Heliyon 10 (2024) e36069

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

The factors driving industrial integration: A fuzzy set qualitative comparative analysis

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ARTICLE INFO

Keywords:
Modern service industry
Advanced manufacturing industry
Coupling coordination degree
Guangdong–Hong Kong–Macao greater bay area
Fuzzy set qualitative comparative analysis method

ABSTRACT

The integration of modern service and advanced manufacturing industries represents deep industrial reform and profound change in quality concepts, mechanisms, and practices. Integrating these two industries is important for achieving high-quality development and is an area of interest for policymakers and academia. This study analyzes the data of 11 regions in 2021 in the Guangdong–Hong Kong–Macao Greater Bay Area using the fuzzy set qualitative comparative analysis method from the configuration perspective. This study explores the effects of multiple factors, such as economic efficiency, technological innovation, and the policy environment, on improving the coupling coordination level of the modern service and advanced manufacturing industries, and analyzes the path selection of industrial integration development. Overall, economic efficiency, technological innovation, and policy environment factors are not necessary conditions for the integration development of the modern service and advanced manufacturing industries. The multiple impacts of economic efficiency, technological innovation, and policy environment form a multi-restructuring path that drives the integration of the two industries. Owing to the economic development level and resource endowment of different regions, the path dictating the degree of integration between the two industries varies by region. From a holistic perspective, all regions should strive to coordinate the multiple conditions of economic efficiency, technological innovation, and policy environment to break through objective constraints such as the government's conditions and external environment based on their own organizational conditions and resource endowments. Additionally, all regions should strengthen exchanges, cooperation, and integration mechanisms and implement complementary development and distinctive development in core cities in the Greater Bay Area. The results clarify the factors affecting industrial convergence in the Greater Bay Area, enriching existing research methods and laying a foundation for a decision-making theory of industrial integration development.

1. Introduction

In 2022, the 20th National Congress of the Communist Party of China report established that the focus of economic development should be on the real economy, promoting new industrialization, building a new system of high-quality and efficient service industries, and promoting deep integration of the modern service and advanced manufacturing industries. In February 2023, the Central Committee of the Communist Party of China and the State Council issued the outline for building a strong quality country. This outline is proposed to continuously promote the upgrading of industrial quality, strengthen the comprehensive quality management of the

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https://doi.org/10.1016/j.heliyon.2024.e36069
Received 12 June 2023; Received in revised form 4 August 2024; Accepted 8 August 2024
Available online 10 August 2024

industrial chain, accelerate the in-depth application of new technologies, such as big data, networks, and artificial intelligence, and promote the integrated development of the modern service and advanced manufacturing industries. The integrated development of modern service and advanced manufacturing industries is an inevitable trend in the in-depth development of industrial reform and an important way to accelerate the upgrading of industrial quality, improve international competitiveness, and achieve high-quality economic development.

Guangdong, Hong Kong, and Macao are geographically close and friendly and have close ties in services, trade, and the economy. Since the reform and opening up, especially after the return of Hong Kong and Macao to the motherland, the partnership of the Guangdong–Hong Kong–Macao Greater Bay Area has been deepening and developing; its economic strength and regional competitiveness have been significantly enhanced, and it has the basic conditions to become an excellent bay area and city cluster; therefore, there is a huge and underexploited integration potential between the two industries in the Guangdong–Hong Kong–Macao Greater Bay Area. Since the Guangdong–Hong Kong–Macao Greater Bay Area plays a key role in China's overall national strategy, the Chinese government will continue to promote the development of the region and support Hong Kong and Macao to better integrate into China's strategic planning.

To promote the integration of the two industries, it is necessary to clarify the factors that affect the development of the integration of the two industries and to study them using scientific methods. Therefore, this study systematically examines the existing literature on the influencing factors of industrial integration, sorts out the existing influencing factors of industrial integration, and constructs influencing factors that promote the deep integration of modern service and advanced manufacturing industries. Based on this, the influence of antecedents on industrial integration is also examined. Unlike previous studies, this study adopts the fuzzy set qualitative comparative analysis (fsQCA) method to seek the joint driving configuration that leads to industrial integration rather than dealing with each prerequisite separately. Second, this study used asymmetric technology to reexamine the relationship between industrial integration and influencing factors.

2. Literature review

In recent years, many studies have been conducted on the factors influencing industrial integration. With the improvement in the level of economic development and the continuous innovation of information (the Internet) and other high-tech industries, the geographical proximity between manufacturing and production services has gradually weakened, and interdependence has been increasing [1]. The levels of economic development and technological innovation are the main factors affecting industrial integration [2]. The development of industrial subsystems promoted industrial integration and coordination [3]. Technological innovation and integration are the main driving forces that promote industrial integration [4–6]. The boundary between manufacturing and production services has blurred due to the influence of the IT industry. Through informatization, the two realized mutual compatibility and extension, as well as cross-border interaction and integration [7–11]. Policy and technology are the driving forces of different types of industrial integration [12,13]. Driven by innovative factors, the deep integration of manufacturing and service industries is effectively promoted at the spatial and regional levels by improving productivity, increasing intermediate inputs, and reducing transaction costs, which are also the internal driving forces of advanced manufacturing and modern service integration [14]. Human resources, as the main body, are also soft powers supporting the development of industry and play a key supporting role in talent [15]. Regional governments should adhere to a two-way opening strategy, enhance the level of scientific and technological innovation, increase the talent introduction plan to optimize the regional human capital structure and formulate appropriate policies to promote the deep integration of manufacturing and production services [16]. The driving force of innovative elements is key to ensuring the coupling of production and manufacturing services [17]. Expanding opening-up, enhancing scientific and technological innovation capacity, expanding industrial scale, and improving industrial efficiency can promote the integration of production and manufacturing services [18]. Knowledge spillover, technological innovation, and the hierarchical division of labor have a positive impact on the collaborative agglomeration of manufacturing and production services [19].

In summary, the level of economic development is the cornerstone of the integration of the modern service and advanced manufacturing industries, which will affect the new round of the information technology revolution and scientific and technological innovation. With the continuous development of the economy and continuous innovation of science and technology, the low-price advantage alone can no longer meet the changing consumer demand, and a single enterprise cannot simultaneously consider whole product value chain links such as research and development design, production, operation, sales, and after-sales services. Therefore, the original independent service industry and the internal value chain of the manufacturing industry gradually decompose and infiltrate each other to achieve deep integration based on the complete integration between the two. Cultivating innovative, skilled, and versatile talent is an essential safeguard for the integrated development of the modern service and advanced manufacturing industries since the level of human capital determines the quality of workers and further affects the level of scientific and technological innovation. A good policy environment is one of the necessary conditions for promoting the upgrading and integrated development of the structure of production, teaching, research, and application and promoting the closer integration of various fields, including the loosening of government regulations and an increase in support for relevant fields. To a certain extent, opening up can promote scientific and technological progress and break technical barriers.

Hence, seven factors, including the levels of economic development, technological innovation, information-technology industry, productivity, human capital, government regulation, and openness, are interrelated and may jointly drive the process of the integration development of modern service and advanced manufacturing industries. A multi-reconfiguration path was formed to promote the coordinated development of the modern service and advanced manufacturing industries. The theoretical model constructed in this study is illustrated in Fig. 1.

The methods to research these driving factors include mainly the panel data model [3,20,21], structural equation modeling and artificial neural network modeling [22], an integration opportunity assessment tool [23], the hesitant-based Fuzzy DEMATEL [24], the analysis of variance technique [25], and the fsQCA [26–36]. Traditional statistical methods such as panel data models, regression, and structural equation models have unique advantages for solving symmetric problems; however, they may not apply to asymmetric problems such as specific scenarios or complex causal relationships. Contrarily, despite the current lack of application in the field of industrial convergence, the fsQCA method, as a powerful analytical method, can promote theoretical construction and test existing theories. The fsQCA accepts the asymmetric and nonlinear attributes of social phenomena and can explore conditional allocation, not limited to the existence or nonexistence of results. It presents asymmetric patterns that reflect the problems faced by real society and are not limited to linear and symmetric problems [32,37,38]. Furthermore, the fsQCA can analyze whether the necessary conditions leading to the occurrence of results are met, but cannot provide information on conditional necessity at different levels of results [37,38]. Considering that there may be asymmetric correlations between conditional variables and outcome variables in the study of industrial integration development in the Guangdong–Hong Kong–Macao Greater Bay Area, this study adopts asymmetric technology to re-examine the relationship between industrial integration and influencing factors in the Greater Bay Area and uses the fsQCA method to deeply analyze the influencing factors of industrial integration, aiming to provide more details of variable relations, especially the interaction results between different conditions [39,40], to provide a practical basis for promoting the in-depth integration of the two industries in the Guangdong–Hong Kong–Macao Greater Bay Area.

3. Fuzzy set qualitative comparative analysis (fsQCA)

3.1. Data sources

The data come from 11 regions in the Guangdong–Hong Kong–Macao Greater Bay Area, including the Hong Kong Special Administrative Region, the Macao Special Administrative Region, and Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing in Guangdong Province. The specific data mainly come from the relevant information collected in the Guangdong Statistical Yearbook in 2022, and refer to the website of the Hong Kong Special Administrative Region Government Statistics website and the Macao Special Administrative Region Government Statistics and Census Bureau website.

3.2. Variable selection and measurement

This study adopts the capacity coupling coefficient model to evaluate the coupling coordination degree between the modern service and advanced manufacturing industries in the Guangdong–Hong Kong–Macao Greater Bay Area in 2021 and takes the coupling coordination degree [41] between the modern service and advanced manufacturing industries as the outcome variable. The conditional variables include the levels of economic development (expressed as per-capita GDP), technological innovation (number of patents per 10,000 people), productivity (per-capita GDP of employed people), human capital (number of people with a college education per 100, 000 people), information technology industry (revenue of the computer, communications and other electronic equipment manufacturing and information transmission, software and information technology services industries), government regulation (proportion of government fiscal expenditure to GDP), and openness (proportion of foreign direct investment, and import and export trade value to GDP).

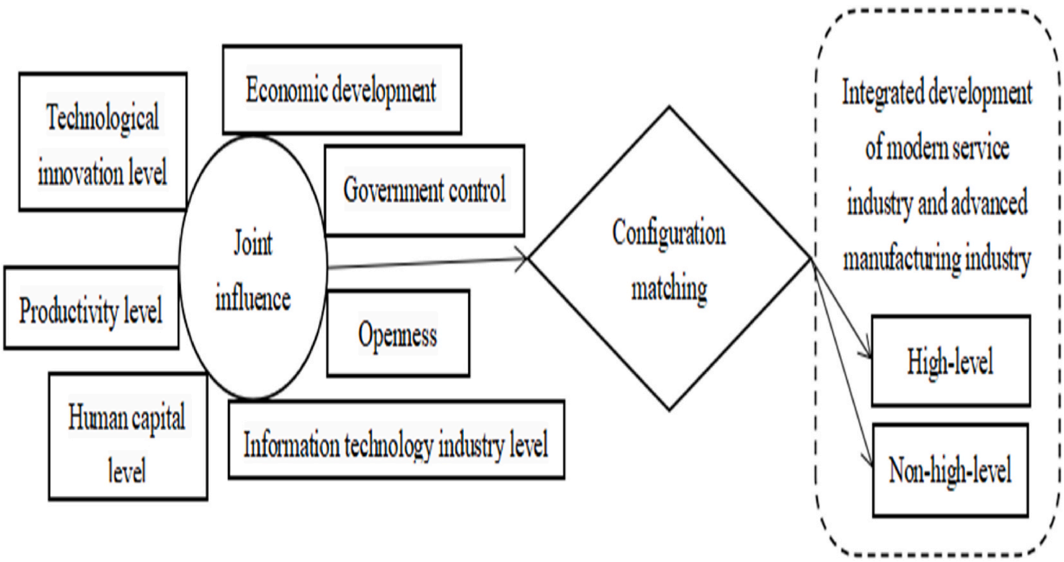

Fig. 1. Configuration model of factors affecting the integration and development of modern service and advanced manufacturing industries.

3.3. Summary of fuzzy set qualitative comparative analysis

When causality in the research phenomenon is both multiple - when an outcome has more than one cause - and conjunctive - when these causes work together to produce the outcome, fsQCA represents an appropriate method. Multiple conjunctural causations are identified by testing various combinations of antecedent conditions. Fuzzy set qualitative comparative analysis is a powerful tool for analysing causal complexity. FsQCA aims to identify necessary and sufficient conditions and the relationships that associate with the outcome of interest. We organize these best practices by the sequential stages of a typical FSQCA research study. Firstly, a calibration procedure must be performed, which entails converting data into measures of set membership via theoretical or substantial knowledge external to the empirical data. Secondly, a truth table must be constructed. The truth table describes all logically possible combinations of causal conditions and classifies the cases in accordance with the logically possible combinations. Thirdly, the method tries to reduce the number of rows in the truth table through the Quine-McCluskey algorithm, This algorithm uses Boolean algebra to attain a set of combinations of causal conditions, in which each combination is minimally sufficient to obtain the outcome [27].

4. Results and analysis

4.1. Data calibration

Measurements in the social sciences are usually based on the use of variables, which must rank situations in a way that (roughly) reflects the underlying theoretical structure and are evaluated according to specific sample statistics, such as mean and standard deviation. Conventional variables were uncalibrated; however, the sample data are only meaningful relative to each other. Fuzzy sets must be calibrated [37]. The fsQCA is based on a clear set qualitative comparative analysis, which transforms variables into fuzzy set variables that vary continuously within a 0–1 closed interval. The numerical values of these variables are referred to as membership. The direct method uses three qualitative anchors for structural calibration: full-set membership, full-set non-membership, and intermediate-set membership. Based on prior studies, in the direct calibration method, 95 %, 5 %, and 50 % can be set as thresholds for full-set membership, intermediate-set membership, and full-set non-membership, respectively [38]. Calibration data for the conditional and outcome variables are presented in Table 1.

4.2. Necessary conditions

After calibrating the variables, the truth table was constructed. A truth table directly examines the types of cases in a given dataset. It lists all the different combinations of causally relevant conditions and treats each combination as a different "kind" of case [37]. Before analyzing different combinations of conditions, it is necessary to test the "necessity" of each condition separately. This study first tests whether a single condition (including its non-set) constitutes the necessary condition for the integration development level of modern service and advanced manufacturing industries in the Guangdong–Hong Kong–Macao Greater Bay Area. The criterion for determining necessity is that if a condition variable always appears when the results are produced, the condition variable is considered a necessary condition for the production of the results. The determination index was measured to ensure consistency. If the consistency is greater than 0.9, then the variable is a necessary condition [38,39]. Table 2 presents the test results of the necessary conditions. In Table 2, the consistency test results of all condition variables are below 0.9; hence, no necessary condition affects the integration development level of modern service and advanced manufacturing industries in the Guangdong–Hong Kong–Macao Greater Bay Area.

4.3. Sufficient analysis of conditional configurations

Sufficient analysis of the impact of the relevant causal conditions was provided by examining all causal condition groups. Sufficient analysis can simultaneously examine the entire group rather than a single variable and simplify the initial truth table configuration process by specifying the frequency and consistency thresholds. The frequency threshold determines the condition groups that are related and can be appropriately selected between 1 and 2 (in small sample sizes (e.g., 10–50 cases), a threshold of 1 is appropriate). Since the number of samples in the Guangdong–Hong Kong–Macao Greater Bay Area is 11, this study chooses 1 as the frequency

Table 1
Calibration table.

Variable		Full-set membership	Intermediate-set membership	Full-set non-membership
Result Variable	Coupling coordination degree (y)	0.687	0.5	0.437
Condition variable	Economic development level (X1)	301393.421	127084.671	69495.291
	Technological innovation level (X2)	134.083	89.755	17.023
	Productivity level (X3)	55.419	20.231	13.032
	Human capital level (X4)	29838.000	16143.000	10312.500
	Information technology industry level (X5)	231781834.7	14996238	1667309.919
	Government control level (X6)	0.301	0.149	0.085
	Openness degree (X7)	5.837	0.765	0.279

Note: Primary indicator data are obtained from official sources. Subsequently, 95 %, 5 %, and 50 % were set as the thresholds for full-set membership, intermediate-set membership, and full-set non-membership, respectively.

Table 2
Necessary conditions test results.

Condition	High integration level		Low integration level	
	Consistency	Coverage	Consistency	Coverage
High economic level	0.800	0.861	0.356	0.429
Low economic level	0.470	0.395	0.885	0.832
High-tech innovation level	0.632	0.716	0.487	0.618
Low-tech innovation level	0.662	0.536	0.776	0.703
High productivity level	0.751	0.855	0.334	0.425
Low productivity level	0.495	0.399	0.886	0.800
High level of human capital	0.896	0.814	0.406	0.413
Low level of human capital	0.354	0.348	0.818	0.898
High information technology industry-level	0.699	0.748	0.458	0.549
Low information technology industry level	0.578	0.488	0.790	0.746
High degree of government control	0.686	0.675	0.465	0.512
Low degree of government control	0.505	0.457	0.705	0.715
High openness	0.657	0.740	0.439	0.553
Low openness	0.603	0.490	0.793	0.721

Note: Analysis of necessary conditions of the calibrated data.

threshold; while the consistency threshold indicates that a high score is considered highly consistent when it is shown in the results, sufficiency is also used to measure the configuration, and the minimum criteria and calculation methods are different from the necessary condition analysis. Schneider and Wagemann established that the consistency level for determining sufficiency should not be less than 0.75 [40], and 0.8 is selected as the high consistency criterion in this study. As the necessity analysis above did not identify any necessary conditions and there is no clear expectation or consensus conclusion on the relationship between the seven conditional variables and the outcome variables, a clear counterfactual analysis is impossible. Therefore, in the intermediate solution causal condition setting of truth table analysis, all variables are defaulted to "existing or missing" [42]. After establishing the truth table, algorithms were used to simplify the combination and minimize the solution. These solutions include complex, parsimonious, and intermediate solutions. The edge and key conditions in the configuration path can be distinguished by comparing the intermediate and parsimonious solutions. When a conditional variable appears in the intermediate and parsimonious solutions, it is considered a key condition, and when the conditional variable only appears in the intermediate solution, it is considered an edge condition. The core

Table 3
Truth table analysis: Parsimonious solution.

```
**********************
    *TRUTH TABLE ANALYSIS*
    **********************
    Model: y = f(X1, X2, X3, X4, X5, X6, X7)
Algorithm: Quine-McCluskey
— PARSIMONIOUS SOLUTION —
frequency cutoff: 1
consistency cutoff: 0.835106
```

	raw Coverage	unique Coverage	consistency
X1*~X7	0.485648	0	0.890498
X1*~X5	0.551146	0	0.894063
X1*~X2	0.581776	0	0.932099
X2*~X7	0.504912	0	0.742703
X3*~X7	0.458678	0	0.881525
X3*~X5	0.528029	0	0.889935
~X2*X3	0.554806	0	0.929032
X4*~X7	0.541514	0.0385282	0.864657
X4*~X5	0.54922	0	0.866565
~X2*X4	0.575997	0	0.903323
~X2*X7	0.539203	0.0248507	0.786457

solution coverage: 0.886149
solution consistency: 0.777421
Cases with greater than 0.5 membership in term X1*~X7: Guangzhou (0.6,0.88),Foshan (0.501,0.501)
Cases with greater than 0.5 membership in term X1*~X5: Macau (0.94,0.93),Foshan (0.501,0.501)
Cases with greater than 0.5 membership in term X1*~X2: HongKong (0.95,0.77),Macau (0.94,0.93)
Cases with greater than 0.5 membership in term X2*~X7: Guangzhou (0.68,0.88),Foshan (0.67,0.501)
Cases with greater than 0.5 membership in term X3*~X7: Guangzhou (0.59,0.88),Foshan (0.501,0.501)
Cases with greater than 0.5 membership in term X3*~X5: Macau (0.92,0.93),Foshan (0.501,0.501)
Cases with greater than 0.5 membership in term ~ X2*X3: HongKong (0.95,0.77),Macau (0.92,0.93)
Cases with greater than 0.5 membership in term X4*~X7: Guangzhou (0.9,0.88),Foshan (0.501,0.501)
Cases with greater than 0.5 membership in term X4*~X5: Macau (0.89,0.93),Foshan (0.501,0.501)
Cases with greater than 0.5 membership in term ~ X2*X4: HongKong (0.95,0.77),Macau (0.89,0.93)
Cases with greater than 0.5 membership in term ~ X2*X7: HongKong (0.95,0.77),Macau (0.69,0.93)

condition showed a strong causal relationship with the result, whereas the edge condition played only an auxiliary role [43]. The parsimonious solution set is a simplified version of the complex solution, based on simplifying assumptions, and presents the most important conditions that cannot be excluded from any solution (Table 3); the intermediate solution is obtained when performing counterfactual analysis on the complex and parsimonious solutions, including only theoretically plausible counterfactuals (Table 4). The path configuration of "modern service and advanced manufacturing industries in Guangdong–Hong Kong–Macao Greater Bay Area" in high-level integration and non-high-level integration is presented in Table 5.

The sufficient analysis of high-level integration shows (see Table 3) that in the three configurations, Solution 1, Solution 2, and Solution 3, the consistency of either a single configuration or the overall solution is higher than the minimum acceptable standard (0.8). The consistency and coverage of the overall solution were 0.897 and 0.673, respectively.

In Solution 1, the existence of economic development level, productivity level, human capital level, openness to the outside world, and lack of technological innovation level constitute the key conditions of high integration, which plays a key role in the integration of modern service and advanced manufacturing industries. The degree of government regulation (i.e., the relaxation of government regulation and the strength of government support for the industry) plays an auxiliary role, and the level of the ITindustry is a dispensable condition.

The core conditions in Solution 2 are the economic development level, technological innovation level, productivity level, human capital level, lack of information-technology industry level, and openness to the outside world. These conditions play key roles in the integration of modern service and advanced manufacturing industries. The marginal condition is a lack of government control.

In Solution 3, the economic development level, technological innovation level, productivity level, human capital level, and lack of openness to the outside world play a key role in the integration of modern service and advanced manufacturing industries. The information technology industry and the level of government regulation play supplementary roles.

According to the three highly integration configurations and their driving paths, it can be concluded that the Guangdong–Hong Kong–Macao Greater Bay Area achieves high integration development with the following driving paths: economic efficiency-talent opening driving path; economic efficiency-talent innovation driving path; and economic efficiency-talent innovation-technological environment driving path.

Analyzing the configuration of non-high-level integration (see Table 3), in the configurations of Solutions 1, 2, and 3, the low levels of economic development, development efficiency, and human capital restrained the high coupling and coordination levels of the modern service and advanced manufacturing industries in the Greater Bay Area of Guangdong, Hong Kong, and Macao. These three configurations can be integrated into a non-high-level integration configuration driving path of economic efficiency and talent restraint.

4.4. *Differentiated paths*

1 Economic Efficiency-Talent Opening Driving Path

According to the high-level integration configuration of Solution 1, high levels of coupling coordination degree are driven by high levels of economic development, high levels of productivity, high levels of talent reserve, and openness to the outside world, even if the level of technological innovation and the IT industry is low. The consistency of this configuration was 0.945, its unique coverage was 0.272, and its original coverage was 0.397. This path can explain approximately 39.7 % of the integrated development of the modern service and advanced manufacturing industries. Moreover, only 27.2 % of the cases could be explained by this path. Typical cases of this driving mechanism are in Hong Kong and Macao. After encountering extreme difficulties in 2020, Hong Kong's economy recovered significantly in 2021, with its gross domestic product growing by 6.3 %, the fastest growth rate since 2010. Hong Kong's import and export of goods, cross-border commerce, and financial services also rose significantly in 2021; its labor market is flexible, its labor force has a good level of education, and its entrepreneurs are efficient and actively innovative. According to data released by

Table 4
Truth table analysis: Intermediate solution.

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**********************
    *TRUTH TABLE ANALYSIS*
    **********************
    Model: y = f(X1, X2, X3, X4, X5, X6, X7)
Algorithm: Quine-McCluskey
— INTERMEDIATE SOLUTION —
frequency cutoff: 1
consistency cutoff: 0.835106
```

	raw Coverage	unique Coverage	consistency
X1*~X2*X3*X4*X6*X7	0.396841	0.271624	0.944954
X1*X2*X3*X4*~X5*~X6*~X7	0.258332	0.0984396	0.937107
X1*X2*X3*X4*X5*X6*~X7	0.302447	0.138702	0.835106

solution coverage: 0.67251
solution consistency: 0.897199
Cases with greater than 0.5 membership in term X1*~X2*X3*X4*X6*X7: HongKong (0.86,0.77),Macau (0.69,0.93)
Cases with greater than 0.5 membership in term X1*X2*X3*X4*~X5*~X6*~X7: Foshan (0.501,0.501)
Cases with greater than 0.5 membership in term X1*X2*X3*X4*X5*X6*~X7: Guangzhou (0.59,0.88)

Table 5
Configuration of the high-level and non-high-level integration of modern service and advanced manufacturing industries in the greater bay area of guangdong, Hong Kong, and Macao value proposition.

	High-level integration			Non-high-level integration		
	Solution 1	Solution 2	Solution 3	Solution 1	Solution 2	Solution 3
Economic development level	●	●	●	⊗	⊗	⊗
Technological innovation level	⊗	●	●	⊗	⊗	•
Productivity level	●	●	●	⊗	⊗	⊗
Human capital level	●	●	●	⊗	⊗	⊗
Information technology industry level		⊗	•		⊗	
Government control level	•	⊗	•	⊗		⊗
Openness	●	⊗	⊗	⊗	⊗	•
Consistency	0.945	0.937	0.835	1.000	1.000	0.948
Raw Coverage	0.397	0.258	0.302	0.573	0.592	0.284
Unique Coverage	0.272	0.098	0.139	0.045	0.1	0.021
Solution consistency	0.897			0.978		
Solution coverage	0.673			0.694		

Note: ● Key condition; ⊗ Missing key condition; • Edge condition; ⊗ Missing edge condition.

the World Trade Organization, Hong Kong was the sixth-largest entity in the world regarding trade in goods in 2021. Despite repeated global epidemics, when Macao's entry measures were relaxed and the number of tourists increased, the revenue of the financial and gambling industries increased by 51.7 % and 25.8 % annually, respectively, and the value added of all industries increased by 24.6 % annually. As of 2021, 30.2 % of the population over the age of 15 years in Macao has a higher education degree, nearly twice the growth rate in 2011. Hong Kong and Macao have high economic development, development efficiency, and openness to the external world. They also have abundant human resources. Under the combined influence of economic development, development efficiency, openness to the outside world, and human resources, Hong Kong's and Macao's modern service and advanced manufacturing industries have a high degree of coupling and coordination.

2 Economic Efficiency-Talent Innovation Driving Path

The high-level integration configuration in Solution 2 shows that the levels of economic development, technological innovation, productivity, and human capital play a key role in the development of highly integrated industries, including a high level of economic development, high productivity, excellent talent reserves, and technological innovation. The consistency of this configuration was 0.937, its unique coverage was 0.098, and its original coverage was 0.258. This path can explain approximately 25.8 % of the integration development of modern service and advanced manufacturing industries. Furthermore, approximately 9.8 % of the cases can only be explained by this path. A typical example of this driving mechanism is Shenzhen. In 2021, under the severe and complex domestic and foreign environment, Shenzhen achieved rapid growth, with an increase of 6.7 %; concurrently, in 2021, Shenzhen's R&D expenditure continued to maintain rapid growth, and the financial expenditure on science and technology increased steadily. The intensity of R&D investment continued to improve and reached 5.49 % (as a percentage of GDP); there were 112.77 patents and inventions per 10,000 people and the number of employees with higher education ranked first in the province. Shenzhen has a high level of coupling and coordinated development of modern service and advanced manufacturing industries under the multiple influences of high-speed economic development, high-tech innovation, innovative and compound talents, and other factors.

3. Economic Efficiency-Talent Innovation-Technological Environment Driving Path

By analyzing the high-level integration configuration of Solution 3, we can see that highly integrated industries are driven by the core driving factors of economic development, productivity improvement, talent reserve increase, and technological innovation, moreover, they are affected by the auxiliary driving factors of the IT industry level and government regulation. The consistency of this configuration was 0.835, its unique coverage was 0.139, and its original coverage was 0.302. This path can explain approximately 30.2 % of the cases in modern service and advanced manufacturing industries. Additionally, approximately 13.9 % of the cases could only be explained by this path. A typical example of this driving mechanism is Guangzhou. In 2021, Guangzhou achieved remarkable results in effectively responding to fluctuations in the pandemic. The gross domestic product of Guangzhou increased by 8.1 %, and revenue from computers, communications manufacturing, and the Internet information-technology service industry achieved rapid growth and maintained a double-digit growth rate. The vitality of technological innovation improved, as did the intensity of R&D investment. More than 27 % of the participants had college degrees. In 2021, the Guangzhou government's fiscal expenditure steadily increased to 18.7 % of the GDP. Guangzhou has a high level of coupling and coordinated development of modern service and advanced manufacturing industries under the influence of multiple factors, such as rapid economic development, obvious improvement in efficiency, abundant human capital, enhanced vitality of technological innovation, and improvement in the level of the information technology industry.

4 Economic Efficiency and Talent Restraint Path

Generally, non-high-level integration configurations can be summarized into a type of path, namely, the path of economic efficiency and talent restraint. The consistency and coverage of the overall solution were 0.978 and 0.694, respectively. This path can explain approximately 69.4 % of the cases in modern service and advanced manufacturing industries. Jiangmen, Zhaoqing, Huizhou, Dongguan, and Zhongshan are examples of the use of this mechanism. In 2021, Jiangmen, Zhaoqing, Huizhou, Dongguan, and Zhongshan demonstrated a low level of economic development, employment, and attraction of high-level talent in the Greater Bay Area of Guangdong, Hong Kong, and Macao, which inhibits the integration development of the modern service and advanced manufacturing industries.

4.5. Robustness check

Two methods are commonly used to validate the configuration results: adjusting the consistency threshold and changing the frequency threshold. If no significant changes in the configuration structure are observed during the verification process using these distinct methods, then the original configuration results remain valid and exhibit high robustness, irrespective of the methodological approach [40]. However, given the small sample size in this study, adjustments to the frequency threshold were deemed inappropriate. Hence, this study adjusted the consistency threshold for robustness testing by increasing the consistency threshold from 0.8 to 0.85 while maintaining the frequency threshold constant. The truth table results align with those in Tables 3 and 4 Altering the consistency threshold did not change the results relative to the original results, further indicating the high robustness of the configuration findings in this study.

5. Discussion and conclusions

5.1. Conclusions

Based on the configuration model of the factors affecting the integrated development of the modern service and advanced manufacturing industries, this study uses the fsQCA method to analyze the conditional configuration of the integrated development of the modern service and advanced manufacturing industries in 11 regions in the Greater Bay Area of Guangdong, Hong Kong, and Macao, exploring the linkage effect and driving path of economic efficiency, talent innovation, and environmental openness, revealing the key conditions and complex interactive nature that affect the integration and development of the modern service and advanced manufacturing industries. The conclusions of this study are as follows.

(1) Overall, the seven factors of economic development level, technological innovation level, information-technology industry level, productivity level, human capital level, government control level, and openness cannot constitute the necessary conditions for high-level and non-high-level industrial integration and development in the Guangdong–Hong Kong–Macao Greater Bay Area alone, indicating that a single condition has weak explanatory power for industrial integration and development.
(2) The coupling and coordinated development of the modern service and advanced manufacturing industries is the result of the synergy of multiple factors. An effective combination of various factors can improve industrial coupling and coordinated development. There are three driving paths for high-level industrial coupling and coordination: the first is the economic efficiency-talent opening driving path, which is composed of economic efficiency, talent opening degree, degree of opening to the outside world, and technological innovation level; the second is the economic efficiency-talent innovation driving path, which is composed of economic efficiency, productivity level, technological innovation level, sufficient talent reserve, and low opening degree; and the third is the economic efficiency-talent innovation-technological environment driving path, which is composed of economic efficiency, productivity level, technological innovation level, sufficient talent reserve, improvement of the information technology industry, easing of government regulation, and low opening degree. In high-level industrial coupling and coordination, the key role of the technological innovation level and opening degree is asymmetric, i.e., in different paths, both higher and lower technological innovation levels and opening degrees can promote high-level industrial coupling and coordination. However, there is only one inhibiting path for low-level industrial integration, the economic efficiency-talent inhibiting path, which comprises lower-level economic development, development efficiency, and human capital status.
(3) Due to the differences in economic efficiency, technological innovation, and policy environment in different regions, there are certain differences in the driving path of the coupling coordination between modern service and advanced manufacturing industries in the Guangdong–Hong Kong–Macao Greater Bay Area.

The integrated development of modern service and advanced manufacturing industries in the Guangdong-Hong Kong-Macao Greater Bay Area is the result of multiple factors working together, were no single factor can be a necessary condition for industrial integration. In different paths, higher or lower levels of technological innovation and openness can foster high-level industrial integration. The variables also have asymmetric relationships. These conclusions are important because they differ from previous studies on the integration and development of modern service and advanced manufacturing industries, which explored only the impact of a single factor on industrial integration and the symmetrical relationship of causal variables. The findings of this study represent a new breakthrough in this research stream.

Based on the above research conclusions, the following policy implications are proposed.

(1) The coupling and coordination levels of modern service and advanced manufacturing industries are affected by many factors. According to the organization's conditions and resource endowments, from the perspective of "integrity," local governments should focus on the linkage and matching of multiple conditions between economic efficiency, technological innovation, and policy environment, and formulate targeted policies to improve the coupling and coordination development level of modern service and advanced manufacturing industries.
(2) To overcome the constraints of the government's conditions, external environment, and other objective conditions, the local government can strengthen the exchange, cooperation, and integration mechanism between various regions and strengthen supporting, complementary, and characteristic development with the core cities of the Greater Bay Area.

5.2. Theoretical implications

The main contribution of this study is to introduce the fsQCA method into research on industrial coupling and coordination development from the perspective of configuration, which not only enriches the research methods but also lays the foundation for the formation of the decision-making theory of industrial integration and development. Existing research on the factors affecting the development of industrial integration is mainly limited to regression analysis and spatial econometric model analysis [3,20–22]. The introduction of the fsQCA method enriches the research methods and tools of industrial integration development and provides a holistic perspective on the complex interaction and causal asymmetry between the conditions behind the development of industrial integration.

5.3. Limitations and further research

Although the integrated analysis framework used in this study covered the influencing factors of economic efficiency, technological innovation, policy environment, and other aspects that have been verified by previous studies, there are still omissions. Limited by the availability of data, this study focuses on the horizontal analysis of the driving path of 11 cities in the Greater Bay Area of Guangdong, Hong Kong, and Macao, without considering the dynamic analysis of changes over time. These limitations can be used as directions for future research.

Funding

This research was funded by the Guangdong Philosophy and Social Science Planning Project "Research on the Monitoring and Evaluation System of the Integrated Development of Modern Service Industry and the Advanced Manufacturing Industry in the Guangdong–Hong Kong–Macao Greater Bay Area" (No: GD20CYJ30). This study was funded by the Shaoguan University Quality Engineering Construction Project (No:13).

Data statements

These data were obtained from the official Statistical Yearbook Series of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing in the Guangdong Province, the statistical website of the Government of the Hong Kong Special Administrative Region, and the website of the Statistics and Census Bureau of the Government of the Macao Special Administrative Region.

Data availability statement

Data are included in the article/supplementary material or referenced in the article.

CRediT authorship contribution statement

Chunchun Hu: Writing – review & editing, Writing – original draft, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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