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Synergistic Patterns of Urban Economic Efficiency and the Economic Resilience of the Harbin–Changchun Urban Agglomeration in China

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Abstract: Regional economic efficiency and resilience are necessary conditions for sustainable regional economic development, and urban agglomerations are the core carriers of regional economic development. Exploring the synergistic patterns between economic efficiency and economic resilience is crucial to the sustainable economic growth and development of urban agglomerations and their surrounding regions. To measure the economic efficiency, economic resilience, and synergistic capacity of the Harbin–Changchun urban agglomeration from 2010 to 2019, the super-efficient SBM model, the entropy-TOPSIS model, and the Haken model are used. The economic efficiency of the Harbin–Changchun urban agglomeration shows a mild upward trend between 2010 and 2019, while its economic resilience shows a more stable upward trend. A distinct phased pattern of synergies exists between economic efficiency and economic resilience. In terms of the time trend, a “down-up-down” pattern emerges, while in terms of the spatial pattern, a dumbbell-shaped structure appears with “highs at the north and south and lows in the middle”. Combined synergy values are highest in the north and south of Qiqihar, Jilin, Siping, Liaoyuan, and Mudanjiang, followed by Harbin and Changchun; the values are lowest in the middle of Suihua, Daqing, and Songyuan. This study also proposes strategies to weaken inter-regional differentiation and to increase economic efficiency and economic resilience across cities in accordance with the actual situation.

Keywords: economic efficiency; economic resilience; Haken model; synergistic pattern; Harbin–Changchun urban agglomeration



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1. Introduction

The concept of sustainable development was developed in the second half of the 20th century and focuses on achieving the long-term synergy of regional economic and social development goals and environmental limits. Economic sustainability is a key aspect of sustainable regional development, and therefore, receives more attention. In the process of exploring sustainable regional economic development, the improvement of economic efficiency has been an important basis for judging the sustainability of economic development. The 2030 Agenda for Sustainable Development describes the importance of economic efficiency. Research on regional economic efficiency has been generally divided into two categories [1]. One category is the perspective of a single factor [2], which typically refers to the efficiency relationship between input factors such as ecology, environment, or energy resources and an effective economic output [3]. The other category is the perspective of total factors [4], which considers the impacts of various factors on economic efficiency and establishes a comprehensive index system to measure that efficiency. In 2008, the global economy experienced a recession. How regions respond to major recessionary shocks to restore sustainable economic growth has become a high-priority issue. The need for economic resilience is becoming an urgent need; economic resilience is also a core component of sustainable economic development, particularly when there is heterogeneity in the ability of different regions to withstand and recover from shocks. Economic resilience

differs from economic efficiency in that economic resilience emphasizes the ability to deal with shocks in an unstable external environment and the ability of the economy as a whole to adjust and transform itself and achieve a “path breakthrough” [5–12]. Existing research on economic resilience covers two main areas: (1) the measurement and performance characteristics of economic resilience [13] and (2) the factors that influence economic resilience [14,15]. The methods used to measure economic resilience include the index system method and the core variable method [16]. The core variable method usually selects employment rate [14] and GDP [17] to analyze the extent to which a region responds to economic shocks. Additionally, many studies have proven that industrial structure [18], social capital [16], and technological innovation ability [19] have certain impacts on regional economic resilience.

As the two current main themes of sustainable regional economic development, economic efficiency and economic resilience together have a strong inherent interactive link between adaptation and feedback. However, most of the existing research on these two themes has mainly analyzed them separately. However, international scholars have begun to conduct preliminary validation studies on the synergistic relationship between the efficiency and resilience of other systems. This approach has positive implications for conducting research on the synergy of the economic efficiency and economic resilience of economic systems. Scholars such as Kahiluoto [20,21] have presupposed that the efficiency of the rational use of resources may lead to a reduction in system diversity, and thus, jeopardize resilience. However, scholars have concluded that diversification as a strategy to enhance farm resilience did not necessarily constrain resource-use efficiency. This shows that there is no contradiction between high efficiency and high resilience and that they can be developed in a balanced way. De Arquer studied the balance between efficiency and resilience in closed-loop supply chains [22]. The study emphasized the importance of combining efficiency and resilience to maintain a proper balance between the two as a basis for modern socioeconomic development towards a more circular model.

Urban agglomerations have become increasingly prominent in driving the regional economy and are the most promising and dynamic core areas in regional economic development patterns [22–26]. At the same time, high-density urban agglomerations have made those areas vulnerable to a high risk of external environmental disturbances, such as resource depletion, shrinking spaces for industrial development, and international shocks [27]. The Harbin–Changchun urban agglomeration is an important economic region in Northeast China. The regional economic development of this agglomeration is dominated by heavy industry, with many major national old industrial bases. The construction of the Harbin–Changchun urban agglomeration is one of the strategies of the revitalization plan in Northeast China. However, with the decreasing role of traditional industries in driving the economy, the regional economic development of the Harbin–Changchun urban agglomeration has gradually slowed down. In 2014, with the economic “cliff-like drop” in Northeast China [28], the Harbin–Changchun urban agglomeration suffered the impact of an economic crisis and the resultant, economic development recession; the restoration of the economy was urgently need. Thus, in order to promote high-quality and sustainable development of regional economies, there is an urgent need to conduct research on the synergistic development of the economic efficiency and economic resilience of urban agglomerations, in order to enhance the sustainability and innovative transformation of economic systems. However, a single emphasis on the economic efficiency of urban agglomerations is not conducive to the adaptation of their economies to external environmental shocks and disturbances. In addition, a one-sided emphasis on resilience can lead to redundant resources and reduced productivity, which can lead, in turn, to lagging development [27]. Current studies that have mainly focused on the study of the economic efficiency and economic resilience of urban agglomerations have mostly been conducted from the perspective of the two independently; not enough studies have been conducted on their synergistic development. Therefore, this study selects the current Harbin–Changchun urban agglomeration, which is a key cultivation area in China, as a case study to explore

the characteristics of the synergistic evolution pattern of economic efficiency and economic resilience of the cities within that agglomeration. On the one hand, this study complements existing research on the sustainable development of regional economies; on the other hand, the results provide guidance for the sustainable development of urban agglomeration areas.

The remainder of this paper is structured as follows: In Section 2, we describe the correlation between economic efficiency and economic resilience, and the study's research methods and data sources are also presented; in Section 3, we analyze the research results; in Section 4, we discuss the research results, and according to those results we provide suggestions for future regional economic development; and in Section 5, we summarize the research results and present our conclusions.

2. Materials, Methods, and Data

2.1. The Relationship between Economic Efficiency and Economic Resilience

Economic efficiency is intrinsic to sustainable development. The main elements of sustainable economic development are the enhancement of the ability to rationally allocate resources and environmental factors, and to promote the formation of “low input, low consumption, high output, and high efficiency” economic growth characteristics. Economic resilience is a necessary guarantee for sustainable development. When economic development faces major risks and challenges, the importance of resilience is significantly highlighted. “Strong resilience” escorts sustainable economic development and smoothly passes the economic crisis. Economic efficiency and economic resilience are essential for sustainable development in an economic system that urgently needs to maintain long-term stable, healthy, and orderly sustainability; therefore, they need to be developed in conjunction, taking into account the urgent sustainability issues in the regional economic system. By analyzing the influencing factors of economic efficiency and economic resilience, the internal correlation is explored.

The impact of economic efficiency on economic resilience Economic resilience consists of three dimensions: resist and recover ability, adapt and adjust ability, and innovate and transform ability. Economic resilience can be measured in different dimensions by using influencing factors, such as industrial structure diversification, social capital richness, and the level of innovation development [15,16]. If the economy is inefficient, factor inputs flow to low-productivity industries, and the industrial structure will need to be adjusted and upgraded, negatively affecting the region's ability to resist and recover. Low economic efficiency indicates a poor level of regional economic development and insufficient social capital, which, in turn, affects regional ability to adapt and adjust when facing major risk challenges. Economic efficiency improvement and production technology advancement indicate a region's innovation and R&D level renewal capability, and innovation transformation enhancement capability. These capabilities help to stabilize socioeconomic diversification and to enhance regional economic resilience (Figure 1).

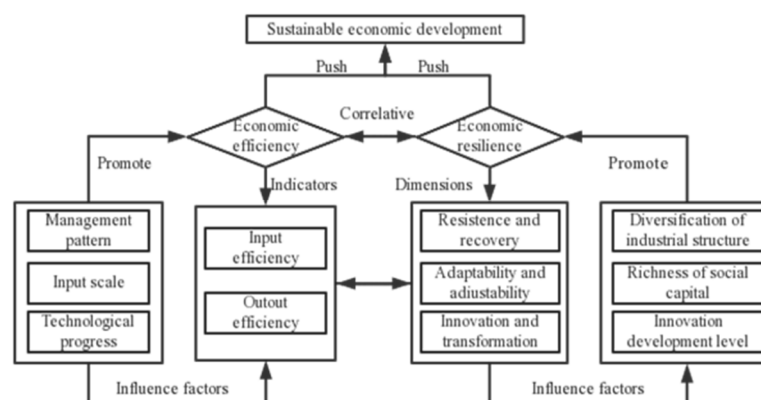


Figure 1. Correlation diagram of economic resilience and economic efficiency.

The impact of economic resilience on economic efficiency As an important indicator of economic efficiency, input–output efficiency relies heavily on the scale of inputs, management patterns, technological progress, and other factors that contribute to improved economic efficiency [28–32]. When the external environment is in an unstable state, and if the economy has poor resilience, the industrial structure and social capital’s single development affect the scale of production factors input. Economic resilience affects the level of regional innovation development. Poor economic resilience and weak innovation capacity can lead to enterprises using backward production and management methods of enterprises, adversely affecting the development of production technology innovation. This would make the economy less efficient and would inhibit sustainable economic development. Sustainable economic development that is only focused on economic efficiency may result in the inability to resolve the uncertainties of the external environment (Figure 1).

2.2. Methods and Data

2.2.1. Super-Efficient SBM Model

The super-efficient SBM model is an extended model of non-angular, non-radial data envelopment analysis (DEA) model proposed by Tone [33]. The model incorporates slack variables into the objective function; this remedies the problem that traditional DEA models cannot distinguish multiple decision units that are valid at the same time [4]. The DEA models use the concept of operations research to evaluate the relationship between the inputs and outputs of decision units through linear programming, in order to measure the relative effectivity [4,34]. In actual production activities, many undesirable outputs are inseparable from production activities, such as the quality of pollutants, which are a growing concern. Therefore, the evaluation of urban economic efficiency necessarily takes pollutant emissions into account [4,34]. The super-efficient SBM model, which takes undesirable outputs into account, is a good way to measure and evaluate the efficiency of undesirable outputs as compared with the traditional SBM model [35]. Therefore, in this study, economic efficiency was evaluated using a super-efficient SBM model based on undesirable outputs; the efficiency values of individual cities in the Harbin–Changchun urban agglomeration, from 2010 to 2019, were measured with the help of the Maxdea software. Input indicators were selected to analyze economic inputs from four perspectives: capital, labor, natural resources, and technology [4]. The output indicators were selected from two perspectives: desired output and undesirable output, as shown in Table 1.

Table 1. Evaluation index system of urban economic efficiency.

Category	Item	Indicator
Input	Capital	Fix assets investment
		Financial expenditure budget
	Labor	Employees
	Natural resources	Construction land area
Output	Technology	Administrative area
	Desirable output	Technology, education expenditure
	Undesirable output	GDP
		Industrial wastewater emissions

2.2.2. Entropy-TOPSIS Integrated Evaluation Model

The evaluation method adopts the entropy-TOPSIS method, in which the entropy method assigns objective weights to the indicator system and the TOPSIS method approximates the ideal solution by evaluating the strengths and weaknesses of each indicator system. The two methods are combined to obtain the economic resilience score of each city [27]. Regional economic resilience is the ability of a regional economy to withstand or recover from shocks through adaptation. However, it is important to note that these two processes exist simultaneously and influence each other. As resistance and recovery are strongly correlated, distinguishing between them when selecting data is difficult, therefore,

resistance and recovery are combined. Therefore, the indicator system for evaluating economic resilience is selected as three dimensions: (1) resistance and recovery, (2) adaptability and adjustability, and (3) innovation and transformation [14,15,36] (Table 2). The construction of specific indicators to evaluate the economic resilience of urban agglomerations draws on relevant studies by scholars such as Briguglio, Ding, and Qi [37–41].

Table 2. Evaluation index system of urban economic resilience.

Target Level	Guideline Level	Index Level	Action Direction	Indicator Explanation	Weight
Economic resilience	Resistance and recovery (0.2991)	GDP	+	Level of regional economic development	0.0542
		Urban and rural savings balance	+	Residents' ability to resist risk	0.0576
		Rural per capital disposable income	+	Rural residents' ability to resist risk	0.0731
		Industrial diversification	—	Level of industrial diversification	0.0604
		Ratio of foreign trade dependence	—	Total export-import volume/GDP	0.0537
	Adaptability and adjustability (0.2743)	Level of financial self-sufficiency	+	Local fiscal revenue/local fiscal expenditure	0.0826
		Local fiscal expenditure	+	Regional government's resource allocation	0.0635
		Gross fixed asset formation	+	Size of regional investment	0.0667
		Total retail sales of social consumer goods	+	Size of regional market scale	0.0614
	Innovation and transformation (0.4267)	Urbanization rate	+	Regional urban population/regional total population	0.0997
		The support efforts of education	+	Level of regional education	0.0424
		Advanced stage of industrial structure	+	Production value of primary industry $\times 1$ + production value of secondary industry $\times 2$ + production value of tertiary industry $\times 3$	0.1102
		Scientific research outputs	+	Number of patents/GDP	0.0998
		Proportion of R&D investment	+	R&D expenditure/GDP	0.0747

Specific indicators are measured as follows:

Industrial diversification is measured by the Herfindahl–Hirschman Index [30]. When calculating the economic resilience evaluation score, it should be noted that the indicator is a negative indicator value. This is calculated as follows:

$$HHI = \sum_{i=1}^N (X_i/X)^2 = \sum_{i=1}^N S_i^2$$

where $N = 3$, X_i is the output value of industry, X is the regional GDP, and S_i is the proportion of output value of industry i to the regional GDP.

2.2.3. Improved Haken Model

Originally applied to thermodynamic systems, the Haken model illustrates the role of subsystems in the development of the overall system and the degree of interaction between two subsystems within the system [42]. The model was later introduced into the study of regional economic systems by Li and others [43]. This study improved the model to analyze

the relationship between regional economic sustainability systems, economic resilience, and economic efficiency. This was achieved by learning from the experience of scholars such as Ouyang, Han, and others [27,44–46].

In the Haken model, it is assumed that one subsystem or parameters of the system are internal forces, and the other subsystem or parameters are controlled by the internal forces. These subsystems or parameters are denoted by q_1 and q_2 , respectively. Let γ_1 and γ_2 be the damping coefficients of subsystems, a and b are the control parameters [47]. The analytical process of the improved Haken model is shown below.

In Step 1, the model assumptions are proposed, the model is discretized, and the equations of motion are constructed as follows:

$$q_1(t) = (1 + \gamma_1)q_1(t-1) + aq_1(t-1)q_2(t-1) \quad (1)$$

$$q_2(t) = (1 + \gamma_2)q_2(t-1) + bq_1(t-1)q_2(t-1) \quad (2)$$

Step 2 involves solving parameters in evolutionary equations: γ_1 , γ_2 , a , b , and determining whether the parameters satisfy the “adiabatic approximation assumption” $|\gamma_1| \gg |\gamma_2|$. Thus, the order parameter q_1 is obtained.

Step 3 involves solving the evolution Equation (3) with the potential function Equation (4), thus, obtaining the stable point of the synergetic development of two subsystems $[q^*, v(q^*)]$ as follows:

$$q = -\gamma_1 q_1 - \frac{ab}{\gamma_2} q_1^3 \quad (3)$$

$$v(q) = \frac{1}{2} \gamma_1 q_1^2 + \frac{ab}{4\gamma_2} q_1^4 \quad (4)$$

$$q^* = \sqrt{\left| \frac{\gamma_1 \gamma_2}{ab} \right|} \quad (5)$$

In Step 4, the two subsystem synergy values are calculated, i.e., d , to obtain the degree of synergy between the subsystems, as follows:

$$d = \sqrt{(q - q^*)^2 + [v(q) - v(q^*)]^2} \quad (6)$$

If the order parameter q_1 is economic efficiency and the subsystem q_2 dominated by q_1 is economic resilience, then γ_1 , γ_2 represents the degree of influence of the two subsystems of economic efficiency and economic resilience on the coordinated development of the economic system (Table 3).

Table 3. Interpretation of the Haken model parameters, with regard to γ_1 , γ_2 .

Parameter	Influence Level of Parameters on System	Directions for the Synergistic Evolution of the System	Note
$\gamma_1 < 0$	Positive effects	The higher the degree of synergy	The order parameter q_1 plays a leading role.
$\gamma_1 > 0$	Negative effects	The lower the degree of synergy	
$\gamma_2 < 0$	Positive effects	Enhanced synergy	Parameter q_2 is dominated by q_1 .
$\gamma_2 > 0$	Negative effects	Weakened synergy	

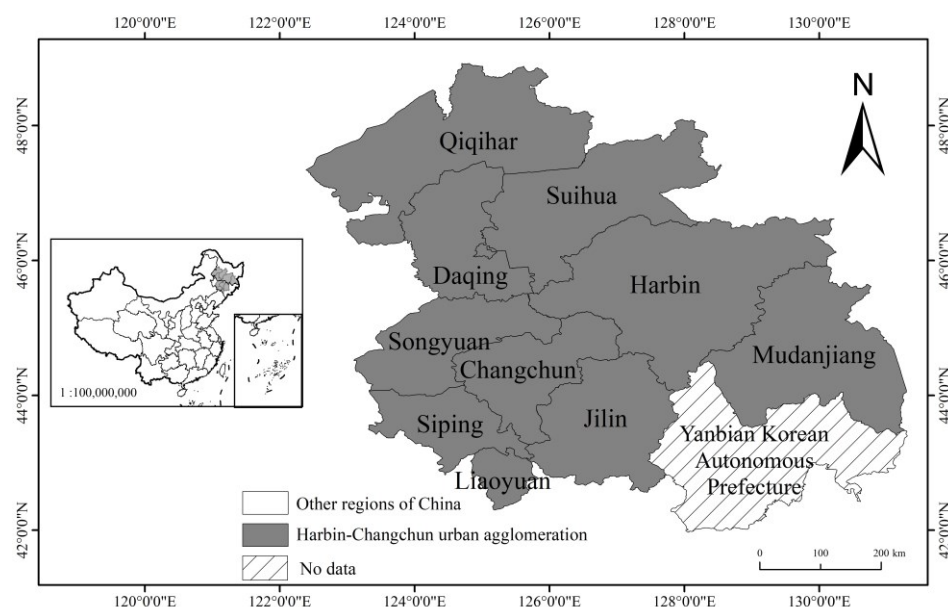
The parameters a and b of the equation represent the interaction between the two subsystems (economic efficiency and economic resilience) (Table 4).

Table 4. Interpretation of the Haken model parameters, with regard to a, b.

Parameter	Interaction between Subsystems	Relationship between Subsystems	Note
$a > 0$	q_2 has a negative effect on q_1 .	q_2 Hinders q_1	$ a b $ the larger the interaction, the more significant the interaction.
$a < 0$	q_2 has a positive effect on q_1 .	q_2 Promotes q_1	
$b > 0$	q_1 has a positive effect on q_2 .	q_1 Promotes q_2	
$b < 0$	q_1 has a negative effect on q_2 .	q_1 Hinders q_2	

2.2.4. Data Sources

The original data of economic efficiency and economic resilience were obtained from the *China City Statistical Yearbook*, *Jilin Statistical Yearbook*, *Heilongjiang Statistical Yearbook* and the Statistical Bulletins on the national economic and social development of the cities of Harbin, Qiqihar, Daqing, Mudanjiang, Suihua, Changchun, Jilin, Siping, Liaoyuan, and Songyuan. In this paper, we selected the Harbin–Changchun urban agglomeration as the study area (Figure 2); the Yanbian Korean autonomous prefecture lacked sufficient data and was not included in the study. The rest of the missing data were added by the interpolation method.

**Figure 2.** Location of the Harbin–Changchun urban agglomeration.

3. Results and Analysis

3.1. Analysis of Economic Efficiency and Economic Resilience

An entropy-TOPSIS model and super-efficiency SBM model of undesirable output were used to measure the economic efficiency and economic resilience of each city in the Harbin–Changchun urban agglomeration. In addition, the ArcGIS10.6 software was used to visualize urban economic efficiency and economic resilience in different years, while the Jenks natural breaks optimization method was adopted to classify the economic efficiency and economic resilience values of the cities into four categories, from low to high.

3.1.1. Urban Economic Efficiency

On the whole, between 2010 and 2019, Figure 3a shows that the average urban economic efficiency of the Harbin–Changchun urban agglomeration increased slowly, from 0.53 to 0.69, with an average annual growth of only 3%. In the Harbin–Changchun urban agglomeration, the development differences of economic efficiency among cities reduced dynamically. In 2010, the kernel density distribution showed a “weak double peak” struc-

ture. In 2018, the “weak double peak” structure evolved into a “strong double peak” structure, having been driven by the city’s high economic efficiency. In 2019, the distribution of kernel density took on a “single peak” structure, in line with the abrupt decrease in the development speed of the city’s high economic efficiency.

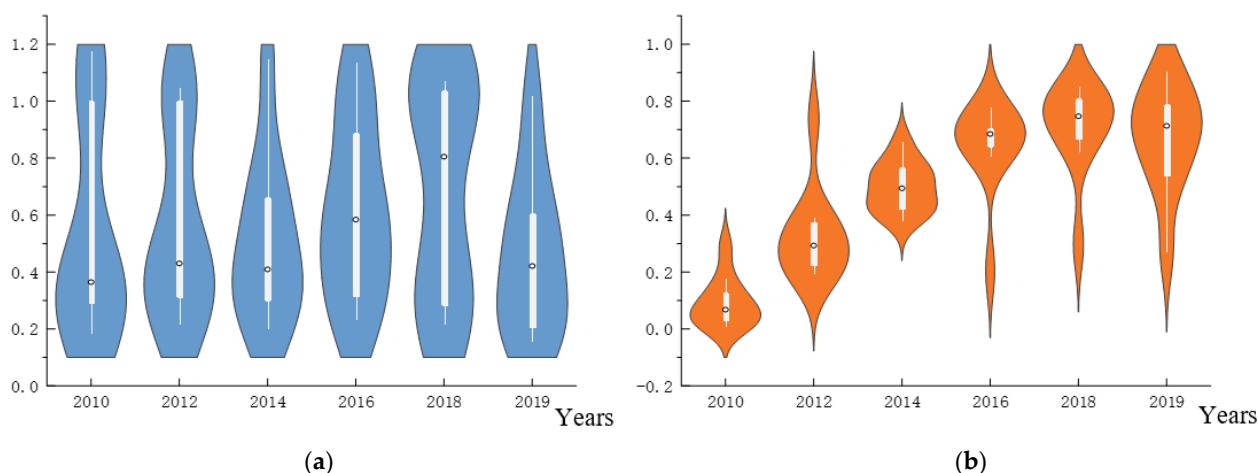


Figure 3. (a) Kernel density estimates of urban economic efficiency in the Harbin–Changchun urban agglomeration; (b) kernel density estimates of urban resilience in the Harbin–Changchun urban agglomeration.

As shown in Figure 4, the low efficiency area includes the two cities of Qiqihar and Jilin. The low level of economic efficiency in Qiqihar was due to the fact that Qiqihar is an old industrial city, with high emissions caused by a high proportion of heavy chemical industries, as well as the influence of the planned economic system. This has resulted in an extensive management model and a lack of awareness of independent innovation among enterprises, making it difficult for those enterprises to improve their technology. The economic efficiency of Jilin City displayed a tendency of first rising and then falling. The city showed an upward trend from 0.29 (in 2010) to 0.35 (in 2013), and then a decline under the influence of the overall economy of Northeast China, from 0.21 (in 2014) to 0.16 (in 2019). The annual average decline was 5%, indicating an economic structure that is dominated by heavy industry and state-owned enterprises makes that local economy vulnerable to the overall economy of Northeast China, and also limits the renewal of enterprise management models.

The medium efficiency area includes four cities: Harbin, Mudanjiang, Liaoyuan, and Siping. The main reason for Harbin being at the middle level during the study period is its high proportion of traditional industries and energy-intensive industries. This restricts the innovation of production enterprise management systems, and also reveals the long-accumulated problems of the traditional economic structure. The economic inefficiency of the city of Mudanjiang is linked to its outdated traditional industrial technology and management model. However, because of the expansion of the city’s cultural tourism industries, some achievements have been made in Mudanjiang’s economic transformation. Liaoyuan is a resource-based city. Its substitutable industries such as textiles and hosiery, emerged in the process of economic transformation, but the city’s economic efficiency is still low, mostly due to the small scale of the industries. The overall level of economic efficiency in Siping City is low and has declined significantly. In 2017, efficiency decreased by 43% as compared with 2016. Traditional industries in Siping are difficult to manage, and the scale of emerging industries is small; the issue of technological innovation also needs to be improved.

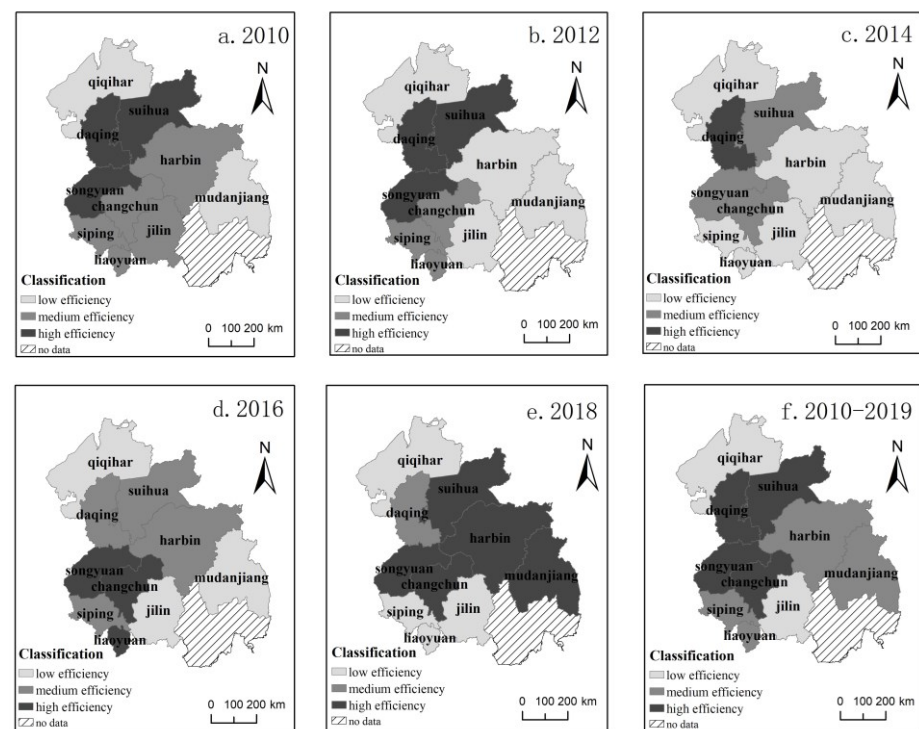


Figure 4. Spatial distribution pattern of urban economic efficiency in the Harbin–Changchun urban agglomeration.

The high efficiency area includes four cities: Changchun, Daqing, Songyuan, and Suihua. From 2010 to 2019, Changchun's economic efficiency showed a yearly upward trend, due to industrial production technology being at the forefront in the northeast region, while the city's industrial foundation and productive scale have certain advantages. Daqing's high economic efficiency is due to the large scale of the city's petroleum industries. The efficiency of business management and the technology level of the petroleum industries mean Daqing takes the lead, both in China and abroad. Songyuan is a petroleum resource-based city with a large scale of leading industries, such as petrochemical enterprises. During the study period, Songyuan effectively promoted economic efficiency because of the city's increased business innovative inputs and improved business management model. Suihua has a smaller industrial scale, but that city's undesirable output efficiency is low. Its pattern of less efficient growth of undesired output saw Suihua reach a high level of efficiency over time.

3.1.2. Urban Economic Resilience

On the whole, Figure 3b illustrates that the average economic resilience of the Harbin–Changchun urban agglomeration showed a relatively stable upward trend, increasing from 0.09 (in 2010) to 0.67 (in 2019), representing an average annual growth of 18%. The kernel density of economic resilience of cities in the Harbin–Changchun urban agglomeration was clustered around the peak which shows a yearly trend towards higher value regions, with a low degree of dispersion. In 2019, a "double-peaks" structure appeared as a result of the downward shift of the kernel density peak. This finding indicates that the disparity between regions is beginning to expand.

As shown in Figure 5, the low resilience area includes three cities: Daqing, Suihua, and Qiqihar. The main reason for Daqing having weak economic resilience is that the degree of industrialization of petroleum industries is high. There is a relatively single industrial structure and high dependence on foreign trade, which makes the city less resilient to recovery. Suihua is vulnerable to risks (such as an economic crisis) because of its weak economic foundation, insufficient accumulation of social capital, small scale of leading

industries, and small proportion of secondary and tertiary industries. Qiqihar is dominated by heavy industry, and the city's ability to innovate is inhibited by the slow development of its tertiary industries, the low degree of industrial upgrading, and the backward technology updating of traditional industries.

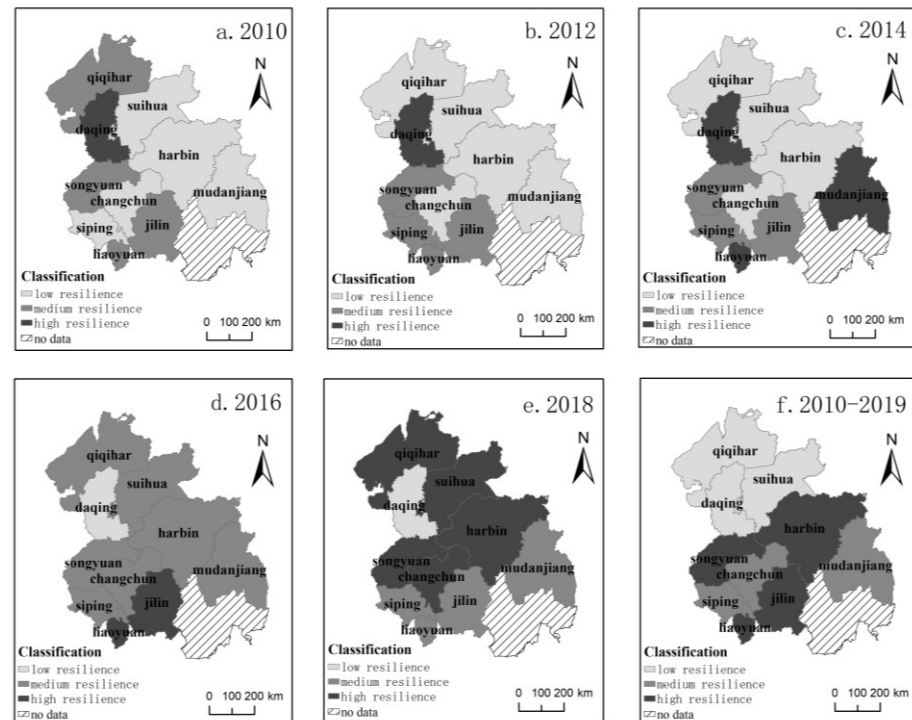


Figure 5. Spatial distribution pattern of urban economic resilience in the Harbin–Changchun urban agglomeration.

The medium resilience area includes three cities: Mudanjiang, Siping, and Changchun. Mudanjiang's economic resilience increased by an annual average of 22.5% over the sampled years, but the city's overall level of increase was still in the medium range. The main reason for this was that Mudanjiang was highly dependent on foreign trade during the study period, which affected the city's ability to resist recovery. Siping City is a significant old industrial base in Northeast China; its economic development has been dominated by industry, resulting in an uncoordinated industrial structure that has negatively affected Siping's economic resilience. Although Changchun has a good industry foundation, its automotive industry is overweighted and has an unreasonable industrial structure; Changchun is also limited by factors such as the city's limited capacity for scientific research input and output. In the future, the level of scientific research must be improved. Steps must be taken to promote the innovative development of enterprises, and open up new paths of economic transformation.

The high resilience area includes four cities: Harbin, Jilin, Songyuan, and Liaoyuan. Harbin is one of the four central cities in Northeast China with strong resistance and recovery abilities. This is because of the city's relatively complete industrial structure. In addition, Harbin has a high level of deployable resources and social capital affluence, and therefore, its capacity for adaptation and adjustment has increased. Jilin is dominated by heavy chemical industries. The city's economic resilience has been enhanced by actively optimizing the industrial structure and a wide range of chemical industries, as well as by rapidly developing advantageous industries, such as healthcare. From 2010 to 2019, the economic resilience of Songyuan increased steadily at a rate between 0.12 and 0.81. The economic resilience increase is connected to the timely adjustment of the city's industrial structure, in which the proportion of tertiary industry expanded gradually. In addition, the economic development mode changed from one of "oil industry dominance" to a

multi-directional economic structure. Liaoyuan's economic development path has mainly relied on resource advantages, but it continues to develop alternative industries such as textiles and medicine, and industrial clusters are expanding in the process of revitalization. Moreover, Liaoyuan's advanced stage of industrial structure level was as high as 2.79 during the study period, indicating that the city's innovation and transformation abilities developed steadily in the long term.

3.2. Synergistic Evolution of Economic Efficiency and Economic Resilience in Urban Agglomerations

3.2.1. Model Construction and Identification of Order Parameter

The model is constructed according to the basic principles of the Haken model, and based on the measured values of the economic efficiency and economic resilience of each city in the Harbin–Changchun urban agglomeration from 2010 to 2019. The economic efficiency and economic resilience are taken as the variables of the system. Finally, this study obtained the model equations for the synergistic evolutionary development of the economic efficiency and economic resilience of cities in the Harbin–Changchun urban agglomeration. The equations of motion were obtained by regressing the panel data with EViews10.0 (Table 5).

Table 5. Parameter estimation and test results of the Haken model.

Model Hypotheses	Motion Equation	Significance		Model Conclusion
		t-Statistic	Prob.	
q_1 = Economic efficiency (EF)	$q_1(t) = -1.0209q_1(t-1) + 1.2236q_1(t-1)q_2(t-1)$	13.30477 −3.92890	0.0000 0.0002	The equation of motion is established. $ \gamma_1 \gg \gamma_2 $ is satisfied; The model hypothesis is established. EF is the order parameter.
q_2 = Economic resilience (RES)	$q_2(t) = 0.5529q_2(t-1) + 0.1538q_1(t-1)q_2(t-1)$	−21.37516 6.816243	0.0000 0.0000	

From the equations of motion in Table 5, the parameters are:

$$\gamma_1 = -2.0209, \gamma_2 = -0.4471, a = 1.2236, b = -0.1538$$

The measured values of synergy between the two subsystems of the economic efficiency and economic resilience d:

$$d = \sqrt{(q - 2.1911)^2 + (v(q) + 2.4266)^2}$$

Table 5 shows that the order parameter q_1 , which plays a leading role, is economic efficiency for the economic system of the Harbin–Changchun urban agglomeration. The variable $\gamma_1 < 0$ indicates the existence of a positive effect of urban economic efficiency on the orderly development of the economic system, which improves the economic input–output efficiency, reduces undesirable output emissions, and realizes the synergistic and orderly development of the regional economy in the Harbin–Changchun urban agglomeration. The variable $\gamma_2 < 0$ indicates that the economic resilience of cities has a positive effect on the evolution of the economic system. This means the subsystem q_2 , economic resilience, is significantly enhanced in the process of economic synergistic development and strengthens the ability of the economic system to develop in an orderly manner. The results are consistent with the actual development path, which is oriented to innovative development, leading to improved economic efficiency and the development of a green Harbin–Changchun urban agglomeration.

The variable parameter $a > 0$ indicates that urban economic efficiency q_1 has a negative influence on the development of economic resilience q_2 . At present, the problem is that the industrial structure is single, and the investment model is still in the transformation stage. This has caused some resistance to the development of economic resilience in the Harbin–Changchun urban agglomeration. The variable parameter $b < 0$ indicates that the economic resilience q_2 hinders the development of economic efficiency q_1 . Because

of the insufficient development of the cities' economic resilience, the development of economic efficiency has declined, indicating that the level of economic resilience needs to be strengthened in the process of sustainable economic development.

Differences exist in the level of economic development among the cities in the Harbin–Changchun urban agglomeration. The order parameter of the leading economic development of each city also changed during the study period. The results are shown in Table 6.

Table 6. Parameter estimation and interpretation of the Haken model for each city.

City	Order Parameter	Model Hypotheses	Motion Equation	Model Conclusion
Harbin	EF	$q_1 = \text{EF}$	$q_1(t) = -4.0417q_1(t-1) + 8.4502q_1(t-1)q_2(t-1)$	$\gamma_1 < 0$, q_1 has a positive effect on system evolution. $\gamma_2 > 0$, q_2 has a negative effect on system evolution.
		$q_2 = \text{RES}$	$q_2(t) = 2.4256q_2(t-1) + 0.9428q_1(t-1)q_2(t-1)$	$a > 0$, q_2 hinders q_1 . $b > 0$, q_1 promotes q_2 .
Qiqihar	RES	$q_1 = \text{RES}$	$q_1(t) = 8.9406q_1(t-1) - 13.9262q_1(t-1)q_2(t-1)$	$\gamma_1 > 0$, q_1 has a negative effect on system evolution. $\gamma_2 < 0$, q_2 has a positive effect on system evolution.
		$q_2 = \text{EF}$	$q_2(t) = -6.1759q_2(t-1) + 9.4993q_1(t-1)q_2(t-1)$	$a < 0$, q_2 promotes q_1 . $b > 0$, q_1 promotes q_2 .
Daqing	EF	$q_1 = \text{EF}$	$q_1(t) = -0.4391q_1(t-1) + 0.6845q_1(t-1)q_2(t-1)$	$\gamma_1 < 0$, q_1 has a positive effect on system evolution. $\gamma_2 > 0$, q_2 has a negative effect on system evolution.
		$q_2 = \text{RES}$	$q_2(t) = 2.1301q_2(t-1) - 1.5874q_1(t-1)q_2(t-1)$	$a < 0$, q_2 promotes q_1 . $b < 0$, q_1 hinders q_2 .
Mudanjiang	EF	$q_1 = \text{EF}$	$q_1(t) = -8.3673q_1(t-1) + 14.8572q_1(t-1)q_2(t-1)$	$\gamma_1 < 0$, q_1 has a positive effect on system evolution. $\gamma_2 > 0$, q_2 has a negative effect on system evolution.
		$q_2 = \text{RES}$	$q_2(t) = 2.9461q_2(t-1) + 1.6418q_1(t-1)q_2(t-1)$	$a > 0$, q_2 hinders q_1 . $b > 0$, q_1 promotes q_2 .
Suihua	RES	$q_1 = \text{RES}$	$q_1(t) = 4.7733q_1(t-1) + 0.8775q_1(t-1)q_2(t-1)$	$\gamma_1 > 0$, q_1 has a negative effect on system evolution. $\gamma_2 < 0$, q_2 has a positive effect on system evolution.
		$q_2 = \text{EF}$	$q_2(t) = -2.5832q_2(t-1) + 0.7343q_1(t-1)q_2(t-1)$	$a > 0$, q_2 hinders q_1 . $b > 0$, q_1 promotes q_2 .
Changchun	RES	$q_1 = \text{RES}$	$q_1(t) = 1.8927q_1(t-1) - 0.8827q_1(t-1)q_2(t-1)$	$\gamma_1 > 0$, q_1 has a negative effect on system evolution. $\gamma_2 < 0$, q_2 has a negative effect on system evolution.
		$q_2 = \text{EF}$	$q_2(t) = 1.5587q_2(t-1) - 3.2286q_1(t-1)q_2(t-1)$	$a < 0$, q_2 promotes q_1 . $b < 0$, q_1 hinders q_2 .

Table 6. Cont.

City	Order Parameter	Model Hypotheses	Motion Equation	Model Conclusion
Jilin	RES	$q_1 = \text{RES}$	$q_1(t) = 5.6733q_1(t-1) - 5.4087q_1(t-1)q_2(t-1)$	$\gamma_1 > 0, q_1$ has a negative effect on system evolution. $\gamma_2 < 0, q_2$ has a positive effect on system evolution.
		$q_2 = \text{EF}$	$q_2(t) = -3.0734q_2(t-1) + 6.3773q_1(t-1)q_2(t-1)$	$a < 0, q_2$ promotes q_1 . $b > 0, q_1$ promotes q_2 .
Siping	EF	$q_1 = \text{EF}$	$q_1(t) = -6.0363q_1(t-1) + 8.2068q_1(t-1)q_2(t-1)$	$\gamma_1 < 0, q_1$ has a positive effect on system evolution. $\gamma_2 > 0, q_2$ has a negative effect on system evolution.
		$q_2 = \text{RES}$	$q_2(t) = 1.0600q_2(t-1) + 0.8789q_1(t-1)q_2(t-1)$	$a > 0, q_2$ hinders q_1 . $b > 0, q_1$ promotes q_2 .
Liaoyuan	EF	$q_1 = \text{EF}$	$q_1(t) = -5.2731q_1(t-1) + 6.6275q_1(t-1)q_2(t-1)$	$\gamma_1 < 0, q_1$ has a positive effect on system evolution. $\gamma_2 > 0, q_2$ has a negative effect on system evolution.
		$q_2 = \text{RES}$	$q_2(t) = 1.7238q_2(t-1) + 1.2726q_1(t-1)q_2(t-1)$	$a > 0, q_2$ hinders q_1 . $b > 0, q_1$ promotes q_2 .
Songyuan	EF	$q_1 = \text{EF}$	$q_1(t) = -4.8668q_1(t-1) + 8.1017q_1(t-1)q_2(t-1)$	$\gamma_1 < 0, q_1$ has a positive effect on system evolution. $\gamma_2 > 0, q_2$ has a negative effect on system evolution.
		$q_2 = \text{RES}$	$q_2(t) = 6.5383q_2(t-1) - 0.9744q_1(t-1)q_2(t-1)$	$a < 0, q_2$ promotes q_1 . $b < 0, q_1$ hinders q_2 .

3.2.2. Analysis of Spatial and Temporal Differences in the Synergistic Evolution of Economic Efficiency and Economic Resilience

Based on the principles of the Haken model, the economic efficiency and economic resilience synergy scores of the cities in the Harbin–Changchun urban agglomeration from 2010 to 2019 can be obtained using Equation (11). However, the d-value (Equation (11)) represents the distance between the measured point and the stable point of the system, and the distance is inversely proportional to the synergy. Therefore, the d-value needs to be normalized and the resulting synergy value divided by Jenks natural breaks optimization method of ArcGIS 10.6.

In terms of temporal trends (Figure 6), the synergistic evolution of economic efficiency and economic resilience in the Harbin–Changchun urban agglomeration generally fluctuated in the direction of advanced synergy. From 2010 to 2019, there was an obvious distinct phase pattern, and the synergistic effect showed a “down-up-down” change pattern. The synergistic value kernel density curve shows a “double peak-single peak-double peak” change trend, with significant differences between regions. From 2010 to 2014, the width of the peak gradually narrowed, the quartile range was significantly reduced, and the structure changed from “double peak” to “single peak”. These findings indicate that cities are clustering towards a high level of synergy, and the differences between regions have decreased. From 2014 to 2018, the kernel density curve shifted downwards, with a shift in structure from “single peak” to “double-peak”. The width of the low-value interval increased, the synergistic effect gradually decreased, and the differences between regions expanded. In 2019, the kernel density curve showed a single peak structure, the synergistic effect increased, and the differences between regions narrowed.

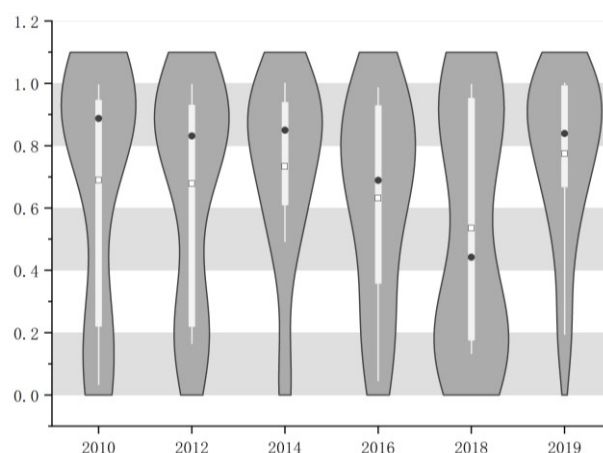


Figure 6. Kernel density analysis of synergistic values of the economic efficiency and economic resilience of cities in the Harbin–Changchun urban agglomeration.

In terms of the spatial pattern (Figure 7), the economic efficiency and economic resilience synergy effect of cities in the Harbin–Changchun urban agglomeration has obvious volatility characteristics in the evolution process, and the synergy pattern of each city shows a fluctuating upward trend. In general, the economic efficiency and economic resilience synergy effect shows the appearance of a dumbbell-shaped structure with “highs at the north and south and lows in the middle”. Combined synergy values are highest in the north and south of Qiqihar, Jilin, Siping, Liaoyuan, and Mudanjiang, followed by Harbin and Changchun. The values were lowest in the middle of Suihua, Daqing, and Songyuan.

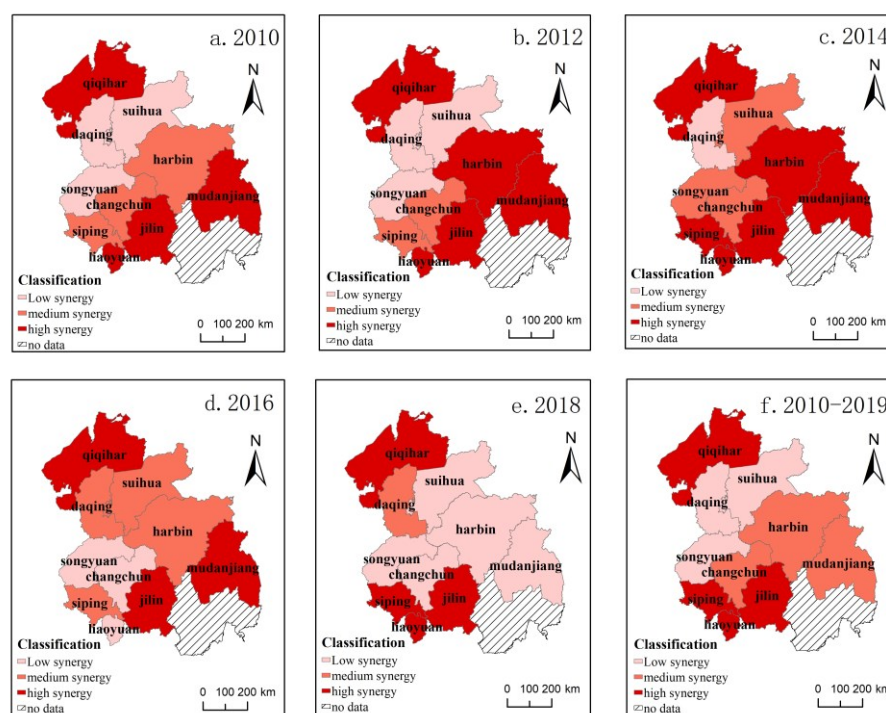


Figure 7. Spatial distribution of synergistic values of the economic efficiency and economic resilience of cities in the Harbin–Changchun urban agglomeration.

3.2.3. Stage Division of the Synergistic Evolution of Economic Efficiency and Economic Resilience

This study calculates that the economic system of the Harbin–Changchun urban agglomeration takes economic efficiency as an order parameter, and economic efficiency controls the synergistic evolution path of a high-quality sustainable economy. Therefore,

it is also necessary to analyze the synergistic evolution stage according to the actual level of economic efficiency (Table 7). There is a pattern of “low efficiency-high synergy” in the process of evolution, which indicates that the greater the difference between economic efficiency and economic resilience is, the lower the level of synergy. Therefore, the high synergy values mentioned in this paper do not imply a high level of synergistic development of their urban economic systems. Sustainable economic development is a dynamic evolutionary process. When there is a low level of economic efficiency and economic resilience and a high level of synergy, this means that the city may show a low-level of disorderly-to-orderly evolution during the study period. A high-level of economic efficiency and economic resilience and a low level of synergy may also be the evolution stage from low level orderly development to higher level disorderly development.

Table 7. Classification of urban synergy stages in the Harbin–Changchun urban agglomeration.

Stage of Synergistic Evolution	Evolutionary Characteristics	Stage of Synergistic Evolution	Evolutionary Characteristics	Stage of Synergistic Evolution	Evolutionary Characteristics
Low efficiency -low synergy	Primary disorderly development	Low efficiency -medium synergy	Primary transition development	Low efficiency -high synergy	Primary synergistic development
Medium efficiency -low synergy	Middle disorderly development	Medium efficiency -medium synergy	Middle transition development	Medium efficiency -high synergy	Middle synergistic development
High efficiency -low synergy	Senior disorderly development	High efficiency -medium synergy	Senior transition development	High efficiency -high synergy	Senior synergistic development

The low efficiency-high synergy area includes the two cities of Qiqihar and Jilin. The overall economic efficiency of Qiqihar City was below 0.4 during the study period, and has been at a low level for a long time within the Harbin–Changchun urban agglomeration, without strong volatility. The economic resilience has been growing yearly. However, because the overall variability of the economic resilience of each city is not significant, the economic efficiency and economic resilience development levels are more balanced. The development directions are all in line with the “growth-lower-growth” model, showing a low level of synergistic development of a sustainable economy. Jilin’s economic resilience is prominent, and the order parameter of Jilin is dominated by economic resilience, and therefore, the level of economic resilience plays an important role in measuring synergy. The development direction of economic efficiency and economic resilience is consistent, and the level of synergy is high. The economic structure of Jilin City, which is dominated by state-owned heavy industry, leads to limitations on the enhancement of the city’s economic efficiency. However, with the implementation of the new strategy, the development of multiple types and diversified industries enhances economic resilience capacity, and economic efficiency and economic resilience are strengthened simultaneously. The two areas are at a low level of synergistic development, and if the level of economic development remains inefficient for a long time, the synergy effect may be inhibited in the later stages of economic development to a lower level.

The medium efficiency-high synergy area includes the two cities of Siping and Liaoyuan. The economic efficiency of Siping City is not high and tended to fluctuate downwards during the sampled years, while the slow growth of economic resilience tended to be stable and the magnitude of fluctuation was not strong. Liaoyuan City had a short-lived sharp increase and decrease in economic efficiency during the study period, and the linear growth of economic resilience tended to be flat. There was little difference in the development of economic efficiency and economic resilience between the two cities, and the synergy effect was high. Alternative industries emerged in both cities as they

transformed their economies, but their industries were small in scale, resulting in lower economic efficiency. However, the level of economic resilience has increased yearly.

The high efficiency-medium synergy area includes Changchun City. Changchun has a good level of economic development and a relatively complete industrial structure, but the heavy proportion of the automotive industry may reduce the level of industrial resilience. This could lead to greater variability in the economic efficiency and economic resilience growth patterns, thereby, affecting the synergy analysis. Changchun belongs to a high-level transitional development stage; the city's economic resilience needs to improve, and the continuous development of Changchun to a more advanced synergy pattern must be promoted.

The medium efficiency-medium synergy area includes the two cities of Harbin and Mudanjiang. The synergy value of Harbin City was at a high synergy stage, from 0.8408 (in 2010) to 0.9288 (in 2014). However, due to the rapid growth of economic efficiency, heterogeneity in economic efficiency and economic resilience emerged, and the synergy effect declined sharply, from 0.8432 (in 2014) to 0.2072 (in 2017), negatively affecting the overall synergistic level. Harbin City has a good industrial foundation, large industrial scale, and high level of economic development. However, as an old industrial city, Harbin has obvious drawbacks in its industrial management model, insufficient industrial technology research and development capabilities, and a heavy industrial layout. There is a large amount of undesirable output, which leads to the inhibiting of economic efficiency. At the same time, the lack of agglomeration of Harbin's leading industries has led to economic resilience that still needs to be improved. The synergy effect in Mudanjiang City decreased significantly in 2017 (0.1881), affecting the overall synergistic pattern. Mudanjiang City is constrained by various factors, such as the lagging level of technology management in traditional industries and the small scale of new industries. The need still exists to continuously expand the scale of industries with advantages (such as cultural tourism), in order to improve the industrial structure and effectively enhance the level of economic efficiency and economic resilience.

The high efficiency-low synergy area includes three cities: Daqing, Suihua, and Songyuan. Daqing has a high degree of economic efficiency and low economic resilience, with economic efficiency playing a dominant role in measuring the synergy value. This is unbalanced with the development of economic resilience, and thus, was at a high level of disorderly development during the evolution. Daqing has a high level of economic efficiency, mainly because the city has a high degree of oil industrialization, a large industrial scale, effective enterprise management, and advanced technology. However, the single industrial structure is too dependent on oil resources and causes serious damage to the environment, resulting in a low level of economic resilience and negatively affecting the synergistic effect. Suihua's economic efficiency is higher than its economic resilience, and the city's high efficiency is due to the small scale of undesirable industrial output. However, the city's small industrial scale and unclear leading industries lead to both a weak ability to resist risks and a low level of economic resilience. Songyuan has a high level of economic efficiency and economic resilience, but the level of synergistic effect is low. The main reason for this is that economic efficiency (0.9529) and economic resilience (0.5145) are quite different; economic efficiency controls the results of synergistic evolution, and inconsistent development paths lead to low synergistic effects. However, the industrial structure is incomplete, the level of economic resilience of the industry is lower than the economic efficiency, and the synergy level is low.

4. Discussion

High synergy values appear in the results when measuring the synergy between urban economic efficiency and economic resilience, however this is not the most desirable synergistic pattern. High synergy can also appear when both economic efficiency and economic resilience are at low levels. Other scholars have also emerged with questions related to such findings, but without specific further reflection [27]. Therefore, instead

of using the synergy value alone when classifying the synergistic evolutionary stages of economic efficiency and economic resilience, the economic efficiency value and the synergy value are combined to analyze the synergistic stages together. After analyzing the evolution process of the synergistic pattern of economic efficiency and economic resilience in the Harbin–Changchun urban agglomeration, through the Haken model, this study concludes that economic efficiency is an order parameter, and enhancing economic resilience can lead to positive synergistic development of efficiency and resilience within an economic system. However, in the process of measuring economic resilience in different studies, the multi-indicator system method has a large variation in the selection of indicator systems and measurement methods. This could lead to a large error in the final results, and therefore, this error may be one of the reasons for the mismatch between the synergistic evolutionary stage of economic efficiency and economic resilience and the level of economic development in cities.

The economic efficiency and economic resilience of the cities in the Harbin–Changchun urban agglomeration have evolved in a synergistic manner, with significant regional differences. In order to achieve sustainable economic development in the Harbin–Changchun urban agglomeration, a synergistic pattern of cities within the urban agglomeration should be planned in stages and at different levels, according to the actual situation.

The economic efficiency growth rate in Harbin and Changchun has slowed down and the level of economic resilience needs to be improved. As provincial capital cities and the core cities of the Harbin–Changchun urban agglomeration, Harbin and Changchun urgently need to transition to a high-efficiency-high-synergy evolutionary stage. The cities should apply scientific information technology to update industrial management models in order to accelerate the level of innovative industrial technology. These actions are required to steadily regain economic efficiency, as well as to adjust the industrial structure, to promote industrial diversification, and to enhance economic resilience. When the two cities of Harbin and Changchun exhibit senior synergistic patterns, they will perform their core city functions and have a trickle-down effect on neighboring cities.

Qiqihar’s future economic development requires an expansion of the industrial scale to enhance efficiency, and also enhancement of innovation and development capabilities, construction of a complete industrial structure to enhance resilience, and evolution of a “low-low-high” to “high-high-high synergistic pattern. Jilin, Liaoyuan, and Siping all need to improve their economic efficiency by actively developing industrial clusters, expanding the scale of their leading industries, accelerating the digitalization of industries, reforming management models, and upgrading industrial technology. Mudanjiang City has an average level of economic efficiency and economic resilience, but still needs to simultaneously strengthen the city’s efficiency and economic resilience. Mudanjiang should take innovation development as the guide, expand the scale of advantageous industries, develop advanced manufacturing industries to improve economic efficiency, construct a diversified industrial system, and enhance the city’s economic adaptation and transformation ability.

All cities in the low-level synergy stage are in the high-level disorderly development stage, presenting a much higher level of economic efficiency than economic resilience. The future needs of these cities are to enhance the level of economic resilience and transition to an advanced level of synergistic development. Daqing has a single industrial structure and will need to promote industrial diversification to grow the city’s non-oil economy, strengthen environmental management, and rely on the ecological environment to vigorously develop ecological industries. Suihua has a weak ability to resist risks and will need to grow its own industries and form a central city function. Songyuan is dominated by the oil industry and needs to adjust its industrial structure, accelerate the release of green industrial potential, and enhance economic resilience and strength.

5. Conclusions

To promote high-quality and sustainable development of the economy of the Harbin–Changchun urban agglomeration, the exploration of the stage of sustainable eco-

economic development and the existence of problems has attracted widespread attention. Most of the existing research on the economic efficiency and economic resilience of urban agglomerations has mainly analyzed them separately, but the synergistic development of economic efficiency and economic resilience is insufficient. A single emphasis on the economic efficiency of urban agglomerations is not conducive to the adaptation of their economies to external environmental shocks and disturbances. In addition, a one-sided emphasis on resilience can lead to redundant resources and reduced productivity, leading, in turn, to lagging development. It is difficult for single-aspect studies to explain the sustainable development pattern embodied by regions in the face of internal structural changes and external environmental disturbances. For this purpose, this study investigates the synergy of economic efficiency and economic resilience, and explores the characteristics of the synergistic evolution pattern of the economic efficiency and resilience of the Harbin–Changchun urban agglomeration. The objective is to provide a research direction that can explain the economic problems arising in the process of the sustainable economic development of the Harbin–Changchun urban agglomeration. In this paper, we use the entropy-TOPSIS model and super-efficiency SBM model of undesirable output to explore the temporal and spatial evolution characteristics of the economic efficiency and economic resilience of the Harbin–Changchun urban agglomeration. The Haken model is used to identify the order parameters in the synergistic evolution process of economic efficiency and economic resilience, and the synergistic pattern of economic efficiency and economic resilience is obtained. The results are as follows:

(1) During the study period, the economic efficiency of cities in the Harbin–Changchun urban agglomeration showed a fluctuating slow growth trend; the economic efficiency kernel density peaks were higher in both high and low values, showing a “double peak” structure. These findings indicate that the regional differences in the economic efficiency of cities were more significant. The economic resilience of cities in the Harbin–Changchun urban agglomeration generally showed a relatively stable upward trend during the study period, with high and narrow peaks of economic resilience kernel density and a small degree of dispersion. These findings indicate that the economic resilience of cities is less significant.

(2) In the identification of the order parameter, economic efficiency was found to be the order parameter for the synergistic evolution of economic efficiency and economic resilience in the Harbin–Changchun urban agglomeration during the study period. Economic efficiency is the dominant factor in the evolution of the system and controls the direction and path of the synergistic development and evolution of the two subsystems. Economic efficiency and economic resilience both had a positive effect on the orderly and synergistic development of the system during the study period. However, economic efficiency and economic resilience development inhibit each other, indicating that they effectively ignore each other in their development, and that they develop in a monolithic manner. Sustainable economic development requires the enhancement of both economic efficiency (so that internal urban resources are rationally allocated and endogenous economic power is strengthened) and the level of economic resilience; both are required to ensure the urban economic system can smoothly respond to external risk challenges. The interlinked development of the two is conducive to promoting the construction of sustainable economic synergistic patterns in urban agglomerations.

(3) The synergistic effects of economic efficiency and economic resilience in the Harbin–Changchun urban agglomeration show a continuous evolution, from intermediate synergy to advanced synergy, in terms of temporal trends time evolution. During this process, the synergistic evolution of economic efficiency and economic resilience fluctuate significantly, but generally develop in an upward trend, reflecting a certain dynamic change in the process of synergistic evolution. The spatial pattern as a whole shows a dumbbell-shaped structure, which appears with “highs at the north and south and lows in the middle”. Combined synergy values are highest in the north and south of Qiqihar, Jilin,

Siping, Liaoyuan, and Mudanjiang, followed by Harbin and Changchun. The values are lowest in the middle of Suihua, Daqing, and Songyuan.

(4) A mismatch effect exists when evaluating the results of the synergistic evolution of economic efficiency and economic resilience in cities. For example, Qiqihar City is in the advanced synergistic stage in the process of the synergistic evolution of economic efficiency and economic resilience. However, the city's urban economic efficiency and resilience are in the low-level stage and there is an obvious mismatch, forming a primary co-ordination pattern, which does not mean its synergy level is high. Economic efficiency, as an order parameter in the model, plays a dynamic role, and the overall economic resilience levels of cities during the study period were low and the regional differences were less significant. The paths of urban economic efficiency and economic resilience development levels were inconsistent, leading to the unequal effects of low efficiency-high synergy. A sustainable economy with high efficiency, high resilience, and high synergy tends to match high levels of economic development. Therefore, the economic system still needs to adjust for the inequality effect and move towards a higher level of synergy in an orderly manner.

(5) Regional differences in the synergistic evolution of economic efficiency and economic resilience are evident in the Harbin-Changchun urban agglomeration. In the synergistic evolutionary development, there is a large difference between the synergy values of the low-level synergy stage and the high-level synergy stage. Daqing and Qiqihar are the most obvious cities. Daqing has high economic efficiency, but the single industrial structure leads to a gap between economic efficiency and economic resilience development, and the synergistic effect of the city is low. Qiqihar has simultaneous economic efficiency and economic resilience development, so the synergistic effect of the city is high. The main reason for this discrepancy is the inconsistent development path of economic efficiency and economic resilience in each city, which leads to an unstable pattern of economic synergy within the Harbin–Changchun urban agglomeration. In order to steadily improve the economy and maintain a dynamic and balanced development, urban economic efficiency and economic resilience need to develop simultaneously. The Harbin–Changchun urban agglomeration still needs to weaken the inter-regional differentiation, increase the economic regulation of low-synergy areas, and propose countermeasures according to the actual situation.

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References

1. Ma, J.W.; Wang, J.H.; Szmedra, P. Economic Efficiency and Its Influencing Factors on Urban Agglomeration—An Analysis Based on China's Top 10 Urban Agglomerations. *Sustainability* **2019**, *11*, 5380. [\[CrossRef\]](#)
2. Niu, X.Q.; Ma, X.J. Measurement and difference analysis on economic efficiency of Chinese wide regional economy. *Stat. Decis.* **2019**, *35*, 116–120. (In Chinese) [\[CrossRef\]](#)
3. Deilmann, C. Data Envelopment Analysis of Cities—Investigation of the Ecological and Economic Efficiency of Cities Using a Benchmarking Concept from Production Management. *Ecol. Indic.* **2016**, *67*, 798–806. [\[CrossRef\]](#)
4. Yan, T.; Zhang, X.P.; Zhao, Y.Y. Spatiotemporal evolution of urban eco-efficiency in China and its influencing factors based on super-efficiency SBM model. *J. Univ. Chin. Acad. Sci.* **2021**, *38*, 486–493. (In Chinese) [\[CrossRef\]](#)
5. Martin, R.; Sunley, P. On the notion of regional economic resilience: Conceptualization and explanation. *J. Econ. Geogr.* **2015**, *15*, 1–42. [\[CrossRef\]](#)
6. Rizzi, P.; Graziano, P.; Dallara, A. A capacity approach to territorial resilience: The case of European regions. *Ann. Reg. Sci.* **2018**, *60*, 285–328. [\[CrossRef\]](#)

7. Holm, J.R.; Østergaard, C.R. Regional employment growth, shocks and regional industrial resilience: A quantitative analysis of the Danish ICT sector. *Reg. Stud.* **2015**, *49*, 95–112. [\[CrossRef\]](#)
8. Breathnach, P.; Van Egeraat, C.; Curran, D. Regional economic resilience in Ireland: The roles of industrial structure and foreign inward investment. *Reg. Stud. Reg. Sci.* **2015**, *2*, 497–517. [\[CrossRef\]](#)
9. Cowell, M.M. Bounce back or move on: Regional resilience and economic development planning. *Cities* **2013**, *30*, 212–222. [\[CrossRef\]](#)
10. Liu, Z.M.; Xiu, C.L.; Song, W. Urban spatial resilience: A review. *Urban. Archit.* **2018**, *2018*, 16–18. (In Chinese) [\[CrossRef\]](#)
11. Liu, Z.; Xiu, C.; Song, W. Landscape-Based Assessment of Urban Resilience and Its Evolution: A Case Study of the Central City of Shenyang. *Sustainability* **2019**, *11*, 2964. [\[CrossRef\]](#)
12. Li, L.G.; Zhang, P.Y.; Tan, J.T.; Guan, H.M. Review on the evolution of resilience concept and research progress on regional economic resilience. *Hum. Geogr.* **2019**, *34*, 1–7. (In Chinese) [\[CrossRef\]](#)
13. Graziano, P.; Rizzi, P. Vulnerability and resilience in the local systems: The case of Italian provinces. *Sci. Total Environ.* **2016**, *553*, 211–222. [\[CrossRef\]](#)
14. Martin, R. Regional economic resilience, hysteresis and recessionary shocks. *J. Econ. Geogr.* **2012**, *12*, 1–32. [\[CrossRef\]](#)
15. Martin, R.; Sunley, P.; Gardiner, B.; Tyler, P. How regions react to recessions: Resilience and the role of economic structure. *Reg. Stud.* **2016**, *50*, 561–585. [\[CrossRef\]](#)
16. Sun, J.W.; Sun, X.Y. Research progress of regional economic resilience and exploration of its application in China. *Econ. Geogr.* **2017**, *37*, 1–9. (In Chinese) [\[CrossRef\]](#)
17. Brakman, S.; Garretsen, H.; Van Marrewijk, C. Regional resilience across Europe: On urbanisation and the initial impact of the Great Recession. *Camb. J. Reg. Econ. Soc.* **2015**, *8*, 309–312. [\[CrossRef\]](#)
18. Angulo, A.M.; Mur, J.; Trávez, F.J. Measuring resilience to economic shocks: An application to Spain. *Ann. Reg. Sci.* **2018**, *60*, 349–373. [\[CrossRef\]](#)
19. Giannakis, E.; Bruggeman, A. Determinants of regional resilience to economic crisis: A European perspective. *Eur. Plan. Stud.* **2017**, *25*, 1394–1415. [\[CrossRef\]](#)
20. Kahiluoto, H.; Kaseva, J. No Evidence of Trade-Off between Farm Efficiency and Resilience: Dependence of Resource-Use Efficiency on Land-Use Diversity. *PLoS ONE* **2016**, *11*, e0162736. [\[CrossRef\]](#)
21. Korhonen, J.; Snakin, J.P. Quantifying the relationship of resilience and eco-efficiency in complex adaptive energy systems. *Ecol. Econ.* **2015**, *120*, 83–92. [\[CrossRef\]](#)
22. De Arquer, M.; Ponte, B.; Pino, R. Examining the balance between efficiency and resilience in closed-loop supply chains. *Cent. Eur. J. Oper. Res.* **2021**, *30*, 1307–1336. [\[CrossRef\]](#) [\[PubMed\]](#)
23. Sun, P.; Song, W.; Xiu, C.; Liang, Z. Non-coordination in China's urbanization: Assessment and affecting factors. *Chin. Geogr. Sci.* **2013**, *23*, 729–739. [\[CrossRef\]](#)
24. Wang, Y.; Chen, X.; Sun, P.; Liu, H.; He, J. Spatial-temporal Evolution of the Urban-rural Coordination Relationship in Northeast China in 1990–2018. *Chin. Geogr. Sci.* **2021**, *31*, 429–443. [\[CrossRef\]](#)
25. Ren, Y.; Fang, C.; Lin, X.; Sun, S.; Li, G.; Fan, B. Evaluation of the eco-efficiency of four major urban agglomerations in coastal eastern China. *J. Geogr. Sci.* **2019**, *29*, 1315–1330. [\[CrossRef\]](#)
26. Kang, L.; Song, Z.Y. Research framework and empirical study of input-output efficiency of resources and environment in China. *Sci. Geogr. Sin.* **2020**, *40*, 1868–1877. (In Chinese) [\[CrossRef\]](#)
27. Han, Z.L.; Zhu, W.C.; Li, B. Synergistic analysis of economic resilience and efficiency of Marine fishery in China. *Geogr. Res.* **2022**, *41*, 406–419. (In Chinese) [\[CrossRef\]](#)
28. Li, L.G.; Zhang, P.Y.; Li, X. Regional economic resilience of the old industrial bases in China—A case study of Liaoning province. *Sustainability* **2019**, *11*, 723. [\[CrossRef\]](#)
29. Solow, R.M. A contribution to the theory of economic growth. *Q. J. Econ.* **1956**, *70*, 65–94. [\[CrossRef\]](#)
30. Li, N.; Li, T.; Fang, Y.; Zhou, L.; Wang, Y.; Zhao, W. Spatiotemporal Pattern Evolution of Economic Efficiency in County Area of Jilin Province Based on Malmquist and ESDA. *Sci. Geogr. Sin.* **2019**, *39*, 1293–1301. (In Chinese) [\[CrossRef\]](#)
31. Nickolaos, T.G. The effect of human capital on countries' economic efficiency. *Econ. Lett.* **2014**, *124*, 127–131. [\[CrossRef\]](#)
32. Abramovitz, M. Resource and output trends in the United States since 1870. *Am. Econ. Rev.* **1956**, *46*, 5–23. [\[CrossRef\]](#)
33. Tone, K. A slacks-based measure of super-efficiency in data envelopment analysis. *Eur. J. Oper. Res.* **2002**, *143*, 32–41. [\[CrossRef\]](#)
34. Kang, L.; Song, Z.Y. Input-Output Efficiency of Economic Growth: A Multielement System Perspective. *Sustainability* **2020**, *12*, 4624. [\[CrossRef\]](#)
35. Tone, K.; Tsutsui, M. Applying all efficiency measure of desirable and undesirable outputs in DEA to US electric utilities. *J. CENTRUM Cathedra Bus. Econ. Res. J.* **2011**, *4*, 236–249. [\[CrossRef\]](#)
36. Ding, J.; Wang, Z.; Liu, Y.; Yu, F. Measurement of economic resilience of contiguous poverty-stricken areas in China and influencing factor analysis. *Prog. Geogr.* **2020**, *39*, 924–937. [\[CrossRef\]](#)
37. Briguglio, L.; Cordina, G.; Farrugia, N.; Vella, S. Economic vulnerability and resilience: Concepts and measurements. *Oxf. Dev. Stud.* **2009**, *37*, 229–247. [\[CrossRef\]](#)
38. Briguglio, L.P. Exposure to external shocks and economic resilience of countries: Evidence from global indicators. *J. Econ. Stud.* **2016**, *43*, 1057–1078. [\[CrossRef\]](#)

39. Qi, X.; Zhang, J.S.; Xu, W.X. A study on the evaluation of the development of county economic resilience in Zhejiang Province. *Zhejiang Soc. Sci.* **2019**, *2019*, 40–46. (In Chinese) [[CrossRef](#)]
40. Mayor, M.; Ramos, R. Regions and Economic Resilience: New Perspectives. *Sustainability* **2020**, *12*, 4693. [[CrossRef](#)]
41. Zhao, R.D.; Fang, C.L.; Liu, H.M. Progress and prospect of urban resilience research. *Prog. Geogr.* **2020**, *39*, 1717–1731. [[CrossRef](#)]
42. Haken, H. Self-organization and information. *Phys. Scr.* **2006**, *35*, 247–254. [[CrossRef](#)]
43. Li, L.; Liu, Y. The driving forces of regional economic synergistic development in China: Empirical study by stages based on Haken model. *Geogr. Res.* **2014**, *33*, 1603–1616. (In Chinese) [[CrossRef](#)]
44. Ouyang, H.; Yang, G.L. Measurement Method of Regional Synergetic Development Based on Haken Model. *Stat. Decis.* **2019**, *35*, 9–13. (In Chinese) [[CrossRef](#)]
45. Sun, C.Z.; Meng, C.C. Evaluation of the development coordination relationship between resilience and efficiency of regional water resources system in China. *Sci. Geogr. Sin.* **2020**, *40*, 2094–2104. (In Chinese) [[CrossRef](#)]
46. Zeng, J.; Qian, Y.; Zhu, L.; Guang, X.; Zhang, Y. Coordinated development and evolution of multidimensional rail transit and new urbanization in western China. *Econ. Geogr.* **2021**, *41*, 77–86. (In Chinese) [[CrossRef](#)]
47. Xue, F.H. Revealing the Synergetic Development Evolution Mechanism of Economic Growth, Energy Consumption, and Environment: An Empirical Analysis Based on Haken Model and Panel Data. *Discret. Dyn. Nat. Soc.* **2022**, *2022*, 6324351. [[CrossRef](#)]

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