of US industry and trade development relationship, that the current continuous expansion of the US trade deficit is an external reflection of the continuous adjustment of the real economic structure. The import of manufactured products has weakened its export capacity. Accompanying the increase in the share of the service industry is the transfer of manufacturing to overseas locations, and this industrial transfer has also contributed to the US trade deficit. The evolution of the industrial structure increases the trade deficit of a country/region. Therefore, it is important to consider the specific relationship between the evolution of China's industrial structure and Cross-Strait trade (see Table 4 and Figure 3).

Table 4 shows that in Cross-Strait trade, China's trade deficit with Taiwan has continued to expand over the last 20 years. Additionally, from the perspective of the evolution of the tertiary industry structure in Mainland China, the primary industry accounts for an increasingly smaller proportion of China's economic output, the secondary industry has remained stable, and the tertiary industry's overall share has increased. This overall trend of change shows that the industrial structure of Mainland China is constantly optimising, that is, it is constantly advancing. Regarding the level of industrial advancement in Mainland China, the specific development trend is shown in Figure 3, which also shows that the development trend of the advanced level of China's Mainland industrial structure and the total trade volume aCross the Taiwan Straits tend to be consistent, indicating a strong correlation. The calculation and verification of the correlation formula shows that the correlation is 0.57 and that there is a significant correlation, which means that the optimisation of the industrial structure is conducive to the expansion of the trade scale. Judging from the development trends of the indicators in Table 4 and Figure 3, as the level of advanced industrial structure in Mainland China increases, the Cross-Strait trade deficit will continue to expand, which can explain why the advancement of China's industrial structure will accelerate the imbalance of Cross-Strait trade.

5.4. Empirical results from benchmark model

As a key finding of this paper, we construct the following benchmark model for further validation.

$$TT = \beta_0 + \beta_1 H + \beta_2 ECFA + \beta_3 FC + \beta_4 DOD + \beta_5 SE + \beta_6 RCPP \tag{11}$$

TT is the volume of Cross-Strait trade, H is the industrial structure supererogation index, $ECFA$ is the dummy variable of the Cross-Strait trade preference agreement, FC is the dummy variable of the financial crisis, DOD is the variable of the economic environment difference between the Cross-Strait, SE is the variable of exchange rate fluctuation, and $RCPP$ is the variable of the difference of capital per capita between Cross-Strait.

The details of the variables are as follows:

H is the industrial structure supererogation index defined above.

The dummy variable $ECFA$ is the trade preference agreement: On June 29, 2010, the Mainland China and Taiwan officially signed the Cross-Strait Economic Cooperation Framework Agreement ($ECFA$). Generally considered that $ECFA$

Table 5. Baseline regression results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
H	8990.851***	8770.985***	8792.779***	8704.698***	8953.271***	7734.259***
	(823.649)	(688.722)	(722.289)	(523.999)	(518.168)	(638.601)
ECFA		297.095***	293.072**	588.020***	537.842***	378.497***
		(98.827)	(104.841)	(106.784)	(105.512)	(107.670)
FC			19.374	−127.007	−134.359	−296.922***
			(120.983)	(95.267)	(90.279)	(98.171)
DOD				−4524.132***	−4097.098***	−2921.668**
				(1150.756)	(1119.279)	(1043.064)
SE					152.247	191.831**
					(91.912)	(78.734)
RCPP						7980.640**
						(3057.397)
R^2	0.8615	0.9042	0.8984	0.9466	0.9522	0.9662

Source: The SE statistics in table 5 are taken from the China Foreign Exchange Trade Center: https://www.chinamoney.com.cn/chinese/homefxrrm/. The RCPP is calculated based on the Helpman (1981).

Table 6. Descriptive statistics.

Variables	Observations	Mean	Std	Max	Min
H	20	2.366	0.067465	2.47	2.27
ECFA	20	0.3	0.470162	1	0
FC	20	0.2	0.410391	1	0
DOD	20	19.005	1.893611	22.7	16.1
SE	20	0.009201	0.393279	0.712500	−0.651667
RCPP	20	1.236877	0.018372	1.261216	1.190396

Note: Obtained by calculation, data from above table.

weakens tariff and non-tariff barriers, reduces institutional barriers, and drives trade expansion, investment expansion and employment growth in related industries in the short term. Therefore, whether it is in the actual effective period of ECFA (2010-2015) is used as a dummy variable to measure the impact of Cross-strait tax policies on trade volume, which is expected to be a positive effect.

Financial Crisis Dummy Variable Finance Crisis (*FC*): the dummy variable sets the period from 2008 to 2011 as the impact period of the financial crisis, and the negative effect is expected.

Difference economic environment between Cross-strait (*DOD*): The similar economic system environment can reduce the transaction cost in the trade process by reducing the information cost. Therefore, this paper uses the ratio of the index of global economic freedom (EFW), which is used to measure a country's (region's) economic environment and the degree of marketization, as a proxy variable to measure the impact of Cross-strait economic environment differences on trade volume. Negative effects are expected.

Exchange rate fluctuation variable (*SE*): In international trade, currency derivatives such as forwards and options are often used to hedge the risk of exchange rate fluctuations. However, that most of the companies on Mainland China and Taiwan using currency derivatives are speculative, and this may intensify exchange rate volatility increases. Therefore it is expected positive effect. (Table 5)

Ratio of Capital Per Person (*RCPP*): The Chamberlin-Heckscher-Ohlin theory believes that the difference in the abundance of factors of production in different countries or regions is the cause of international trade (Helpman,1981). Therefore,

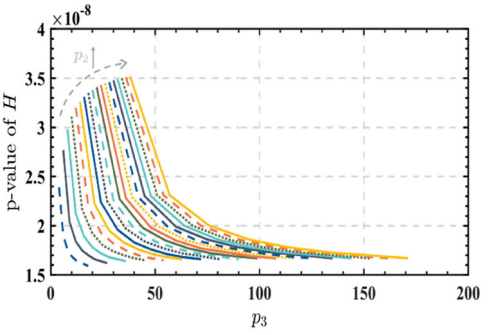

Figure 4. Robustness tests.
Note: Obtained by calculation, data from above table.

this paper uses the ratio of the capital ratio per capita on both sides of the Cross-Strait to reflect the difference, which is expected to be a positive effect.

For the time series data of this model, the White test rejects the null hypothesis of heteroskedasticity, so Table 6 only reports the results obtained from the baseline regression model estimated using the least squares method. In column (1), the estimated coefficient of H is 8990.851, and is significant at the 1% level. Columns (*2*)-(*6*) show that H is still significant at the 1% level after the control variables are gradually introduced. This indicates that the effect of industrial structure in Mainland China on Cross-strait trade volume is still significantly present after controlling for various factors. In addition, the signs of all coefficients are consistent with expectations, supporting result *5.1*.

In summary, it can be concluded from the results of the benchmark regression that the rationalization of the industrial structure of the Mainland China will have a significant impact on the Cross-strait trade volume, and result *5.1* is verified.

In addition, considering that the H-index requires the introduction of hyperparameters, we conduct a robustness test. The significance level of H was compared by changing the relative coefficients of the three major industries of the H index, as shown in Figure 4. When kept p_1, p_2 fixed, increasing the proportion of the tertiary industry makes the significance of H increase; when fixed the proportion p_1, p_2 and p_3, with the increase p_2 the significance of H decreases, but still far exceeds the significance of 1%. Therefore, it can be seen that the change in the parameters of the H index will not affect the conclusion as long as the importance principle of tertiary industry > secondary industry > primary industry is followed.

6. Conclusion

In contrast to existing macroscopic studies on the relationship between industry and trade across the Taiwan Strait, In contrast to existing macroscopic studies on the industry and trade relationship between Cross-Strait, economic policies and political factors have impact on Cross-Strait trade. The contribution of this paper can be seen as an empirical demonstration of the impact of industrial structural upgrading changes in mainland China on Cross-Strait trade through a microscopic perspective. This study used the GRA to investigate the impact of Mainland China's industrial

structure on Cross-Strait trade. The findings show that the Mainland industry plays a significant role in the development of Cross-Strait trade. Furthermore, the evolution of the Mainland's industrial structure will hasten the imbalance in Cross-Strait trade, while also facilitating trade expansion. Therefore, between the Mainland's current industrial transformation and upgrade and the development of Cross-Strait trade, it is necessary to expedite the Mainland's industrial advancement, thereby driving the expansion of Cross-Strait trade. Additionally, it is critical to prioritise the influence of Cross-Strait trade on the growth of the Mainland's industry while sustaining Cross-Strait trade coordination.

In the current state of Cross-Strait trade, Taiwan-funded enterprises—particularly those dominated by processing exports—can help upgrade the Mainland's export product structure while also assisting the Mainland's integration into the global industrial division and improving its industrial development. Overall, maintaining the coordinated development of Cross-Strait trade is critical for guiding Cross-Strait trade to influence the development of Mainland industries. In addition to the effects of Cross-Strait industrial development, the current imbalance in Cross-Strait trade is caused by Taiwan's excessive supervision of investment on the Mainland, resulting in the inability of 'two-way investment' to properly impact resource allocation. Consequently, improving the environment for the development of industries and trade aCross the Strait as well as maintaining the coordinated development of Cross-Strait trade has become critical for Cross-Strait economic development and achieving a win–win situation.

The study has some limitations. The GRA method used in this study, it can empirically prove the impact of industrial structure development in Mainland China on Cross-Strait trade. However, the sample data analyzed are still not sufficient. In addition, this study mainly uses the traditional GRA method, and a more comprehensive analysis of this topic can be conducted by the extended GRA method in the future.

Disclosure statement

No potential conflict of interest was reported by the author.

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