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The Industrial Decision Analysis of Regional Coordinated Development Considering Information Distribution and Fairness Preference

Linwei Pan [1], Xueyu Liao [1], Rui Li [2] and Shuangping Cao [3,*]

[1] School of Economics and Management, Chongqing Jiaotong University, Chongqing 400074, China; panlinwei2000@sina.com (L.P.)
[2] School of Management Science and Real Estate, Chongqing University, Chongqing 400044, China
[3] Architecture and Engineering Institute, Chongqing College of Architecture and Technology, Chongqing 401331, China
* Correspondence: csp2017010032@cqrec.edu.cn

Abstract: Regional industry synergistic planning contributes to the achievement of Goal 11 of the United Nations' Sustainable Development Goals. The reasonable layout of regional industries is an important measure for achieving sustainable development through distinguishing between different industries. Taking into account the competitive and cooperative relationships between regional cities, this study created a Stackelberg model considering information distribution and fairness preferences. It analyzed the industrial selection strategies and influencing factors under the requirements of output maximization and profit maximization between regions. The model discussions and numerical simulation results showed that regional industrial planning and adjustment should consider both internal and external behavioral factors. The impact of information distribution and fairness preferences on the selection of heterogeneous and homogeneous industries varies. Differentiated industrial selection should be conducted based on output maximization or profit maximization. Furthermore, following cities should take the initiative to integrate into the industrial development plans of nearby large cities, and leading cities should effectively layout and optimize regional productivity. Both industrial planning and choice require the establishment of regional coordination mechanisms. By enhancing the level of mutual trust and reciprocity among cities, reducing information asymmetry, and guiding fairness preferences, regional industrial synergy is promoted, and conditions are created for sustainable industrial development.

Keywords: coordinated regional development; industry planning; industry choosing; information distribution; fairness preference; Stackelberg model

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1. Introduction

Synergistic regional industrial planning helps establish positive economic and social ties between urban, peri-urban, and rural areas, thereby promoting the achievement of Goal 11 of the 17 Sustainable Development Goals (SDGs) of the United Nations. Against the backdrop of multiple factors such as Sino-US economic and trade friction, and post-epidemic overlap, international industrial competition is intensifying. The reconfiguration of global value chains has increased industrial competition among countries, and implementing national industrial policies in global value chains has become a new tool for competition among major powers. China has accelerated the construction of a new development pattern with domestic distribution as the main focus, and domestic and international distribution promoting each other. This will reshape the spatial layout of China's industries and thus put forward new requirements for industrial synergy policies. The overlapping of industrial choice and the vicious competition of homogeneous industry will lead to resource waste that is not conducive to sustainable regional development. However, industry planning and selection can help promote the high-quality collaborative development of regional industries.

The spread of globalization, marketization, and decentralization has led to administrative fragmentation, making it difficult for higher levels of government to maintain regulatory authority over lower levels [1]. In this context, higher-level governments desire cooperation, and the central government actively implements top-down regional planning, which can, to some extent, prevent inter-city competition and achieve more coordinated regional development [2,3]. However, follower cities may not be receptive to this, and competition is still the essence of local government behavior. Most cities do not actively cooperate but compete with each other owing to conflicting interests and poorly developed coordination mechanisms [4]. For example, the industrial layout and development among the cities in the Guangdong–Hong Kong–Macao Greater Bay Area are relatively crude, with a high degree of similarity in industrial structure and obvious homogenization [5]. The synergistic development of industries in the city clusters in the western region is at the stage of low-level synergy, with relatively small differences among industries within the city clusters, and the phenomenon of convergence of industrial structure is serious, which has triggered problems such as homogeneous competition [6]. Ding et al. [7] found that the development of small cities will follow the successful pattern of city development and may lead to the homogenization of urban form between cities at different stages.

There is a phenomenon of "active competition and negative cooperation" among cities in a cluster, and local protectionism is a serious concern. Increasing urban competition can lead to the duplication of infrastructure, homogeneous competition, and waste of resources, thus hindering the development of regional integration in urban agglomerations. The relationship between cities in urban agglomerations is competitive but potentially cooperative [8]. Inter-city competition can be circumvented by strengthening complementary functional ties that transcend local and regional scales [9]. Two cities will compete if their geographic markets overlap, but they can cooperate if they have strong intercity linkages and complementary geographic markets [9].

Cooperation between competitors is known as "cooperative competition"; it can discourage unhealthy competition between competitors [10], promote organizational learning and innovation [11], and enable cities to quickly build advantages in dynamic environments, such as emerging industries [12]. Compared with the development of individual cities, inter-city cooperation based on city clusters facilitates overall development [13]. Exploiting synergistic relationships among cities, strengthening cooperation and joint efforts among multiple cities, and clarifying the agglomeration patterns of city subgroups can help realize inter-regional resource complementation and the industrial chain division of labor cooperation, accelerate the integration of resource elements in large, medium, and small cities, and achieve a mutually beneficial situation among cities [13–16].

The literature suggests that several core factors affecting inter-city cooperative competition generally focus on behavioral factors, such as industry characteristics [10], co-benefits of cooperation, and preference diversity. Under a given industry structure and level of competition, opportunities for the co-creation of value among competitors may arise from information resource sharing [17] and complementary strengths and capabilities [18]. An appropriate level of resource sharing influences the cooperation strategy between cities [19–21]. Adequate information exchange between cities is crucial to determine the direction of cooperation and improve understanding and trust between cities [1], which can lead to Pareto improvements and promote sustainable industrial development [22]. However, the stability of the cooperative relationship will be impacted if city governments do not actively engage in cooperation, which will prevent partners from exchanging information and reduce small cities' capability for sharing [23]. Considering the similarity between Xiamen and Pingtan in terms of location characteristics and development positioning, Wang Hui et al. [24] constructed a Stackelberg model to analyze the strategic choices between the industries of the two cities from the perspective of industrial overlap. Ma et al. [25] discovered that the game utility derived from a fusion of behavioral preferences and game benefits influences participants' choice of game strategy, wherein avoiding unfair choices is more favorable for the establishment of network cooperation.

Industrial management decisions often deviate from the optimal solutions of traditional operations research models. This is because traditional operations research models often start with the assumption that decision makers are perfectly rational [26]. However, in complex real-life situations, decision makers could be influenced by multiple behavioral factors, resulting in less-than-optimal decisions [27–29]. The behavioral school of industrial location choice theory argues that the behavioral factors of decision makers influence location choice, and the thoughts, behaviors, and values of decision makers often become determinants of location. More scholars are combining behavioral factors with traditional models of industrial decision research to make their research more emulative of actual situations. Qu et al. [30] use game theory and behavioral science to construct a supply chain decision model based on behavioral factors and examine the optimal decision of supply chain node businesses. Owing to knowledge monopolies, industry barriers, or conflicts of interest, each enterprise usually withholds some critical information from cooperating enterprises, and the information gap between enterprises can cause information asymmetry.

Some scholars have conducted more comprehensive studies on the information distribution among decision makers [31–33]. For example, Yang and Liu [34] used the Stackelberg game to discuss the optimal supply chain strategy under specific conditions of information asymmetry. According to Lou et al. [35], asymmetric and incomplete information resulted in robust decision models for two-level supply chain Stackelberg game problems. With incomplete information, Wang et al. [26] established an asymmetric quantum Stackelberg model, and the participants' profits rose with information uncertainty. Additionally, some scholars have focused on the preference for equity among decision makers [36]. For instance, Fan et al. [37] discovered that decision makers' preferences for equity and altruism affect each firm's decision in a Stackelberg game with limited rationality. Guan et al. [38] studied a different leader–follower relationship, considering the impact of members' fairness concerns on optimal strategies. Yan et al. [39] used the manufacturers' preference of fair behavior to study the fresh produce supply chain and the optimal decision-making problem. In the Stackelberg game, Gächter et al. [40] introduced fairness factors and discovered that followers react optimally in response to the leader's contribution. Zhao et al. [41,42] applied the Rabin model to a chained multiple principal agent model with procedural preferences.

According to the available studies, inter-city cooperation is a new phenomenon and an under-researched area in urban and regional development. There are still many problems to be solved, and scholars should focus more on the process of forming cooperative relationships and actors' interactions in their analyses. The modern location theory has clarified the influence of decision makers' behavioral factors on industrial location selection. However, the existing theory has not further investigated the specific behavioral factors and how they affect industrial location selection. Model research has focused mainly on the Stackelberg model of industrial decision-making research on supply chains, with limited research on industrial planning and regional synergy. Although some scholars have conducted extensive research on behavioral factors in decision making, the majority of their studies only consider the influence of individual behavioral factors on decision making, with little literature studying the impact of both information distribution and fairness preferences on industrial planning. This study's goal was to examine inter-city industrial decisions by considering the influence of internal and external behavioral factors, aiming to maximize regional output and overall benefits.

In this study, we propose the following research questions:

Research Question 1: Do regional productivity layout and industrial planning follow a competitive or cooperative strategy, and should industrial development prioritize homogeneous or heterogeneous industries?

Research Question 2: When making decisions to maximize total regional output and total benefit, how do willingness to share information and an unfavorable, inequitable distribution mentality influence cities to choose homogeneous industries?

Research Question 3: When making decisions to maximize total regional output and total benefit, how do willingness to share information and an unfavorable, inequitable distribution mentality influence cities to choose heterogeneous industries?

To answer these questions, this study focused on model discussion and integrated analytical methods such as locational choice theory, separately included information distribution conditions and behavioral factors of result fairness preference into the model, constructed a Stackelberg model under synergistic conditions, and analyzed the incentives of cooperative industrial planning decisions under the leader–follower model from the perspective of overall regional productivity.

Our study provides the following contributions: First, based on the requirements of regional productivity distribution optimization, this study considered the internal and external behavioral factors on regional industry selection and its consequences, and validates the behavioral school of location choice theory. That is, behavioral factors lead to industrial duplication and resource waste, so a solution to the problem is proposed: differentiated selection based on output maximization or income maximization, so as to provide a regional industrial development proposal.

The remainder of the paper is organized as follows. Section 2 presents the applicability analysis of the Stackelberg model under collaborative conditions. Section 3 discusses the impacts of information distribution and fairness preference on the homogeneous and heterogeneous industries in the Stackelberg model under the synergy condition, respectively, while Section 4 analyzes further numerical simulations. Finally, Section 5 provides a conclusion and recommendations.

2. Applicability Analysis of the Stackelberg Model under Collaborative Conditions

This study analyzed the industrial selection strategies between neighboring cities with leading and following relationships in the region. Owing to the similarities in the location characteristics and development orientation of neighboring cities, there are bound to be overlapping industries between neighboring cities, resulting in a competitive relationship. If industries that can replace or complement the leading city are selected to enter the market, they will certainly impact the leading city, and the two cities can form a dynamic game of "leader and follower." In addition, the leading city is in a special position in the industrial selection strategy and belongs to the higher decision-making level of the leader, so it can choose an industrial strategy first while sending a signal of cooperation and innovation. In contrast, the other neighboring cities, with the lower decision-making level of the follower, make their own decisions after observing the decision-making strategy of the leading city. In addition, the leading city first chooses a certain strategy, which can be regarded as a signal; after observing the signal, the follower cities choose the optimal strategy to maximize their own interests according to the behavioral strategy principle of maximizing their own interests. This is a non-cooperative, perfect information, dynamic game process, which is consistent with the Stackelberg equilibrium; thus, it can be used to describe the industrial selection decision process in the leader–follower model among cities in a region with a leading city.

2.1. Model Assumptions

Large cities can decide their own output and are leaders in regional industrial planning, whereas small cities are followers who must decide their output based on the output of the leaders. Thus, the Stackelberg game is established for industry selection strategy among cities, and the assumptions are as follows:

Hypothesis 1: *Without considering new entrants, the fixed costs of two nearby cities—large city A and small city B—are the same; for the sake of generality, the fixed costs are assumed to be zero.*

Hypothesis 2: *For the sake of simplicity, we assume that the unit costs of large city A and small city B are fixed.* c_1 *and* c_2 *are the unit costs of large city A and small city B, respectively, and* $c_1 < c_2$.

Hypothesis 3: *The regional demand function for productivity is:*

$$P_i = a - q_i + mq_j$$

where $i, j = 1, 2,\ i \neq j;\ a$; represents the fundamental regional demand; $a > 0$; and q_1 and q_2 denote the regional demand of large city A and small city B, respectively. When $-1 < m < 0$, the industry is homogeneous; when $0 < m < 1$, the industry is heterogeneous. This study does not consider the case of $m = 0$ (industries are not related).

2.2. Comparative Analysis of the Traditional Stackelberg Model and the Stackelberg Model under Cooperative Conditions

The traditional Stackelberg game is a perfect information dynamic game with sequential actions. Under the assumption of perfect information, city A will know of city B's entry and adjust its output strategy. Both parties compete for output based on their respective maximized interests, which meets the conditions of the Stackelberg model. Cities A and B play a two-stage game in which city A decides the final production to maximize its own interests, and city B decides the output to maximize its own interests based on the supplied marginal output of city A. At this point, the revenue functions of cities A and B are as follows (denote π_1, π_2 as the revenue of cities A and B of the traditional Stackelberg model):

$$\pi_1 = q_1(a - q_1 + mq_2 - c_1) \tag{1}$$

$$\pi_2 = q_2(a - q_2 + mq_1 - c_2) \tag{2}$$

In the traditional Stackelberg model, decision makers aim to maximize their own benefits and do not consider the adverse effects of their output decisions on maximum regional benefits. At this time, the industrial planning decision belongs to a sub-game of the refined Nash equilibrium, which is solved using the inverse induction method. The optimal outputs and benefits of cities A and B are as follows (denote ${q_1}^{n*}$, ${q_2}^{n*}$, q^{n*} as the optimal output of city A, city B, and the region of the traditional Stackelberg model, ${\pi_1}^{n*}$, ${\pi_2}^{n*}$, π^{n*} as the optimal benefit of city A, city B, and the region of the traditional Stackelberg model):

$${q_1}^{n*} = \frac{2(a - c_1) + (a - c_2)m}{2(2 - m^2)}$$

$${q_2}^{n*} = \frac{a - c_2}{2} + \frac{2(a - c_1)m + (a - c_2)m^2}{4(2 - m^2)}$$

$${\pi_1}^{n*} = \frac{[2(a - c_1) + (a - c_2)m]^2}{8(2 - m^2)}$$

$${\pi_2}^{n*} = \left[\frac{a - c_2}{2} + \frac{2(a - c_1)m + (a - c_2)m^2}{4(2 - m^2)}\right]^2$$

Regionally coordinated development must consider maximizing regional benefits. City A, as the leader of industrial planning, has the responsibility to lead and coordinate the region's industrial development. Instead of making output decisions with the goal of maximizing its own benefits, city A has a broader perspective. In this case, the Stackelberg model is transformed into a suboptimal output decision under collaborative conditions with the goal of maximizing regional benefits. Cities A and B still play a two-stage game; however, city A decides the final production to maximize its regional interests, and city B decides the output to maximize its own interests based on the supplied marginal output of city A. In such a scenario, the optimal outputs and benefits of cities A and B are as follows (denote ${q_1}^{c*}$, ${q_2}^{c*}$, q^{c*} as the optimal output of city A, city B, and the region of the traditional Stackelberg model under synergistic conditions, ${\pi_1}^{c*}$, ${\pi_2}^{c*}$, π^{c*} as the optimal benefit of city A, city B, and the region of the traditional Stackelberg model under synergistic conditions):

$${q_1}^{c*} = \frac{2[a - c_1 + (a - c_2)m]}{4 - 3m^2}$$

$${q_2}^{c*} = \frac{a - c_2}{2} + \frac{(a - c_1)m + (a - c_2)m^2}{4 - 3m^2}$$

$${\pi_1}^{c*} = \frac{[a - c_1 + (a - c_2)m]\left[(a - c_1)\left(4 - m^2\right) - (a - c_2)m^3\right]}{\left(4 - 3m^2\right)^2}$$

$${\pi_2}^{c*} = \left[\frac{a - c_2}{2} + \frac{(a - c_1)m + (a - c_2)m^2}{4 - 3m^2}\right]^2$$

The equilibrium results of the traditional Stackelberg model and the Stackelberg model under synergistic conditions are compared in Table 1.

Table 1. Equilibrium output and profit of the traditional Stackelberg model and the Stackelberg model under synergistic conditions.

Decision Variables	Traditional Stackelberg Model	Decision Variables	Stackelberg Model under Synergistic Conditions
${q_1}^{n*}$	$\frac{2(a-c_1)+(a-c_2)m}{2(2-m^2)}$	${q_1}^{c*}$	$\frac{2[a-c_1+(a-c_2)m]}{4-3m^2}$
${q_2}^{n*}$	$\frac{a-c_2}{2} + \frac{2(a-c_1)m+(a-c_2)m^2}{4(2-m^2)}$	${q_2}^{c*}$	$\frac{a-c_2}{2} + \frac{(a-c_1)m+(a-c_2)m^2}{4-3m^2}$
q^{n*}	$\frac{2(a-c_1)(2+m)+(a-c_2)\left(4+2m-m^2\right)}{4(2-m^2)}$	q^{c*}	$\frac{(a-c_1)(4+2m)+(a-c_2)\left(4+4m-m^2\right)}{2(4-3m^2)}$
${\pi_1}^{n*}$	$\frac{[2(a-c_1)+(a-c_2)m]^2}{8(2-m^2)}$	${\pi_1}^{c*}$	$\frac{[a-c_1+(a-c_2)m]\left[(a-c_1)\left(4-m^2\right)-(a-c_2)m^3\right]}{\left(4-3m^2\right)^2}$
${\pi_2}^{n*}$	$\left[\frac{a-c_2}{2} + \frac{2(a-c_1)m+(a-c_2)m^2}{4(2-m^2)}\right]^2$	${\pi_2}^{c*}$	$\left[\frac{a-c_2}{2} + \frac{(a-c_1)m+(a-c_2)m^2}{4-3m^2}\right]^2$
π^{n*}	${\pi_1}^{n*} + {\pi_2}^{n*}$	π^{c*}	${\pi_1}^{c*} + {\pi_2}^{c*}$

Conclusion 1: In synergistic competition, city B has more output, benefit, and total regional output and benefit than under traditional competition; city A has less output and benefit than under traditional competition in homogeneous industry selection and less benefit but more output than under traditional competition in heterogeneous industry selection. Policymakers prefer to engage in synergistic competition.

Conclusion 1 shows that the decision makers are more inclined to carry out collaborative competition and avoid homogeneous industry competition when they make decisions to maximize total regional output. Thus, this modified Stackelberg model is more realistic than the traditional Stackelberg model, under the cooperative condition of secondary optimization, which is a better strategic decision for regional industry planning. The difference in the output and benefits of decision makers is due to the fact that they all aim to maximize their own interests in "separate governance", and individual rationality replaces collective rationality. Under the collaborative condition, city A, as the leader, has coordinated regional development and a sense of the overall situation and makes output decisions that may be suboptimal, though yielding some benefits, thereby eliminating, to a certain extent, the adverse effects of its own output decisions on regional interests.

Proof:

$${q_1}^{n*} - {q_1}^{c*} = -\frac{2(a - c_1)m^2 + (a - c_2)\left(4 - m^2\right)m}{2\left(2 - m^2\right)\left(4 - 3m^2\right)}$$

$${q_2}^{n*} - {q_2}^{c*} = -\frac{2(a - c_1)m^3 + (a - c_2)\left(4 - m^2\right)m^2}{4\left(2 - m^2\right)\left(4 - 3m^2\right)}$$

$$q^{n*} - q^{c*} = -\frac{2(a-c_1)\left(4+2m-m^2\right)m + (a-c_2)\left(4-m^2\right)m^2}{4(2-m^2)(4-3m^2)}$$

$${\pi_1}^{n*} - {\pi_1}^{c*} = \frac{\left[2(a-c_1)m^2 + (a-c_2)\left(4-m^2\right)m\right]^2}{8(2-m^2)(4-3m^2)^2}$$

$${\pi_2}^{n*} - {\pi_2}^{c*} = -\frac{\left(8-5m^2\right)\left[2(a-c_1)m^2 + (a-c_2)\left(4-m^2\right)m\right]^2}{16(8-10m^2+3m^4)^2}$$

$$\pi^{n*} - \pi^{c*} = -\frac{\left[2(a-c_1)m^2 + (a-c_2)\left(4-m^2\right)m\right]^2}{16(4-3m^2)(2-m^2)^2}$$

From ${q_i}^{c*}, {q_i}^{n*} \geq 0$, we derive $2(a-c_1)m + (a-c_2)\left(4-m^2\right) > 0$, when $-1 < m < 0$, ${q_1}^{n*} > {q_1}^{c*}$, ${q_2}^{n*} < {q_2}^{c*}$, $q^{n*} < q^{c*}$, ${\pi_1}^{n*} > {\pi_1}^{c*}$, ${\pi_2}^{n*} < {\pi_2}^{c*}$, ${\pi_2}^{n*} < {\pi_2}^{c*}$; when $0 < m < 1$, ${q_1}^{n*} < {q_1}^{c*}$, ${q_2}^{n*} < {q_2}^{c*}$, $q^{n*} < q^{c*}$, ${\pi_1}^{n*} > {\pi_1}^{c*}$, ${\pi_2}^{n*} < {\pi_2}^{c*}$, ${\pi_2}^{n*} < {\pi_2}^{c*}$; thus, Conclusion 1 holds. □

3. Construction of the Stackelberg Extension Model under Collaborative Conditions

Compared with the traditional Stackelberg model, the Stackelberg model under synergistic conditions eliminates, to a certain extent, the negative impact of its own output decision on regional interests and is a better strategic choice for regional industrial planning. Therefore, this study further extends the Stackelberg model under synergy conditions. Traditional location theory and game theory assume that economic decision makers are full of rationality and seek to maximize their own interests. The above-mentioned Stackelberg game under synergistic conditions also assumes that information is perfect and complete. However, in reality, different cities choose to keep or hide industry-related information to maximize their own interests. Thus, output competition is conducted in a state of incomplete information. Therefore, the conclusions of the Stackelberg model under the synergy condition do not fully reflect realistic industry selection strategies and benefits. The behaviorist locational theory holds that behavioral factors impact economic behavior. Participants' game strategy choice is no longer limited by the game benefits but by the game utility gained from the fusion of game benefits and behavioral preferences. Information distribution and fairness preferences are important behavioral preferences of decision makers that affect the establishment and maintenance of cooperative regional relationships. Hence, the Stackelberg model under synergistic conditions is extended by introducing information distribution and fairness preference.

3.1. Stackelberg Model under Cooperative Conditions and Considering Information Distribution

Take k_1, k_2 to denote the information-sharing coefficient of cities A and B, where $k_1, k_2 \in (0,1)$. The higher the information-sharing coefficient's value, the more likely it is that the city will be willing to share relevant information. At this point, the benefit functions of cities A and B are transformed (denote T_1, T_2 as the revenue of cities A and B of the traditional Stackelberg model under synergistic conditions considering information distribution, ${q_1}^{x*}$, ${q_2}^{x*}$, q^{x*} as the optimal output of city A, city B, and the region of the traditional Stackelberg model under synergistic conditions considering information distribution, ${T_1}^{x*}$, ${T_2}^{x*}$, T^{x*} as the optimal benefit of city A, city B, and the region of the traditional Stackelberg model under synergistic conditions considering information distribution).

$$T_1 = (1-k_1)\pi_1 + k_1(\pi_1 + \pi_2) \tag{3}$$

$$T_2 = (1-k_2)\pi_2 + k_2(\pi_1 + \pi_2) \tag{4}$$

City A, as the leader, uses the response function of city B as the basis for output decisions. Therefore, city A's decision is transformed into the following:

$$\max_{q_1 \geq 0} T = q_1(a - q_1 + mq_2{}^x - c_1) + k_1 q_2{}^x(a + mq_1 - q_2{}^x - c_2) + q_2{}^x(a + mq_1 - q_2{}^x - c_2)$$
$$+k_2 q_1(a - q_1 + mq_2{}^x - c_1)$$

For $\frac{\partial^2 T}{\partial {q_1}^2} < 0$, the optimal output and benefit of cities A and B and the regional optimal total output and total benefit are the following:

$$q_1{}^{x*} = \frac{2(a - c_1)(1 + k_2) + (a - c_2)(2 + k_1 + k_2)m}{(1 + k_2)\{4 - [3 + k_1 + k_2 - k_1 k_2]m^2\}} \tag{5}$$

$$q_2{}^{x*} = \frac{2(a - c_1)(1 + k_2)m + (a - c_2)\left(4 - m^2 + k_1 k_2 m^2\right)}{8 - 2[3 + k_1 + k_2 - k_1 k_2]m^2} \tag{6}$$

$$q^{x*} = q_1{}^{x*} + q_2{}^{x*} \tag{7}$$

$$T_1{}^* = q_1{}^{x*}(a - q_1{}^{x*} + mq_2{}^{x*} - c_1) + k_1 q_2{}^{x*}(a + mq_1{}^{x*} - q_2{}^{x*} - c_2) \tag{8}$$

$$T_2{}^* = q_2{}^{x*}(a + mq_1{}^{x*} - q_2{}^{x*} - c_2) + k_2 q_1{}^{x*}(a - q_1{}^{x*} + mq_2{}^{x*} - c_1) \tag{9}$$

$$T^* = T_1{}^* + T_2{}^* \tag{10}$$

Conclusion 2 (1): When information distribution is symmetric, with the increase in the information-sharing coefficient, homogeneous industry choice causes the output of city A to increase, the output of city B to decrease, and the total regional output to decrease; however, heterogeneous industry selection causes the output of city A, city B, and the total regional output to increase.

Conclusion 2 (2): When the information distribution is asymmetric, homogeneous industry choice causes decision makers' output to decrease with the increase in their own information-sharing coefficient and increase with the increase in each other's information-sharing coefficients; the total regional output to decrease with the increase in the information-sharing coefficient of city A; and grow and then decrease with the increase in the information-sharing coefficient of city B. Heterogeneous industry choice, with the increase in the information-sharing coefficient of city A and city B, causes the output of city A, city B, and the total regional output to increase.

Conclusion 2 shows that, with the decision to maximize regional aggregate output, it is easy to make homogeneous industry choices when the willingness to share information is weak, and it is easy to make heterogeneous industry choices when the willingness to share information is strong.

Under the condition of homogeneous industrial choice, when faced with symmetric information distribution, the stronger the willingness to share information in city A, the more it can benefit from the leading advantage; for city B, with a higher output cost, the stronger the willingness to share information, the more advantages are lost; the total regional output is influenced more by city B than by city A. When facing information distribution asymmetry, the stronger the willingness of city A to share information, the lower the leading advantage and the greater the impact on total regional output; the stronger the willingness of city B to share information, the greater the trust of city A, enabling the maximization of regional benefits, and the increase in output. However, with the increase in willingness to share, the decrease in city B's advantage is obvious, and the impact on total regional output is greater.

Under the condition of heterogeneous industrial choice, the stronger the willingness to share information, the easier it is for cities to have a differentiated regional industrial layout with a clear division of labor and complementary advantages and the output advantage is also obvious.

Proof of Conclusion 2 (1): When $k_1 = k_2 = k$, Equations (5)–(7) each output with respect to k as first-order derivatives, which are as follows:

$$\frac{\partial {q_1}^{x*}}{\partial k} = \frac{4(1-k)\left[(a-c_1)m^2 + (a-c_2)m^3\right]}{\left[4-(3+2k-k^2)m^2\right]^2}$$

$$\frac{\partial {q_2}^{x*}}{\partial k} = \frac{\left[(a-c_1)m + (a-c_2)m^2\right]\left[4-(1+k)^2 m^2\right]}{\left[4-(3+2k-k^2)m^2\right]^2}$$

$$\frac{\partial q^{x*}}{\partial k} = \frac{\left[(a-c_1)m + (a-c_2)m^2\right]\left[4+4(1-k)m-(1+k)^2 m^2\right]}{\left[4-(3+2k-k^2)m^2\right]^2}$$

When $-1 < m < 0$, $\frac{\partial {q_1}^{x*}}{\partial k} > 0$, $\frac{\partial {q_2}^{x*}}{\partial k} < 0$, $\frac{\partial q^{x*}}{\partial k} < 0$; when $0 < m < 1$, $\frac{\partial {q_1}^{x*}}{\partial k} > 0$, $\frac{\partial {q_2}^{x*}}{\partial k} > 0$, $\frac{\partial q^{x*}}{\partial k} < 0$; thus, Conclusion 2 (1) holds. □

Proof of Conclusion 2 (2): When $k_1 \neq k_2$, Equations (5)–(7) each output with respect to k_1, k_2 as first-order derivatives, respectively, and are as follows:

$$\frac{\partial {q_1}^{x*}}{\partial k_1} = \frac{2(a-c_1)(1-k_2^2)m^2 + (a-c_2)\left[4-(1+k_2)^2 m^2\right]m}{(1+k_2)\left[4-(3+k_1+k_2-k_1k_2)m^2\right]^2}$$

$$\frac{\partial {q_2}^{x*}}{\partial k_1} = \frac{2(a-c_1)\left(1-{k_2}^2\right)m^3 + (a-c_2)\left[4-(1+k_2)^2 m^2\right]m^2}{2\left[4-(3+k_1+k_2-k_1k_2)m^2\right]^2}$$

$$\frac{\partial {q_1}^{x*}}{\partial k_2} = \frac{2(a-c_1)(1-k_1)(1+k_2)^2 m - (a-c_2)\left(9+7k_1+4k_2+{k_2}^2-2k_1k_2-k_1{k_2}^2-2{k_1}^2k_2\right)m^2}{(1+k_2)^2\left[4-(3+k_1+k_2-k_1k_2)m^2\right]^2}$$

$$\frac{\partial {q_2}^{x*}}{\partial k_2} = \frac{4(a-c_1)\left[2-(1+k_1)m^2\right]m + (a-c_2)\left[4-(1+k_2)^2 m^2\right]m^2}{2\left[4-(3+k_1+k_2-k_1k_2)m^2\right]^2}$$

$$\frac{\partial q^{x*}}{\partial k_1} = \frac{\partial({q_1}^{x*}+{q_2}^{x*})}{\partial k_1},\ \frac{\partial q^{x*}}{\partial k_2} = \frac{\partial({q_1}^{x*}+{q_2}^{x*})}{\partial k_2}$$

When $-1 < m < 0$, $\frac{\partial {q_1}^{x*}}{\partial k_1} < 0$, $\frac{\partial {q_2}^{x*}}{\partial k_1} > 0$, $\frac{\partial q^{x*}}{\partial k_1} < 0$, $\frac{\partial {q_1}^{x*}}{\partial k_2} > 0$, $\frac{\partial {q_2}^{x*}}{\partial k_2} < 0$, $\frac{\partial q^{x*}}{\partial k_2}$ is first greater than 0 and then less than 0; when $0 < m < 1$, $\frac{\partial {q_1}^{x*}}{\partial k_1} > 0$, $\frac{\partial {q_2}^{x*}}{\partial k_1} > 0$, $\frac{\partial q^{x*}}{\partial k_1} > 0$, $\frac{\partial q^{x*}}{\partial k_1} > 0$, $\frac{\partial q^{x*}}{\partial k_2} > 0$, Conclusion 2 (2) holds. □

3.2. Stackelberg Model under Cooperative Conditions and Considering Fairness Preference

The utility function of fairness preference is defined by introducing parameters that use the other party's benefit as a reference point for its own side (denote f_r as a parameter):

$$f_r = -\alpha max\{\pi_i - \pi_j, 0\} - \beta max\{\pi_j - \pi_i, 0\}$$

α shows that the negative utility of unfavorable inequity is equal to α times the difference between equity gain and monetary gain when its own gain is lower than the other party's gain, and β shows that the negative utility of favorable inequity is equal to β times the difference between monetary gain and equity gain when its own gain is higher than the other party's gain. Ferhr and Schmidt [43] noted that, with respect to inequitable distribution, unfavorable inequity elicits stronger feelings than favorable inequity; thus, $0 < \beta < 1$, $\alpha > \beta$. Therefore, in this study, only the unfavorable inequitable distribution of decision makers is considered; after introducing it into the Stackelberg model under the synergy condition, the benefit function of cities A and B is transformed into the following (denote u_1, u_2 as the revenue of cities A and B considering fairness preference):

$$u_1 = \pi_1 - \alpha_1(\pi_2 - \pi_1),\ u_2 = \pi_2 - \alpha_2(\pi_1 - \pi_2)$$

For the purpose of model analysis, given $U_i \equiv \frac{u_i}{1+\alpha_i}$, $\hat{\alpha_i} = \frac{\alpha_i}{1+\alpha_i}$, U_i is the radiation change to u_i that involves only a change in magnitude and can still be used as a measure of the city's benefit. $\hat{\alpha_i}$ is the fairness preference coefficient, which is an increasing function of α_i. When $\hat{\alpha_i} \in (0,1)$, $\alpha_i \to 0$, that is, $\hat{\alpha_i} = 0$, the city is equity-neutral; when $\alpha_i \to +\infty$, that is, $\hat{\alpha_i} = 1$, the city has an extreme preference for equity. At this time, the utility functions of cities A and B are as follows (denote U_1, U_2, U as the revenue of city A, city B, and the region of the traditional Stackelberg model under synergistic conditions considering fairness preference, ${q_1}^{g*}, {q_2}^{g*}, q^{g*}$ as the optimal output of city A, city B, and the region of the traditional Stackelberg model under synergistic conditions considering fairness preference, and ${U_1}^*, {U_2}^*, U^*$ as the optimal benefit of city A, city B, and the region of the traditional Stackelberg model under synergistic conditions considering fairness preference):

$$U_1 = \pi_1 - \hat{\alpha_1}\pi_2 \tag{11}$$

$$U_2 = \pi_2 - \hat{\alpha_2}\pi_1 \tag{12}$$

Similarly, the decision of city A to maximize the regional benefit translates into

$$\begin{aligned} \underset{q_1 \geq 0}{max} U = {} & q_1(a - q_1 + m{q_2}^g - c_1) - \hat{\alpha_1}{q_2}^g(a + mq_1 - {q_2}^g - c_2) + {q_2}^g(a + mq_1 - {q_2}^g - c_2) \\ & - \hat{\alpha_2}q_1(a - q_1 + m{q_2}^g - c_1) \end{aligned}$$

As $\frac{\partial^2 U}{\partial {q_1}^2} < 0$, the optimal output and benefit of cities A and B and the regional optimal total output and total benefit, respectively, are as follows:

$${q_1}^{g*} = \frac{2(a - c_1)(1 - \hat{\alpha_2}) + (a - c_2)(2 - \hat{\alpha_1} - \hat{\alpha_2})m}{(1 - \hat{\alpha_2})[4 - (3 - \hat{\alpha_1} - \hat{\alpha_2} - \hat{\alpha_1}\hat{\alpha_2})m^2]} \tag{13}$$

$${q_2}^{g*} = \frac{2(a - c_1)(1 - \hat{\alpha_2})m + (a - c_2)\left[4 - (1 - \hat{\alpha_1}\hat{\alpha_2})m^2\right]}{2[4 - (3 - \hat{\alpha_1} - \hat{\alpha_2} - \hat{\alpha_1}\hat{\alpha_2})m^2]} \tag{14}$$

$$q^{g*} = {q_1}^{g*} + {q_2}^{g*} \tag{15}$$

$${U_1}^* = {q_1}^{g*}(a - {q_1}^{g*} + m{q_2}^{g*} - c_1) - \hat{\alpha_1}{q_2}^{g*}(a + m{q_1}^{g*} - {q_2}^{g*} - c_2) \tag{16}$$

$${U_2}^* = {q_2}^{g*}(a + m{q_1}^{g*} - {q_2}^{g*} - c_2) - \hat{\alpha_2}{q_1}^{g*}(a - {q_1}^{g*} + m{q_2}^{g*} - c_1) \tag{17}$$

$$U^* = {U_1}^* + {U_2}^* \tag{18}$$

Conclusion 3 (1): When the fairness preference is the same, with the increase in the fairness preference coefficient, homogeneous industry choice causes the output of city A to decrease, the output of city B to increase, and the total regional output to decrease; heterogeneous industry choice causes the output of city A, city B, and the total regional output to decline.

Conclusion 3 (2): When the fairness preference is different, homogeneous industry choice makes decision makers' output to increase with the increase in their own fairness preference effect coefficient and decrease with the increase in the other party's fairness preference effect coefficient; the total regional output follows the same trend as city A. The heterogeneous industry choice causes city A's output to decrease with the increase in their own fairness preference effect coefficient and increase with the increase in the other party's fairness preference effect coefficient; city B's output decreases with the increase in the fairness preference effect coefficient of city A and city B. The total regional output decreases with the increase in the coefficient of the fairness preference effect of city A and decreases and then increases with the increase in the coefficient of the fairness preference effect of city B.

Conclusion 3 shows that, when the fairness preferences are the same, under the condition of total regional output maximization, the weaker the unfavorable inequitable allocation psychology, the more favorable the industrial decision. When facing different equity preferences, the strength of the fairness preferences of different cities and their interrelationships should be distinguished. When the leading city has a stronger unfair allocation psychology, it is easy to make the homogeneous industry choice; when the following city has a stronger unfair psychology, it is easy to make the heterogeneous industrial choice.

Proof of Conclusion 3 (1): When $\hat{\alpha_1} = \hat{\alpha_2} = \hat{\alpha}$, Equations (13)–(15) each output with respect to $\hat{\alpha}$ for the first-order derivative, respectively, which are as follows:

$$\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha}} = \frac{2[a - c_1 + (a - c_2)m]\left[4 - (1 - \hat{\alpha})^2 m^2\right]}{[4 - m^2(3 - 2\hat{\alpha} - \hat{\alpha}^2)]^2}$$

$$\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha}} = -\frac{4[a - c_1 + (a - c_2)m]\left[4 - (1 - \hat{\alpha})^2 m^2\right]m}{[8 - 2m^2(3 - 2\hat{\alpha} - \hat{\alpha}^2)]^2}$$

$$\frac{\partial q^{g*}}{\partial \hat{\alpha}} = \frac{\partial {q_1}^{g*}}{\partial \hat{\alpha}} + \frac{\partial {q_2}^{g*}}{\partial \hat{\alpha}}$$

When $-1 < m < 0$, $\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha}} < 0$, $\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha}} > 0$, $\frac{\partial q^{g*}}{\partial \hat{\alpha}} < 0$; when $0 < m < 1$, $\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha}} < 0$, $\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha}} < 0$, $\frac{\partial q^{g*}}{\partial \hat{\alpha}} < 0$, so Conclusion 3 (1) holds. □

Proof of Conclusion 3 (2): When $\hat{\alpha_1} \neq \hat{\alpha_2}$, Equations (13)–(15) each output with respect to $\hat{\alpha_1}$, $\hat{\alpha_2}$ as first-order derivatives, respectively, which are as follows:

$$\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha_1}} = -\frac{2(a - c_1)\left(1 - \hat{\alpha_2}^2\right)m^2 + (a - c_2)\left[4m - (1 - \hat{\alpha_2})^2 m^3\right]}{(1 - \hat{\alpha_2})[4 - (3 - \hat{\alpha_1} - \hat{\alpha_2} - \hat{\alpha_1}\hat{\alpha_2})m^2]^2}$$

$$\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha_1}} = -\frac{2(a - c_1)\left(1 - \hat{\alpha_2}^2\right)m^3 + (a - c_2)\left[4 - (1 - \hat{\alpha_2})^2 m^2\right]m^2}{2[4 - (3 - \hat{\alpha_1} - \hat{\alpha_2} - \hat{\alpha_1}\hat{\alpha_2})m^2]^2}$$

$$\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha_2}} = \frac{4(a - c_2)(1 - \hat{\alpha_1})m - 2(a - c_1)(1 + \hat{\alpha_1})(1 - \hat{\alpha_2})^2 m^2}{(1 - \hat{\alpha_2})^2[4 - (3 - \hat{\alpha_1} - \hat{\alpha_2} - \hat{\alpha_1}\hat{\alpha_2})m^2]^2} - \frac{(a - c_1)\left(5 - 3\hat{\alpha_1} - 4\hat{\alpha_2} + \hat{\alpha_2}^2 - 2\hat{\alpha_1}\hat{\alpha_2} + 2\hat{\alpha_1}^2\hat{\alpha_2} + \hat{\alpha_1}\hat{\alpha_2}^2\right)m^3}{(1 - \hat{\alpha_2})^2[4 - (3 - \hat{\alpha_1} - \hat{\alpha_2} - \hat{\alpha_1}\hat{\alpha_2})m^2]^2}$$

$$\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha_2}} = -\frac{(a - c_1)\left[8 - 4(1 - \hat{\alpha_1})m^2\right]m + (a - c_2)\left[4 - (1 - \hat{\alpha_1})^2 m^2\right]m^2}{2[4 - (3 - \hat{\alpha_1} - \hat{\alpha_2} - \hat{\alpha_1}\hat{\alpha_2})m^2]^2}$$

$$\frac{\partial q^{g*}}{\partial \hat{\alpha_1}} = \frac{\partial({q_1}^{g*} + {q_2}^{g*})}{\partial \hat{\alpha_1}}, \frac{\partial q^{g*}}{\partial \hat{\alpha_2}} = \frac{\partial({q_1}^{g*} + {q_2}^{g*})}{\partial \hat{\alpha_2}}$$

When $-1 < m < 0$, $\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha_1}} > 0$, $\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha_2}} < 0$, $\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha_1}} < 0$, $\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha_2}} > 0$, $\frac{\partial q^{g*}}{\partial \hat{\alpha_1}} > 0$, $\frac{\partial q^{g*}}{\partial \hat{\alpha_2}} < 0$; when $0 < m < 1$, $\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha_1}} < 0$, $\frac{\partial {q_1}^{g*}}{\partial \hat{\alpha_2}} > 0$, $\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha_1}} < 0$, $\frac{\partial {q_2}^{g*}}{\partial \hat{\alpha_2}} < 0$, $\frac{\partial q^{g*}}{\partial \hat{\alpha_1}} < 0$, $\frac{\partial q^{g*}}{\partial \hat{\alpha_2}}$ is first less than 0 and then greater than 0. Thus, Conclusion 3 (2) holds. □

4. Numerical Simulation and Analysis

To further analyze the above decision results, this study used MATLAB to investigate the influence of information distribution and equity preferences on the decision making of regional industry selection and planning (Equations (5)–(10) and (13)–(18)), which were simulated and visualized for evaluation. Based on the relevant data from the existing literature and the methods used in this study, we set the relevant parameters as follows:

The base values for each parameter are $a = 50$, $c_1 = 1$, $c_2 = 3$, at $m = -0.8$ when the industry is homogeneous, and $m = 0.8$ when the industry is heterogeneous. In the figure below, the colors of each graph follow the RGB color mode, with larger values closer to yellow and smaller values closer to blue.

4.1. Incentives for Homogeneous Industrial Strategy Choices

4.1.1. Impact of Information Distribution on Total Regional Output and Total Revenue

Figure 1 shows the variations of the output of each city and total regional output with the information-sharing coefficient for homogeneous industries, wherein the decision makers are willing to share information. The output of the decision makers increases with the information-sharing coefficient of the other city at a certain level of information-sharing coefficient, and the smaller the coefficient, the larger the increase; at a certain level of the information-sharing coefficient of the other city, it decreases with the information-sharing coefficient of the other party, and the larger the coefficient, the larger the decrease. When the information-sharing coefficient of city A remains unchanged, the total regional output increases and then decreases with the increase in the information-sharing coefficient of city B; similarly, when the information-sharing coefficient of city B remains unchanged, the total regional output decreases with the increase in the information-sharing coefficient of city A.

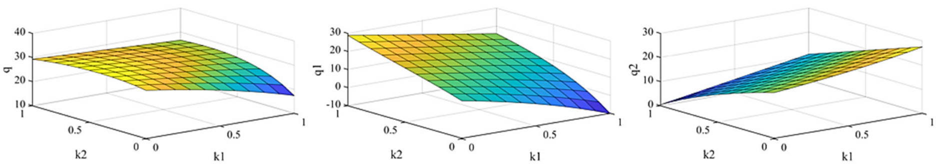

Figure 1. When the homogeneous industry is selected, (**a**) shows the variation of regional total output with the information-sharing coefficient, (**b**) shows the variation of city A output with the information-sharing coefficient, and (**c**) shows the variation of city B output with the information-sharing coefficient.

Figure 2 shows the variations of each city's benefit and total regional benefit with the information-sharing coefficient for homogeneous industries, wherein the decision makers are willing to share information. When the information-sharing coefficient of city A is constant, the benefit of city A increases with the information-sharing coefficient of city B. When the information-sharing coefficient of city B is less than 0.9, it increases with its own information-sharing coefficient. If it is greater than 0.9, it decreases first and then increases. When the information-sharing coefficient of city B is less than 0.5, the benefit of city B increases with the information-sharing coefficient of city A; when it is greater than 0.5, it increases first and then decreases; when it is larger and close to 1, it decreases with it. When the information-sharing coefficient of city A is less than 0.5, it increases with its own information-sharing coefficient. If it is greater than 0.5, it decreases first and then increases. The change trend of regional total income is roughly the same as that of city B. Its nodes are the information-sharing coefficient 0.8 and 0.5 of city A and city B, respectively.

Figure 1 shows that decision makers have an information-sharing willingness, and when cities A and B have a weaker and stronger information-sharing willingness, respectively, the total regional output is greater than under the synergistic condition. To maximize output, decision makers reduce their own information-sharing coefficients and want the other to have a larger information-sharing coefficient. City A's information-sharing coefficients have a greater impact on total regional output. Therefore, the weaker the willingness of leading cities to share information, the more likely both cities are to make homogeneous industrial choices under the decision requirement of maximizing total regional output. Figure 2 shows that decision makers have the willingness to share information, and the decision makers have more benefits and total regional benefit than in the synergistic condition. As the information-sharing coefficient of city B has a greater impact on the total regional benefit, to maximize the benefit, decision makers will increase their own information-sharing coefficient and expect the other to also increase its information-sharing coefficient. Therefore, the weaker or stronger the information-sharing willingness of the leading city and the following city, respectively, the easier it is to make homogeneous industrial choices under the decision requirement of maximizing total regional benefit.

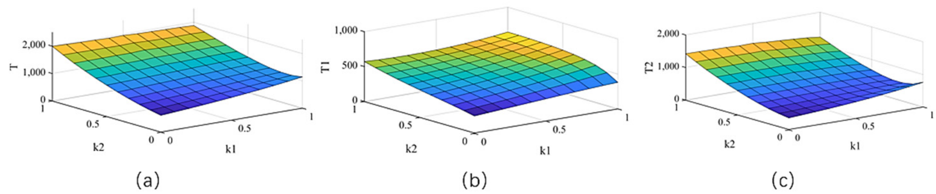

Figure 2. When the homogeneous industry is selected, (**a**) shows the variation of regional total benefit with the information-sharing coefficient, (**b**) shows the variation of city A benefit with the information-sharing coefficient, and (**c**) shows the variation of city B benefit with the information-sharing coefficient.

4.1.2. Impact of Fairness Preference on Total Regional Output and Total Revenue

Figure 3 shows the variations of the output of each city and total regional output with the fairness preference coefficient for homogeneous industries, wherein the decision makers have a fairness preference mentality. The decision makers' output decreases with the other party's fairness preference coefficient when their own fairness preference coefficient is certain, and the larger the coefficient, the larger the decrease; it increases with the coefficient of their own fairness preference effect when the other party's fairness preference coefficient is certain. The total regional output decreases with the fairness preference coefficient of city B when the fairness preference coefficient of city A is less than 0.75, and increases and then decreases with the coefficient when it is greater than 0.75; it increases with the fairness preference coefficient of city A when the fairness preference coefficient of city B is certain.

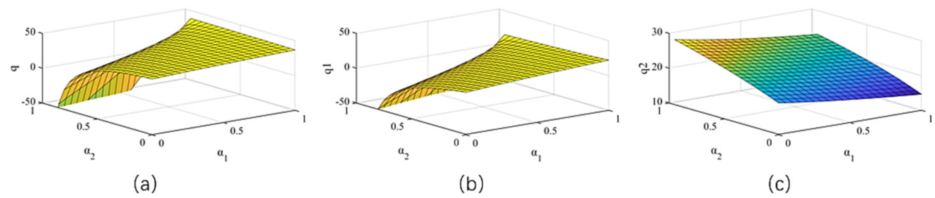

Figure 3. When the homogeneous industry is selected, (**a**) shows the variation of regional total output with the fairness preference coefficient, (**b**) shows the variation of city A output with the fairness preference coefficient, and (**c**) shows the variation of city B output with the fairness preference coefficient.

Figure 4 shows the variations of each city's benefit and total regional benefit with the fairness preference coefficient for homogeneous industries, wherein decision makers have a fairness preference mentality. The trend of regional total benefit is roughly the same as that of city B. Regional total benefit decreases and then increases with city B's fairness preference coefficient when city A's fairness preference coefficient is less than 0.9; decreases with it when it is greater than 0.9; and decreases with city A's fairness preference coefficient when city B's fairness preference coefficient is certain.

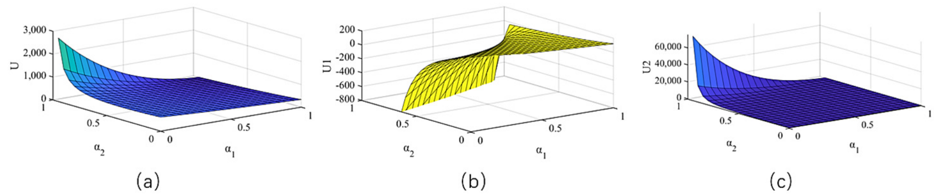

Figure 4. When the homogeneous industry is selected, (**a**) shows the variation of regional total benefit with the fairness preference coefficient, (**b**) shows the variation of city A benefit with the fairness preference coefficient, and (**c**) shows the variation of city B benefit with the fairness preference coefficient.

Figure 3 shows that decision makers have fair preference psychology, and when decision makers have a stronger fair preference psychology, the total regional output is higher than in the synergistic condition. To maximize output, decision makers increase their own fair preference coefficients and city A's fair preference coefficient has a greater impact on total regional output. Therefore, under the decision requirement of maximizing total regional output, the stronger the unfavorable inequitable distribution psychology of the leading city, the more favorable the homogeneous industry selection.

Figure 4 shows that, under the condition that decision makers have a fair preference mentality when considering positive returns, the total regional return is less than under the synergistic condition. To maximize regional gain, the region expects that none of the decision makers have a fair preference mentality, nor do they compete normally and collaboratively. Therefore, under the decision requirement of maximizing the total regional gain, the weaker and stronger the unfair allocation psychology of the leading city and following city, respectively, the more likely it is to make homogeneous industrial choices.

4.2. Incentives for Heterogeneous Industry Strategy Choices

4.2.1. Impact of Information Distribution on Total Regional Output and Total Revenue

Figure 5 shows the variations of output of each city and total regional output with an information-sharing coefficient for heterogeneous industries, wherein decision makers are willing to share information. The output of city A increases with the information-sharing coefficient of the other party when its own information-sharing coefficient is less than 0.4, decreases and then increases with the coefficient of the other party when it is greater than 0.4, and increases with the coefficient of the other party when the coefficient of the other party's information-sharing coefficient is certain. The output of city B and the total output of the region increase with the information-sharing coefficient.

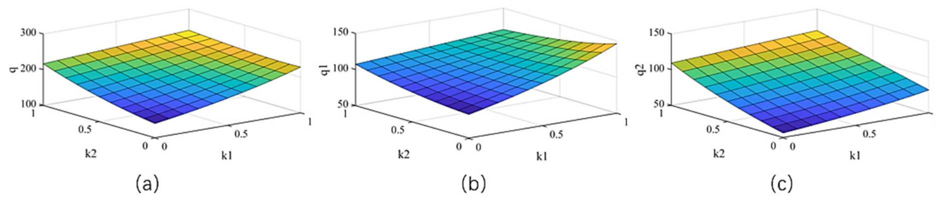

Figure 5. When the heterogeneous industry is selected, (**a**) shows the variation of regional total output with the information-sharing coefficient, (**b**) shows the variation of city A output with the information-sharing coefficient, and (**c**) shows the variation of city B output with the information-sharing coefficient.

Figure 6 shows the variations of the output of each city and the total regional output of the heterogeneous industry with the information-sharing coefficient, wherein the decision maker is willing to share information. The trend in total regional benefit is roughly the same as that of city B. When the information-sharing coefficient of city A is constant, the regional total benefit increases first and then decreases with the information-sharing coefficient of city B. When the information-sharing coefficient of city B is constant, it increases with the information-sharing coefficient of city A.

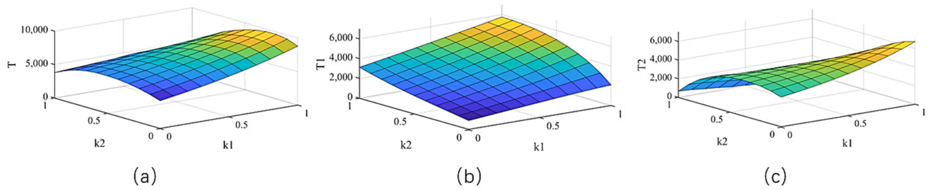

Figure 6. When the heterogeneous industry is selected, (**a**) shows the variation of regional total benefit with the information-sharing coefficient, (**b**) shows the variation of city A benefit with the information-sharing coefficient, and (**c**) shows the variation of city B benefit with the information-sharing coefficient.

Figure 5 demonstrates that decision makers are open to sharing information and that their output and the overall regional output are higher than they would be in a synergistic situation. The information-sharing coefficients of both parties have a stronger impact on the overall regional production when decision makers improve their own information-sharing coefficients to optimize output. Consequently, the more attractive the choice of heterogeneous industries, the higher the willingness to share information under the decision criterion of optimizing total regional output.

Figure 6 shows that decision makers have the willingness to share information, and the total regional gain is greater than in the synergistic condition when the willingness to share information is stronger and weaker in cities A and B, respectively. To maximize the gain, decision makers increase their own information-sharing coefficients and want the other to have larger information-sharing coefficients. City A's information-sharing coefficient has a greater impact on the total regional benefit. Therefore, the stronger and weaker the information-sharing willingness of the leading city and the following city, respectively, the more favorable the heterogeneous industry selection under the decision requirement of maximizing the total regional benefit.

4.2.2. Impact of Fairness Preference on Total Regional Output and Total Revenue

Figure 7 shows the variations in the output of each city and total regional output with the fairness preference coefficient for heterogeneous industries, wherein the decision makers have a fairness preference mentality. When the fairness preference coefficient of city A is less than 0.9, the output of city A increases with the fairness preference coefficient of the other city, and decreases when the fairness preference coefficient of city A is greater than 0.9. When the other party's fair preference coefficient is constant, it decreases with its own fair preference coefficient. The output of city B decreases with the fair preference coefficient. The change trend of regional total output is roughly the same as that of city A. The total regional output is more influenced by the fairness preference coefficient of city B.

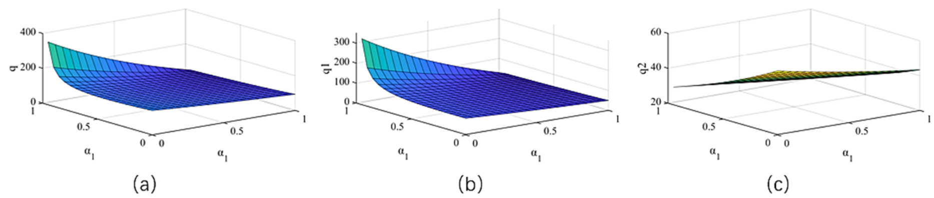

Figure 7. When the heterogeneous industry is selected, (**a**) shows the variation of regional total output with the fairness preference coefficient, (**b**) shows the variation of city A output with the fairness preference coefficient, and (**c**) shows the variation of city B output with the fairness preference coefficient.

Figure 8 shows the variations of each city's benefit and total regional benefit with the fairness preference coefficient for heterogeneous industry, wherein the decision makers have a fairness preference mentality. The total regional benefit decreases and then increases with the city B fairness preference coefficient as the city A fairness preference coefficient approaches 0; decreases with it as it approaches the value of 1; and decreases with the city

A fairness preference coefficient until a certain city B fairness preference coefficient. The total regional benefit is more influenced by city B's fairness preference coefficient.

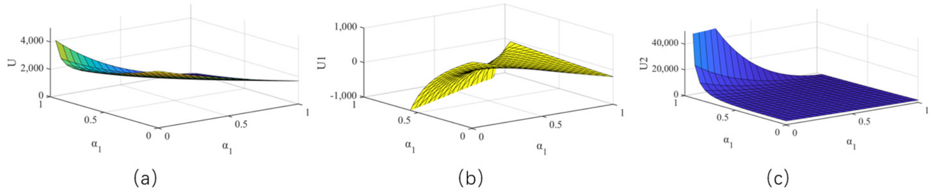

Figure 8. When the heterogeneous industry is selected, (**a**) shows the variation of regional total benefit with the fairness preference coefficient, (**b**) shows the variation of city A benefit with the fairness preference coefficient, and (**c**) shows the variation of city B benefit with the fairness preference coefficient.

Figure 7 shows that decision makers have a fairness preference psychology, and when cities A and B have weaker and stronger fair preference psychologies, respectively, the total regional output is higher than in the synergistic condition. To maximize output, decision makers reduce their own fair preference coefficients, and city B's information-sharing coefficient has a greater impact on total regional output. Therefore, the weaker and stronger the unfavorable inequitable distribution psychology of leading and following cities, respectively, the more favorable the heterogeneous industry selection under the decision requirement of maximizing total regional output.

Figure 8 shows that decision makers have a fairness preference psychology when considering the positive gain. When cities A and B's fairness preference psychology is almost 0 and 1, the total regional gain is less than in the synergistic condition, and in the rest of the cases, the total gain here is more than in the synergistic condition. To maximize the gain, city A will reduce its own fairness preference coefficient, city B will increase its own fairness preference coefficient, and city B's information-sharing coefficient will have a greater impact on the total regional gain. Therefore, under the decision requirement of maximizing total regional return, the unfavorable unfair allocation psychology of the leading city and following city is 0 and 1, respectively, which are most favorable for heterogeneous industry selection. The leading city and following city do not have an unfavorable unfair allocation psychology, which are the second strongest in favor of heterogeneous industry selection.

5. Conclusions

To promote the achievement of Goal 11 of the 17 SDGs of the United Nations, this paper built a Stackelberg model for two nearby cities, A and B, and introduced internal and external behavioral factors (information distribution and fairness preference) to analyze the effect of the cities' industrial planning decisions on the goal of maximizing regional output and benefit. At this stage, most of the cities in China, such as the cities in the Guangdong–Hong Kong–Macao Greater Bay Area and the city clusters in the western region, are experiencing the phenomenon of the convergence of industrial structures and obvious homogeneous competition. On the contrary, city clusters in foreign countries such as Chicago and the Silicon Valley are developing synergistically, and the distribution of industries in the region shows a diversified and complementary pattern. Chicago is the main body of a number of central cities in the function of their respective strengths, interdependence, common development, and the formation of the development of urban agglomerations in tandem with the characteristics. Model discussion and numerical simulation results show that regional industrial planning and adjustments should consider both internal and external factors. The coordination between regional productivity layout and industrial selection should be coordinated and competitive, aiming at reducing the homogeneous industry selection and increasing the heterogeneous industry selection. Therefore, China's city clusters should strengthen synergy like other city clusters in the United States and Europe, while considering the influence of internal and external behavioral factors. The conclusions are as follows:

Homogeneous industry selection strategy: (1) With the decision to maximize total regional output, the weaker the willingness of leading cities is to share information and the stronger the unfavorable inequitable distribution mentality, and the more favorable homogeneous industry selection becomes. (2) With the decision to maximize total regional benefit, the weaker and stronger the willingness to share information of the leading and following cities is, respectively, and the weaker and stronger the unfavorable inequitable distribution mentality is, respectively, and the more favorable homogeneous industry selection becomes.

Heterogeneous industry selection strategy: (1) With the decision to maximize total regional output, the stronger the willingness of leading and following cities is to share information, the weaker and stronger the unfavorable inequitable distribution mentality is, respectively, and the more favorable heterogeneous industrial selection becomes. (2) With the decision to maximize total regional benefit, the stronger and weaker the willingness to share information of leading and following cities is, respectively, and the more favorable heterogeneous industry selection becomes. When the unfavorable inequitable distribution mentality of leading and following cities is 0 and 1, respectively, the most favorable choice is heterogeneous industry selection. When both cities do not have an unfavorable inequitable distribution mentality, heterogeneous industry selection is the second most favorable choice.

Homogeneous competition makes it difficult for each regional factor system to match the needs of industrial development planning. To a certain extent, this intensifies the competition for scarce factors and regional division, and the disorderly and unplanned agglomeration brings about a mismatch of production resources, which is not conducive to the formation of cross-administrative industrial linkage and a synergistic development model. Therefore, we propose the following recommendations.

Firstly, good work must be completed in the overall planning of regional industrial coordination, a reasonable urban function division system must be formed, and the division of labor and coordination between core cities must be deepened and developed. The relations and cooperation between Chinese cities are still limited by administrative regions, and there is no complex and diverse system of cooperation and division of labor, which needs the regulation and guidance of policies. Only cooperation and competition can reflect the comprehensive strength of a region, and inter-regional urban cooperation is the key to regional competitive advantage. In fact, Los Angeles has become a global city through competition and cooperation with its traditional center, San Francisco, as evidenced by the growth of the Los Angeles metropolitan area, Orange County. At the same time, based on the comparison of resource endowments and advantages and disadvantages within the region, unnecessary competition and loss caused by industrial non-homogeneity should be avoided, and the influence of internal and external behavioral factors should be taken into account. Through differentiated regional industrial layout and the regional division of labor, a competitive relationship of the division of labor and complementarity, tacit cooperation and mutual benefit should be established to break intra-regional division and share infrastructure. With the help of effective industrial integration, a unique advantageous industrial development model between regional cities can be created to form a reasonable and efficient industrial structure. In the cooperation of the capital economic circle, Tianjin can combine its own industrial advantages and regional advantages, make use of the symbiotic advantages of the urban agglomeration economy, and through the integration and complementary development of Beijing and Hebei in the fields of manufacturing and the service industry, assume the functions of the capital economic circle in the country and even the world in the fields of high-end manufacturing, port and logistics, financial service innovation, and technological research and development transformation, so as to achieve the goal of Tianjin's urban development.

Secondly, under the conditions of the existing industrial system between the cities, good work must be completed in industrial adjustment and planning. Improving the conditions of information distribution and solving unfavorable and unfair distribution is an important way to establish mutual trust between cities and realize the synergistic development of regional industries, as well as facing homogenized industries and guiding existing industries to industrial adjustment. Large cities should pay more attention to the influence of external behavioral factors, while small cities should pay more attention to the influence of internal behavioral factors. This approach reduces the negative consequences of resource waste and vicious competition caused by industrial homogenization. When heterogeneous industries exist in a region, cities at all levels should consider the influence of both internal and external behavioral factors. Cities are guided to make positive forward-looking layouts that take into account expected changes. Implementing a compensation mechanism is also essential to address distributional inequities. In addition, the establishment of sound benefit-sharing and incentive mechanisms provides incentives for parties that suffer losses in order to maintain long-term trust and cooperation.

Notably, this study discusses industrial selection strategies based on the assumption of a "leader–follower" relationship among different cities, wherein small- and medium-sized cities become important parties in each other's strategic choices, regional industrial planning, and overall productivity layout. These cities should actively adapt to the industrial characteristics and development trends of the bigger, core cities, formulate industrial policies with their own resource endowments and advantages, and actively integrate into the overall planning for collaborative regional development. Research on agglomeration theory also shows that small- and medium-sized cities can obtain development advantages they do not have by borrowing functions or scale from neighboring large cities so that they can leapfrog development. Correspondingly, large cities can also concentrate their advantages through functional differentiation from the synergistic industrial development with neighboring cities, improve the efficiency of resource allocation in a larger area, and effectively drive and enhance the high-quality development of regional economies.

The efficiency of resource allocation and utilization can be improved and regional sustainable development can be realized through the proper selection of and cooperation among homogeneous or heterogeneous industries in the region. Maintaining long-term trust and cooperation between regions, reducing unfavorable inequitable distribution, and creating a regular, institutionalized, industrial coordination and incentive system are necessary for the growth of synergistic competition among cities. The development of benefit-sharing systems, as well as the strengthening of trust and reciprocity between cities in various areas, will all help enhance the internal dynamics of a region and promote the economic development of the region as a whole. To create conditions for sustainable industrial development, it is necessary to ensure the stability and durability of competition by strengthening the management and coordination of functional zone planning and industrial distribution.

The limitation of this paper lies in the limited literature on the application of the Stackelberg model to urban industrial development problems and the limited available data. At the same time, the city is a very complex entity, which is affected by many factors. This paper only considers the influence of information distribution and equity preference among behavioral factors on urban industrial development. In future research, it is necessary to consider the impact of more factors on the development of urban industry, and to then comprehensively analyze the problem.

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