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Effect of Collaborative Innovation on High-Quality Economic Development in Beijing–Tianjin–Hebei Urban Agglomeration—An Empirical Analysis Based on the Spatial Durbin Model

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Abstract: High-quality economic development is an innovation-driven economy, and collaborative innovation is key to maximizing its effects. In terms of the influence of cooperative innovation of urban agglomerations on high-quality economic development, urban agglomerations are of considerable relevance to the coordinated development of China's regional economy. This research established an evaluation system of high-quality economic development indicators for the Beijing–Tianjin–Hebei urban agglomeration based on panel data of 13 cities from 2003 to 2020, and then estimated the level of high-quality development of each city's economy. The spatial Durbin model was used in this article to examine the effects of collaborative innovation on the high-quality development of the economy. The findings indicated that, although high-quality economic development was increasing across the board in the Beijing–Tianjin–Hebei urban agglomeration, it varied greatly between the individual cities. Beijing and Tianjin had much higher levels of high-quality economic development than the other cities in Hebei, and there was some variation within the Hebei cities as well. The high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration exhibited no spatial correlation characteristics under the weight of geographical distance. However, there was an aggregation effect on the differential relationship of economic development, which was also significant under the dual influence of economic geography. The collaborative innovation of Beijing–Tianjin–Hebei urban agglomeration could promote the high-quality economic development of both the inner and surrounding cities, and could also improve the high-quality economy development level of the overall urban agglomeration.

Keywords: high-quality economic development; collaborative innovation; spatial Durbin model

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1. Introduction

Countries begin to pay attention to the mode of economic development while pursuing economic development as the global climate situation deteriorates. To achieve sustainable development, the rate of economic development is no longer the exclusive criterion for measuring economic development. China used extensive development in the past to promote quick economic growth. Although it has made some truly remarkable advancements—becoming the second-largest economy in the world and making contributions to the global economy—it is impossible to ignore the resource waste and environmental degradation it has produced. China must transform its development strategy from high-speed growth to high-quality development as the "two-carbon" objective gains traction and low-carbon and sustainable development gain global consensus [1].

China requires a development path appropriate to its national circumstances, unlike Western developed nations, in order to meet the rising demands of China's lifestyle [2].

Therefore, the Chinese government has put forward the concept of innovative, coordinated, green, open, and shared development and highlighted that development is the main goal of the Party in governing and renewing the country. To achieve high-quality economic development, we must adopt the new development philosophy completely, precisely, and exhaustively. Regional coordination is essential to achieving sustainable economic development and resolving the contradiction between limited regional territory and endless demand in the context of high-quality economic development. To meet the criteria of China's high-quality economic development, it is essential to execute the new development model and promote coordinated regional development.

The high-quality development of the regional economy is influenced directly or indirectly by scientific and technical innovation, which is also a growth mode of the innovation-driven economy. In the course of high-quality regional economic development, this impact can be bidirectional. On the one hand, it can advance technology through scientific and technological innovation, increase production effectiveness, encourage industrial transformation, overcome geographic constraints, have positive knock-on effects, and encourage high-quality, coordinated economic development between regions. On the other hand, the siphoning effect of scientific and technical innovation activities in central cities on diverse production factors and resources such as talents and money may impede the high-quality economic development of nearby cities.

In this context, urban agglomeration plays a significant role in the coordinated growth of the regional economy as the primary carrier of the phenomenon of innovation spillover. Thus, research on cooperative innovation and high-quality economic development of urban agglomerations have practical guiding relevance for China's economic development. Among China's numerous urban agglomerations, the Beijing–Tianjin–Hebei region, the Yangtze River Delta, and the Pearl River Delta are regarded as the three major economic growth poles, with their total economic output approaching 45% of the country's total and internal R and D expenditure approaching 55% of the country's total [3]. Among these urban agglomerations, the Beijing–Tianjin–Hebei urban agglomeration, as a city cluster with two municipalities directly under the central government and eleven prefecture-level cities in the capital Beijing and Tianjin, is considered to have comparative advantages over the Yangtze River Delta and the Pearl River Delta. Especially after the implementation of the Beijing–Tianjin–Hebei coordinated development strategy in 2014, the level of integrated development of the Beijing–Tianjin–Hebei urban agglomeration has increased dramatically. However, the Beijing–Tianjin–Hebei urban agglomeration lags behind the other two urban agglomerations in terms of actual economic development activity and overall regional revenue, and there is also a significant development gap across cities. How should the high-quality economic development level of cities in the Beijing–Tianjin–Hebei urban agglomeration be measured under these conditions? How does the collaborative innovation of the Beijing–Tianjin–Hebei urban agglomeration affect the quality of urban economic development?

The Beijing–Tianjin–Hebei urban agglomeration is an essential supporting area for China's scientific, technological, and economic development, and it plays a significant demonstration role in the high-quality development of the regional economy. To examine how collaborative innovation affects high-quality economic development, this study uses the Beijing–Tianjin–Hebei urban agglomeration as its research object. Research on innovation and economic development, as early as Michael Porter's four-stage theory of national competitive advantage, claimed that with rising factor costs and declining investment efficiency, a country's economy can only achieve further growth by relying on innovation. As China's economy transitions from a quantitative growth stage to a qualitative growth stage, Baoping Ren also believes that it is necessary to develop an innovative economy, implement an innovation-driven development strategy, build and improve a collaborative innovation system, and promote development model innovation [4]. The analysis of other nations by Pavlo Ilchuk and Iryna Mushenyk reveals a strong positive correlation between the index of national innovation systems' development and the index of GDP per capita [5].

Rana Pratap Maradana et al. discovered both unidirectional and bidirectional Granger causation between innovation and economic growth, but results vary from country to country [6]. Innovation is linked to long-term economic growth, according to research by Rudra P. Pradhan et al. [7]. Kais Mtar and Walid Belazreg suggest that the relationship between innovation and economic growth is complex, and country-specific characteristics can play an important role in fostering innovation and productivity [8]. Furthermore, there are relatively few overseas studies on innovation and high-quality economic development, yet it is widely accepted that innovation affects high-quality economic development. Hailun Zhang and Sheng Xu believe that innovation can boost the tertiary sector by decreasing the number of primary and secondary industries, converting China's economic structure into a more advanced pattern [9]. According to Wensheng Xiao et al., China's innovation-driven economic development plan is crucial [10]. Chenhui Ding et al. discovered that technical innovation is a crucial transmission mechanism for the development of a high-quality digital economy [11]. Although the preceding articles explain the relationship between innovation and economic development relatively thoroughly, the research on collaborative innovation and high-quality economic development is gradually becoming a new research entry point due to the spillover effect of innovation and the inseparability of urban geography. However, there is a lack of research on collaborative innovation and high-quality economic development outside of China, where the majority of relevant research is conducted. For example, Lv Ping observed that technological innovation plays a part-mediating role in the process of coordinated agglomeration of the two industries to promote high-quality economic development, and there are considerable geographical variances and industry heterogeneity [12]. Hu Yan et al. discovered, based on data from the Yangtze River Delta city agglomeration, that the collaborative innovation of the Yangtze River Delta city agglomeration boosts regional economic growth via direct, indirect, and total effects [13].

In previous literature, the measurement of high-quality economic development evolved from a single indicator such as GDP to a multi-indicator system. In their study, Tao Zhu et al. used labor productivity (GDP per capita) to express high-quality economic development [14], and Atif Jahanger used total factor productivity to represent high economic quality [15]. Yun Liu et al. [16], Die Li and Sumin Hu [17] use green total factor productivity as an indication of high-quality economic development. Nevertheless, a single indicator is frequently unable to convey the complexities of high-quality economic development. Several scholars have developed a number of indicator evaluation systems for high-quality economic development from various vantage points. Xiaowei Ma and Junwei Xu [18] have developed an evaluation system for high-quality economic indicators that includes three elements of "economic development-social life-ecological environment". Yu Hong et al. [19] divided China's high-quality development evaluation system into four components using the scientific meaning of new economic momentum: technical innovation, structural reform, transformation and upgrading, and development effectiveness. Guoqiang Wang [20], Xin Sun [21], and others constructed the evaluation technique for the high economic quality index using four different variables. Xinhuan Huang et al. [22] evaluated the high quality of economic development from the perspectives of innovation development, urban–rural coordination, ecological environment, opening to the outside world, and people's livelihoods. The economic high-quality index evaluation method developed by Wang Yiting [23], Yu Fu et al. [24], Ziyue Rong [25], Ming Chen, and Hongbo Wang [26] likewise contains five dimensions, but the selected indices are also distinct. The meaning of high-quality economic growth has been further enlarged with the introduction of the five major development ideas. Based on the five major development concepts, Xiao-Hong Shi et al. [27], Xiaosheng Li et al. [28], Yating Zhu [29], Cao Xiaochen [30], Lingming Chen, and Congjia Huo [31], among others, constructed various evaluation systems for high-quality economic indicators.

Based on the aforementioned literature, the existing literature has conducted rich discussions on innovation and economic development. Nonetheless, the following challenges of collaborative innovation and high-quality economic growth merit additional in-depth research: First, several researchers have chosen single or composite index evaluation systems to assess high-quality economic development, but no unified and reliable evaluation system has been developed. Therefore there is no established criterion for measuring high-quality regional economic development at the moment. Second, current research on the measurement and evaluation system construction of high-quality economic development and related factors focuses primarily on the inter-provincial level, with relatively few studies on the urban agglomeration level, much less the Beijing–Tianjin–Hebei urban agglomeration. Even if the research object of Beijing–Tianjin–Hebei is viewed as a whole, the majority still analyze and discuss at the province level, seldom conducting research on each city of Beijing–Tianjin–Hebei as the research target, and the research data utilized are typically outdated. Third, while there has been a lot of research on the impact of technological innovation on economic development, there has been less research from the perspective of regional collaborative innovation. The research findings on the influence of high-quality economic development are also not entirely consistent, and this area of study continues to be highly active in China's economic development.

This study employs 13 cities in the Beijing–Tianjin–Hebei urban agglomeration as its research focus and uses data from 2003 to 2020 as samples to solve the existing research deficiencies. The spatial gravity model is utilized to estimate the level of collaborative innovation in each city, and the entropy approach is used to construct a high-quality economic development index system based on five fundamental development principles, exploring the effects of collaborative innovation between the Beijing–Tianjin–Hebei urban agglomeration on high-quality economic development using the spatial Dubin model in spatial econometrics. It is concluded that the Beijing–Tianjin–Hebei city cluster's high-quality economic development is growing overall, but the pace of development differs substantially amongst cities. In addition, the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration does not have spatial correlation characteristics under the weight of pure geographical distance. However there is a clustering effect on the differential relationship of economic development, and the clustering effect is also significant under the dual influence of economic geography. The Beijing–Tianjin–Hebei urban agglomeration's collaborative innovation not only fosters the high-quality growth of the local economy but also has favorable effects on the high-quality growth of bordering economies.

The innovation points of this paper are: First, instead of using subjective techniques such as expert scoring, an objective evaluation system of high-quality economic indicators is created for the Beijing–Tianjin–Hebei urban agglomeration at the municipal level using innovative mathematics. Second, the mathematical model is used to assess the degree of urban collaborative creativity, and urban innovation is further assessed by the addition of the spatial aspect. Thirdly, using a mathematical model, spatial econometrics analyses the influence and spillover effect of collaborative innovation on high-quality economic development in a number of aspects.

The rest of this paper is organized as follows: Section 2 details the theoretical framework and hypothesis. Section 3 introduces the research methodology and data. Section 4 shows the results of the empirical analysis and further analysis of the research results, and Section 5 presents the conclusions.

2. Theoretical Framework and Hypothesis

2.1. The Internal Mechanism of Collaborative Innovation on High-Quality Economic Development

China is at the nexus of the world's economic structure transformation, and upgrading and the new technological revolution, and innovation-driven high-quality development has gradually gained acceptance. In the knowledge economy era, regional innovation capability has developed into a significant source of competitive advantages in the region [32]. The change of innovation mode is crucial to the path of high-quality economic development since it is an innovation-driven growth mode and innovation is technological advancement as the primary engine of economic growth [33]. High-quality economic development can be stimulated by collaborative innovation at all levels of the five development principles. From the perspective of economic innovation, collaborative innovation has the potential to change the industrial structure [34], lower production costs, increase output quality and efficiency, and advance ideas and technologies to support high-quality economic growth. From the standpoint of economic coordination, industrial allocation optimization brought about by collaborative innovation can encourage the integration and utilization of inter-regional resource circulation, as well as the quicker and more efficient utilization of the positive externalities of central cities, in order to achieve collaborative growth with central cities [35], close the inter-regional economic gap, and promote coordinated and synchronous development of regions. From an economic green perspective, collaborative innovation can lessen the intensity of carbon emissions [36,37] by utilizing clean energy more effectively and using less fossil fuels, which will result in resource conservation, pollution reduction, emission reduction, and other effects. This will also support sustainable development and maximize long-term benefits. From the standpoint of economic opening, collaborative innovation can encourage the upgrading of socialized service ability, the international technological spillover [38], the healthy interchange of economy, and the improvement of economic quality in order to accomplish the stable development of economy. In terms of economic sharing, collaborative innovation can enhance sharing structures, broaden sharing domains, raise sharing standards, encourage growth and alleviate poverty through externalities [39], and achieve sharing of economic resources and elements. On the basis of the study above, Hypothesis 1 is suggested.

Hypothesis 1. *Collaborative innovation can significantly promote high-quality economic development.*

2.2. Spillover Mechanism of Collaborative Innovation on High-Quality Economic Development

It has been shown in several studies that innovation has geographical spillover and that talent is concentrated in cities, making urban agglomeration the spatial carrier of innovation [40]. Innovation and regional economic growth are closely related. Collaborative innovation can influence the high-quality growth of the surrounding economy in the following ways, in addition to directly encouraging the high-quality development of the local economy. The first benefit of collaborative innovation is that it encourages local technology upgrading, boosts corporate productivity [41], deepens the division of labor, completely utilizes initial resources, raises capital stock substantially [42], and encourages businesses to innovate [43]. At the same time, it also causes related imitation effects in surrounding areas [44], so as to achieve high-quality regional economic development. Second, through the flow of innovation factors, regional collaborative innovation can efficiently combine technology, talent, capital, and other scientific and technological resources, break down regional barriers, and innovation and invention can support one another [45]. Additionally, it can play on the talent classification effect to boost regional production efficiency [46], establish a cross-regional deep cooperation mechanism to boost productivity, and then generate positive spatial spillover effects on surrounding areas. The third is the mechanism for competition brought about by collaborative innovation. Regional awareness of innovation will be fostered so that each region can compete through innovation and complex production processes [47], take the initiative to learn advanced experience from other regions, and independently engage in innovation behavior, thereby driving regional technological upgrading and industrial transformation. In the learning competition, to raise the level of high-quality economic development of the local and other regions. Based on the preceding analysis, the second hypothesis is proposed.

Hypothesis 2. *Collaborative innovation can promote high-quality economic development through space spillover.*

3. Methodology and Data

3.1. Research Methods and Models

3.1.1. Entropy Method

Starting from the connotation of high-quality economic development, based on the five development concepts, considering that the statistical caliber of some data of prefecture-level cities in Hebei has changed in different years, the selection of indicators, based on the research results of a large number of literature [20,24,25,28,31] studies and data collection, and giving full consideration to the scientificity, hierarchy, and availability of data, determined the following: The index evaluation system of high-quality economic development from six dimensions of economy, innovation, coordination, green, openness, and sharing is shown in Table 1. This research uses the entropy method [48] to establish the precise weight of each index to prevent subjective empowerment's arbitrary nature. The entropy method, one of the objective weighting methods, may calculate the index's weight based on the original data from the objective environment, guaranteeing the system's scientific nature and resolving the issue of information overlap across various index variables. The specific measurement steps of the entropy value method are as follows:

Step 1: Since each indicator unit is different, the indicators must be standardized. In the following equation x'_{ij} denotes the value of the jth indicator of the ith city $(i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, m)$, the specific procedure of corresponding positive indicators and negative indicators is as follows:

$$Positiveindicators : x'_{ij} = \frac{x_{ij} - \min\{x_{ij}, \ldots, x_{nj}\}}{\max\{x_{1j}, \ldots, x_{nj}\} - \min\{x_{1j}, \ldots, x_{nj}\}}, \quad (1)$$

$$Negativeindicators : x'_{ij} = \frac{\max\{x_{ij}, \ldots, x_{nj}\} - x_{ij}}{\max\{x_{1j}, \ldots, x_{nj}\} - \min\{x_{1j}, \ldots, x_{nj}\}}, \quad (2)$$

Step 2: The contribution p_{ij} of the jth indicator representing the city i is as follows:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, i = 1, \ldots, n, j = 1, \ldots m, \quad (3)$$

Step 3: The entropy value of the jth indicator is calculated with the following formula:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij}, \quad (4)$$

where $k = 1/\ln(n) > 0$, and $e_j \geq 0$.

Step 4: The x_j variance coefficient of the indicator is calculated with the formula $d_j = 1 - e_j$.

Step 5: Finally, the weight of the jth indicator is calculated with the formula $w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$, that is x_j, the weight w_j coefficient of the entropy method operation.

Step 6: Calculation of the final composite index, high-quality economic development index (HQED): $\mathrm{HQED}_i = \sum_j w_j \times x_{ij}$.

Table 1. Calculation results of entropy weights.

Primary Indexes	Secondary Indexes	Tertiary Indexes	Attribute	Unit	Weight Coefficient W
Economy	Level of economic growth	GDP growth rate	+	%	1.30%
Innovation	The level of innovation output	Number of patents granted per 10,000 people	+	pieces/10,000 people	7.66%
	Innovation output capacity	R and D is equivalent to full-time equivalent	+	Year of the man	11.68%
	Level of investment in innovation	Internal expenditure on R and D funding per capita	+	CNY 1 million	9.23%
	Innovative products increase profitability	New product sales revenue/main business income	+	%	3.38%
Harmonize	Stable employment	jobless rate	-	%	1.58%
	The level of industrial coordination	Industrial rationalization (Thiel index).	-	%	3.41%
		Industrial upgrading (tertiary industry output value/secondary industry output value).	+	%	1.27%
	The level of urban–rural coordination	The ratio of per capita income of urban and rural residents	-	%	0.35%
Green		Per capita consumption ratio of urban and rural residents	-	%	0.49%
	Greening level	Green coverage in built-up areas	+	%	0.42%
	The proportion of high-quality arable land	The total sown area of crops/total area of area	+	%	2.34%
	Resource utilization	Energy consumption per unit of GDP	-	Tons/CNY 10,000	0.93%
		Water consumption per unit of GDP	-	Tons/CNY 10,000	0.43%
		Electricity consumed per unit of GDP	-	kWh/CNY 10,000	0.78%
	Environmental costs	wastewater	-	ton	0.25%
		exhaust gas	-	ton	0.18%
		solid	-	ton	0.05%
Opening	The level of openness to the outside world	Actual foreign investment amount used in the year/GDP	+	%	7.05%
		Import and export trade of goods/GDP	+	%	7.02%
		The number of inbound tourists received	+	10,000 visitors	13.05%
Share	The basic livelihood of the people	Road area per capita	+	square meter	1.13%
		Library holdings per capita	+	Thousand copies	7.52%
		Physicians per capita	+	person	4.58%
		Passenger traffic per capita	+	times	6.57%
		Educational resources per capita	+	Yuan	7.35%

3.1.2. Gravitational Model

The primary explanatory variables measure the degree of coordinated development of technical innovation among cities in the Beijing–Tianjin–Hebei urban agglomeration. They represent collaborative innovation between regions. The gravitational model [49] is used to gauge the level of collaborative innovation across cities in the Beijing–Tianjin–Hebei region, taking into account not just each city's capacity for innovation but also the spatial impact effect between cities. The measurement method is shown in Equations (5) and (6).

$$\text{Index}_{\,ij} = \frac{I_i \times I_j}{d_{ij}^2} = \frac{I_{1i} \times I_{2i} \times I_{1j} \times I_{2j}}{d_{ij}^2}, \tag{5}$$

$$Tsi_i = \sum_{i \neq j} \text{Index}_{\,ij}, \tag{6}$$

Among them, it is used to measure the Index_{ij} degree of spatial connection of innovation between cities, which is the financial I_1 expenditure on scientific and technological innovation, which is used to measure the government's financial support for technological innovation. It is the number of employees in scientific and technological I_2 activities, which is used to measure the number of people participating in scientific and technological activities in enterprises. d_{ij} represents the distance between cities, and the calculation process is shown in Equation (7), where R is the radius of the earth, and lat and long are latitude and longitude, respectively.

$$d_{ij} = 2R \arcsin\left(\sqrt{\sin^2\left(\frac{lat_i - lat_j}{2}\right) + \cos(lat_i)\cos\left(lat_j\right)\sin^2\left(\frac{long_i - long_j}{2}\right)}\right), \tag{7}$$

3.1.3. Moran's I Index

To verify whether there is a spatial spillover effect of collaborative innovation on high-quality economic development, it is necessary to conduct a spatial autocorrelation test for high-quality economic development. Only when the dependent variable has spatial effects can spatial econometric research be conducted on it. The Moran's I index test is now frequently used to examine if factors have spatial effects. Cliff et al. first used Moran's I index for the global spatial correlation test [50], and this paper uses Moran's I index to test the correlation between global neighboring regions, and its calculation formula is as shown in the following Equation:

$$\text{Moran's } I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(\text{HQED}_i - \overline{\text{HQED}}\right)\left(\text{HQED}_j - \overline{\text{HQED}}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}, \tag{8}$$

where n is the total number of cities, w_{ij} is the element in the spatial weight W, and the levels of HQED_i, HQED_j are the high-quality economic development of City I and City J, respectively. $\overline{\text{HQED}}$ is the average level of high-quality economic development and S^2 is the variance. The value of Moran's I index is in the range $[-1, 1]$. A value greater than 0 indicates a positive correlation, and the closer it is to 1, the stronger the positive connection between locations with high-quality economic development space. If Moran's I index is close to 0, it suggests that there is no spatial autocorrelation in high-quality economic development, and the space is randomly distributed. Less than 0 indicates a negative correlation, and the closer it is to -1, the stronger the negative correlation between regions in the space of high-quality economic development.

3.1.4. Spatial Econometric Models

After the variable has passed the Moran's I index test, a spatial econometric model can be built for research purposes. There are three types of interactions in the spatial econometric model [51]: exogenous interactions between independent variables, endogenous interactions between dependent variables, and interactions between random perturbation terms. This paper adopts the spatial Durbin model (SDM) with endogenous interaction to investigate the spatial spillover effect brought by the collaborative innovation of various urban agglomerations to the high-quality economic development of surrounding places and themselves, namely direct effects and indirect effects (or intraregional and interregional effects). During regression analysis, logarithms are taken for each variable to lessen the model's heteroscedasticity and collinearity.

$$\begin{aligned} \mathrm{HQED}_{it} = \alpha + \lambda W \times \mathrm{HQED}_{it} + \beta_1 Tsi_{it} + \delta_n \textstyle\sum_{n=1}^{4} \times Ctrl_{nit} \\ + \rho_1 W \times Tsi_{it} + \theta_n \textstyle\sum_{n=1}^{4} W \times Ctrl_{nit} + \phi_i + \varepsilon_{it} \end{aligned} \quad (9)$$

HQED stands for High-quality Economic Development Index; *Tsi* stands for Collaborative Innovation; W stands for the spatial weight matrix; λ is the spatial autocorrelation coefficient, which indicates the direction and degree of the spillover effect of high-quality economic development in local and surrounding areas. β_1, δ_n represent collaborative innovation and the elastic coefficient of the control variable; ρ_1, θ_n represent the elastic coefficients of the spatial interaction terms of the explanatory variables and the control variables, respectively; ϕ_i and ε_{it} represent unobserved individual effects and random error terms, respectively.

$Ctrl_{nit}$ denotes a series of control variables. In addition to collaborative innovation and financial development, there are still many factors that will affect the level of regional economic development. In this paper, a number of control factors are defined to reduce the bias caused by missing variables, mostly containing the following:

(1) Population density (HUM) relates to numerous characteristics of a city's development. While a high population density puts pressure on the distribution of resources and other aspects of the city, it also increases the labor supply to some extent. Population density is represented by the ratio of population to urban area.

(2) Urbanization (UA) has always been the focus of scholars' research on economic development. To some extent, the urbanization level represents the allocation of labor resources. The movement of workers from urban areas to cities is beneficial for the growth of the secondary and tertiary industries, the improvement of the industrial structure, and the promotion of high-quality economic development. The degree of urbanization is expressed by the proportion of the urban population.

(3) It is generally accepted that the growth of human capital (HC) will contribute significantly to economic development; nevertheless, as HC increases, so do labor expenses, which will have an impact on economic advantages. Human capital is represented in this study by the percentage of people with higher education levels.

(4) The number of workers in urban units is used to calculate the labor force level (LAB). The impact on the high-quality development of the economy is frequently diverse due to the different degrees of full employment. As a result, the degree of full employment is represented by the number of employees in urban units.

Therefore, to improve the scientific model, this paper introduces four indicators, "population density", "urban population proportion", "human capital", and "labor force level", which were used as control variables.

3.1.5. Construction of Spatial Weight Matrix

Relevant studies have shown that distance between regions and economic factors are two important factors affecting spatial spillover effects [52], so in the study of spatial spillover effects, the weights used usually include general adjacency weights, geographical distance weights, economic distances weights, and economic geography nested weight matrices, etc. This article builds all four weights.

(1) General adjacency weight matrix

W_l is a matrix of adjacency weights, which are indicated by $W_l ij = 1$ when the cities of Beijing–Tianjin–Hebei are adjacent and $W_l ij = 0$ when they are not adjacent. The formula is as follows:

$$W_{lij} = \begin{cases} 1, & \text{City i is adjacent to city j} \\ 0, & \text{City i is not adjacent to city j} \end{cases} \tag{10}$$

(2) Geographic distance weighting matrix

W_{geo} is the geographical distance weight matrix. The reciprocal of the geographical distance between cities is selected, and the element is the geographical distance between cities shown d_{ij} in Equation, measured by the latitude and longitude of the city, the closer the geographical distance of the city, the closer the connection between its high-quality economic development. The formula is as follows:

$$W_{geo} = \begin{cases} 1/d_{ij} & i \neq j \\ 0 & i = j \end{cases} \tag{11}$$

(3) Economic distance weight matrix

W_{eco} is the economic distance matrix, $\overline{gdp_i}$ is the average of the per capita GDP of each city in the period from T_0 to T_1 in the Beijing–Tianjin–Hebei region, and the average of the $\overline{gdp}$ per capita of the urban agglomeration as a whole in the period from T_0 to T_1. g_{ij} is the economic distances between cities shown.

$$\begin{gathered} \overline{gdp_i} = \sum_{T_0}^{T_1} gdp_i/(T_1 - T_0 + 1) \\ \overline{gdp} = \frac{1}{n}\sum_{i=1}^{n} \overline{gdp_i} \\ g_{ij} = \frac{\overline{gdp_i} - \overline{gdp_j}}{\overline{gdp}} \\ W_{\text{eco}} = 1/\left(\left|g_{ij}\right| + 1\right) \end{gathered} \tag{12}$$

(4) Economic geography nested weight matrix

W is the economic geography nested weight matrix, as shown in Equation (8), where α represents the weight of economic factors, $1 - \alpha$ represents the weight of geographical factors, and the α value depends on the size and significance of the global Moran's I index.

$$W = \alpha W_{eco} + (1 - \alpha) W_{\text{geo}} \quad (0 < \alpha < 1) \tag{13}$$

3.2. Samples and Data Sources

The panel data from 2003 to 2020 were chosen as the study sample in this paper, which included 13 cities from the Beijing–Tianjin metropolitan agglomeration as research samples.

The primary data sources were: China Urban Statistical Yearbook, China Reform Yearbook, China Regional Economic Database, China Urban and Rural Construction Database, Hebei Economic Yearbook, Hebei Statistical Yearbook, Hebei Science and Technology Yearbook, Beijing Statistical Yearbook, Tianjin Statistical Yearbook, prefecture-level municipal statistical yearbook, statistical bulletins, etc.

Some of the missing data have been completed using interpolation. To avoid spurious regression and reduce heteroscedasticity, variables are taken by logarithms in the analysis.

4. Empirical Results

4.1. Measurement Analysis of High-Quality Economic Development of Beijing–Tianjin–Hebei Urban Agglomeration

According to the index system in Table 1, the measured high-quality economic development results of Beijing–Tianjin–Hebei cities are shown in Table 2.

Table 2. Measurement analysis of high-quality economic development of Beijing–Tianjin–Hebei urban agglomeration.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.3798	0.4302	0.4691	0.4724	0.4907	0.5036	0.5067	0.5493	0.5815	0.5880	0.5813	0.5809	0.5872	0.5883	0.6102	0.6592	0.6932	0.6248
Tianjin	0.2115	0.2373	0.2519	0.2679	0.2803	0.2920	0.2881	0.3061	0.3358	0.3630	0.3714	0.3952	0.4353	0.4561	0.4012	0.3583	0.3569	0.3105
Shijiazhuang	0.0950	0.1014	0.1078	0.1098	0.1040	0.1183	0.1269	0.1293	0.1349	0.1428	0.1459	0.1605	0.1478	0.1540	0.1560	0.1731	0.1752	0.1951
Tangshan	0.0843	0.0920	0.0899	0.0923	0.1020	0.1106	0.1051	0.1111	0.1170	0.1251	0.1258	0.1231	0.1478	0.1502	0.1454	0.1556	0.1689	0.1768
Qinhuangdao	0.1119	0.1223	0.1228	0.1198	0.1307	0.1341	0.1291	0.1396	0.1456	0.1486	0.1473	0.1523	0.1672	0.1711	0.1773	0.1868	0.1929	0.1821
Handan	0.0711	0.0829	0.0823	0.0850	0.0899	0.0944	0.0954	0.0998	0.1055	0.1111	0.1152	0.1158	0.1221	0.1369	0.1376	0.1453	0.1447	0.1411
Xingtai	0.0832	0.0829	0.0844	0.0859	0.0838	0.0831	0.0888	0.0923	0.0964	0.0937	0.1010	0.1060	0.1095	0.1122	0.1165	0.1270	0.1351	0.1441
Baoding	0.0902	0.0938	0.0998	0.1025	0.1094	0.1152	0.1118	0.1152	0.1168	0.1164	0.1161	0.1247	0.1389	0.1414	0.1425	0.1672	0.1618	0.1618
Zhangjiakou	0.0606	0.0621	0.0636	0.0691	0.0752	0.0714	0.0747	0.0768	0.0826	0.0946	0.0907	0.0984	0.1047	0.1122	0.1213	0.1262	0.1243	0.1171
Chengde	0.0631	0.0728	0.0656	0.0707	0.0784	0.0757	0.0786	0.0870	0.0966	0.0981	0.0939	0.1031	0.1047	0.1055	0.1108	0.1140	0.1133	0.1077
Cangzhou	0.0853	0.0899	0.0968	0.0911	0.0879	0.0978	0.1035	0.1005	0.0986	0.0998	0.0993	0.1054	0.1095	0.1128	0.1214	0.1352	0.1359	0.1449
Langfang	0.1134	0.1183	0.1267	0.1306	0.1314	0.1336	0.1300	0.1474	0.1257	0.1322	0.1374	0.1471	0.1418	0.1414	0.1537	0.1678	0.1703	0.1621
Hengshui	0.1031	0.1096	0.1091	0.1037	0.0959	0.1037	0.1111	0.1188	0.1254	0.1431	0.1419	0.1257	0.1269	0.1316	0.1568	0.1616	0.1562	0.1528

4.1.1. Temporal Variation Characteristics of High-Quality Economic Development in the Beijing–Tianjin–Hebei Urban Agglomeration

It can be seen from Table 3 that the high-quality economic development level of all parts of the Beijing–Tianjin–Hebei city cluster has shown an upward trend, with a substantial increase from 2003 to 2020. In 2020, as a result of the impact of the epidemic, the data in some regions fell slightly, but the magnitude was not very great. The general increasing trend is quite significant. This demonstrates that as a result of the economic development of the Beijing–Tianjin–Hebei region, the high-quality level of the economy in a variety of different places is also continuously improving. However, the rate of growth of high-quality economic development varies greatly from one location to another. The highest growth rate can be found in Shijiazhuang and Tangshan, where it has more than doubled the increase in the level of high-quality economic development. In contrast, the growth rate in Langfang and Hengshui is less than fifty percent.

4.1.2. Spatial Variation Characteristics of High-Quality Economic Development in the Beijing–Tianjin–Hebei Urban Agglomeration

At the same time, the degree to which various regions have seen high-quality economic development differs substantially. The level of the high-quality economic development index in Beijing is significantly higher than that of other cities in the Beijing–Tianjin–Hebei region, and the level of the high-quality economic development index in Tianjin is generally higher than that of other cities in Hebei, even being twice as high as that of some cities. Nonetheless, there is a slight disparity in quality amongst the cities in Hebei. Only Shijiazhuang, Tangshan, and Qinhuangdao are comparatively high, whereas Hengshui and Chengde have the lowest economic quality development index.

4.2. Unit Root Test

To ensure the validity of the estimation, several unit root tests were carried out on the variables in this study to test the stationarity of panel data. Table 3 shows the results of the unit root test, where all test values are significant and prove to be stable. Table 3 shows the unit root test of explained variable HQED, explanatory variable Tsi, and control variable HUM, UV, HC, LAB.

Table 3. Unit root test results.

Variable	t	p	AIC
HQED	−4.516	0.000 ***	−855.992
Tsi	−2.941	0.041 **	11,243.134
HUM	−3.66	0.005 ***	3649.39
UA	−3.72	0.004 ***	1460.216
HC	−2.791	0.060 *	−1648.989
LAB	−9.351	0.000 ***	2196.506

Standard errors are shown in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

4.3. Non-Spatial Panel Test Results

The measurement software used in this paper is Stata, and the descriptive statistics of relevant variables are shown in Table 4:

Table 4. Data sources and definition of variables and descriptive statistics.

Variable	Average	Standard Deviation	Minimum	Maximum
HQED	0.1675	0.1300	0.0606	0.6932
Tsi	2.24×10^{10}	8.48×10^{10}	1.07×10^{4}	4.36×10^{11}
HUM	3168.0240	2208.0530	641.0000	11,880.0000
UA	51.8662	15.5378	28.1700	87.5500
HC	0.0196	0.0154	0.0017	0.0558
LAB	91.2293	177.7659	8.4100	819.3000

Table 5 displays the results of fitting non-spatial panel data. Collaborative innovation can provide high-quality economic growth and pass the significance level test of 1% when the geographical effect is not taken into account for regression, so hypothesis 1 is tested. High-quality economic development can be significantly boosted by increased levels of collaborative innovation. While urbanization level, human capital, and labor force size all significantly improve high-quality economic development, population density has a detrimental impact on it.

Table 5. Results of the nonspatial panel model.

HQED	OLS
$lnTsi$	0.0167 ***
	(0.00591)
$lnHUM$	−0.0431 **
	(0.0208)
$lnUA$	0.714 ***
	(0.113)
$lnHC$	0.0194
	(0.0244)
$lnLAB$	0.203 ***
	(0.0207)
Constant	−5.353 ***
	(0.440)
Observations	234
R-squared	0.852

Standard errors are shown in parentheses. ** and *** denote significance at the 5% and 1% levels, respectively.

4.4. Spatial Correlation Analysis

After the Moran's I index test it is found that, whether it is the weight of general adjacency or geographical distance, the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration has not yet formed a synergistic effect in the pure geographical location, and the Moran's I index is negative and insignificant. The high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration has created a synergistic effect of strong aggregation in economic ties, according to the weight of economic distance. The high-quality economic development of the Beijing–Tianjin–Hebei city cluster has been shown to have a synergistic effect through the economic geography nested weight matrix, and all the data have passed the significance test of 1%, indicating that in the process of collaborative innovation affecting the high-quality development of the local economy, there is also an indirect spillover effect to the surrounding areas. Consequently, through spatial econometric modeling, it is required to further investigate the influence direction (positive and negative direction) and degree of collaborative innovation on high economic quality.

Cities are not only geographically related, but also cannot be separated economically since whether each city's high-quality economic development has a synergistic impact is frequently influenced by geographical position and economic development to some extent. As a result, the spatial weight matrix of this study is the nested weight matrix W of economic geography. It can more thoroughly reflect the spatial link between cities. It has been demonstrated that the Moran's I index is significant when α is between 0.1 and 0.9; when α is 0.9, the value of Moran's I index is closer to 1 and the aggregation effect is more pronounced, confirming that economic distance has a significant impact on the synergistic effect of Beijing–Tianjin–Hebei urban agglomeration. Therefore, α is set to 0.9 in this paper. Table 6 displays the results of Moran's I index test.

Table 6. $\alpha = 0.9$ Moran's I index test results.

Year	M	Z	*p*
2003	0.011	4.846	0.000
2004	0.015	5.056	0.000
2005	0.012	4.871	0.000
2006	0.017	5.137	0.000
2007	0.023	5.482	0.000
2008	0.026	5.555	0.000
2009	0.021	5.383	0.000
2010	0.021	5.361	0.000
2011	0.023	5.502	0.000
2012	0.024	5.508	0.000
2013	0.025	5.508	0.000
2014	0.025	5.519	0.000
2015	0.035	5.988	0.000
2016	0.033	5.873	0.000
2017	0.024	5.500	0.000
2018	0.017	5.344	0.000
2019	0.023	5.709	0.000
2020	0.023	5.675	0.000

4.5. The Impact of Collaborative Innovation on High-Quality Economic Development

4.5.1. Regression Results

According to Table 7, the results of the spatial Durbin model's estimation show that the regression coefficient of collaborative innovation is positive and passes the 1% significance test, indicating that it significantly contributes to the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration. As a result, both Hypotheses 1 and 2 have been investigated. Collaborative innovation can not only significantly promote high-quality economic development, but can also have a positive impact on the high-quality economic development level of neighboring regions through the spatial spillover effect. From the perspective of the control variables, the degree of urbanization also encouraged the coordinated development of the Beijing–Tianjin–Hebei urban agglomeration, and the human capital and labor levels failed to play a significant role in the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration, while the impact of population density was insignificant.

Table 7. Space panel regression results.

Variable	*p*
Tsi	0.087 ***
	(0.000)
H UM	0.014
	(0.166)
UA	0.234 ***
	(0.000)
HC	−0.032 *
	(0.079)
LAB	−0.140 ***
	(0.000)
λ	−2.369 ***
	(0.000)
σ^2	0.002 ***
	(0.000)

Standard errors are shown in parentheses. * and *** denote significance at the 10% and 1% levels, respectively.

4.5.2. Effect Decomposition

Although the coefficients of explanatory variables in the fitting results of the spatial Durbin model can explain the promotion of collaborative innovation on high-quality economic development to a certain extent, taking into account the existence of spatial effects, the partial differential method of Lesage and Pace [53] is referred to here to more thoroughly explore the impact of collaborative innovation on high-quality economic development of various urban agglomerations. The impact of collaborative innovation on high-quality economic development is decomposed into direct effects, indirect effects, and total effects, according to Table 8.

From the perspective of direct effects, the Tsi_i direct effect coefficient of collaborative innovation on high-quality economic development was 0.028, which was significantly positive from the perspective of direct effects. This result shows that collaborative innovation can indeed support the high-quality development of urban economies and raise the degree of high-quality development of local economies. In terms of indirect effects, the indirect effect coefficient of collaborative innovation on high-quality economic development in the Beijing–Tianjin–Hebei urban agglomeration is 0.277, which is also significant, indicating that collaborative innovation not only supports the high-quality development of the local economy but also has a positive spillover effect on neighboring regions and has a significant pull on the high-quality economic development of neighboring cities. The total effect of collaborative innovation on high-quality economic development is 0.305, which also passes the significance test at the 1% level. In general, increasing the level of collaborative innovation is beneficial to raising the overall level of high-quality economic development in the region and encourages the synchronous and coordinated growth of the area. As a result, both Hypotheses 1 and 2 have been put to the test once more.

Table 8. Decomposes regression results.

Variable	Direct Effects	Indirect Effects	Total Effect
Tsi	0.028 ** (0.023)	0.277 *** (0.000)	0.305 *** (0.000)
HUM	0.017 (0.162)	−0.012 (0.162)	0.004 (0.191)
UA	0.287 *** (0.000)	−0.215 *** (0.000)	0.072*** (0.000)
HC	−0.039 * (0.062)	0.029 * (0.067)	−0.010 * (0.075)
LAB	−0.168 *** (0.000)	0.125 *** (0.000)	−0.042 *** (0.000)

Standard errors are shown in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

4.5.3. Other Control Variable Regression Results

The direct and indirect effects of population density on the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration were not significant, showing that merely increasing population density did not promote high-quality economic development. While growing population density brings in more labor, it does not always result in economic growth and productivity gains because increases in population density are frequently the result of economic development rather than the cause. The current pursuit of high-quality economic development is a balanced and steady development, and an increase in population density without a supply of high-quality employment and supporting resources and facilities will only increase the burden on the city, make resource allocation more difficult, and result in slumping.

The direct effect of urbanization level on the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration is significantly positive, and the indirect effect is significantly negative, indicating that the improvement of urbanization level promotes the high-quality development of the local economy but is not conducive to the high-quality economic development of the surrounding areas. Mainly because a city's towns often bear more responsibilities for economic growth, scientific and technological development, etc., with the development of the city, the migration of population to the town will also absorb and gather more talents, further promoting the urban science and technology and economic development, thereby promoting the high-quality development of the local economy, and if the personnel is transferred from the surrounding areas, it will inhibit the high-quality economic development of the surrounding areas.

While it plays a positive function in fostering the high-quality growth of the economies of the adjacent regions, human capital has a restraint effect on the local economy of the Beijing–Tianjin–Hebei urban agglomeration. It may be because the increase in the proportion of the higher education population in the Beijing–Tianjin–Hebei region at this stage has failed to provide a direct boost to the local economy, but has caused an increase in employment costs and intensified the imbalance between employment supply and demand. In addition, the improvement in industrial technology brought about by the rise in local human capital enables the neighbors to experience good spillover effects without having to shoulder the cost of employing people, thereby supporting the high-quality economic development of the neighbors.

The labor level also did not play a role in promoting the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration, indicating that the driving force of traditional factors for economic growth began to decline, and the advantages of China's demographic dividend were different from the past. The rise in the number of employed persons in urban units alone cannot support the improvement of economic quality but may produce local labor depreciation, consequently hurting local economic development. This outcome is consistent with the phased characteristics of China's economic development under the new normal.

4.6. Robustness Test

4.6.1. LR Test and Hausmann Test

There are many forms of panel models, and different choices of panel models will affect the final results of empirical research. This research performs a quantitative test of pertinent statistics on the model to increase the robustness of the results.

The fixed effects and random effects of the variable intercept model in panel models are often evaluated by the Hausman test method. To avoid the failure of the classical Hausman test due to issues such as heteroscedasticity or sequence correlation, this paper chooses a robust Hausman test to determine fixed and random effects. The results are shown in the last row of Table 9, with a statistic of 105.12 and a *p*-value of 0, indicating that choosing a fixed-effects model is more appropriate.

The fixed effects of the model were also tested once more using the LR test. Table 9 displays the test findings. At the 1% level, all three fixed effects are significant. The LR statistic of time individual double fixed effects, which reaches 361.7738, is the highest of them all. This article's use of the spatial Durbin model with time-individual double fixed effects is hence robust.

Table 9. The results of LR test and Hausman test.

Panel Effect	Statistic	*p*
Individual Fixed Effects	305.5137 ***	0.0000
Time Fixed Effect	114.7093 ***	0.0000
Double Fixed Effect of Time Individual	361.7738 ***	0.0000
Robust Hausman	105.12 ***	0.0000

Standard errors are shown in parentheses. *** denotes significance at the 1% levels, respectively.

4.6.2. Selection of Spatial Panel Models

Although the spatial Durbin model should be adopted based on relevant research experience, statistical approaches are utilized here for additional testing to increase the persuasiveness and robustness of the model selection. With the sample data presented in this study (see Table 10), both LM-Lag and LM-Error passed the significance test of 1% in the LM test, demonstrating that both the error term and the spatial lag term of the explanatory variable exhibited spatial autocorrelation characteristics. RLM-Lag and RLM-Error both passed the 1% significance criteria in the RLM test. In addition, the Wald test and likelihood ratio test on the results of the regression indicates that Wald-Lag and Wald-Error passed the significance test at the 1% level, as did LR-Lag and LR-Error, i.e., the null hypothesis "SDM model may be reduced to SEM model and SLM model". As a result, the SDM model utilized in this paper is reliable and sensible from a statistical perspective. Additionally, it confirms the accuracy of estimates of the significant direct and indirect effects of collaborative innovation on the high-quality economic development of the Beijing–Tianjin–Hebei metropolitan agglomeration.

Table 10. Selection of spatial panel models.

Relevant Inspections	*p*
LM-Lag	0.0000
LM-Error	0.0000
RLM-Lag	0.0000
RLM-Error	0.0000
Wald-Lag	0.0000
Wald-Error	0.0000
LR-Lag	0.0000
LR-Error	0.0000

4.6.3. Local Moran's I Index Test

A local Moran's I index test is also performed to increase the study's robustness. Figure 1 displays the stata-drawn scatterplot of the Moran's I index of High-Quality Economic Development Level. The number of cities in the thirteenth quadrant of the Beijing–Tianjin–Hebei urban agglomeration surpasses half of the samples, and the fitted line tilts to the upper right. In general, the test results follow the direction of the global Moran's I index test. The chosen model in this paper is scientific and reliable because it is demonstrated that the explained variables have a positive spatial association.

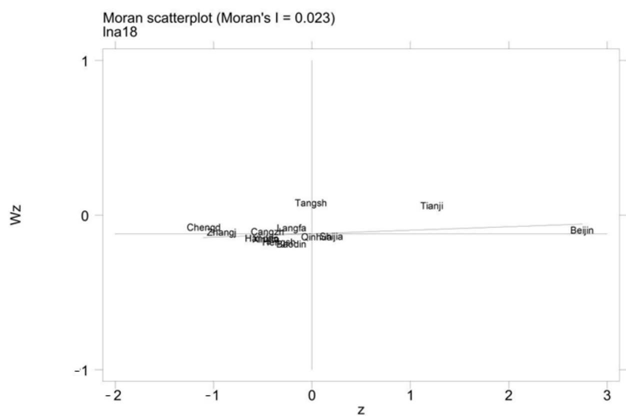

Figure 1. Local Moran's I index test.

5. Conclusions

5.1. Conclusions and Policy Recommendations

In the context of China's call for high-quality economic development, this paper studies the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration and the impact of collaborative innovation on high-quality economic development and draws the following conclusions: (1) The level of high-quality economic development in the Beijing–Tianjin–Hebei urban agglomeration is on the rise as a whole, but the development in individual cities varies greatly. The level of high-quality economic development of Beijing and Tianjin is significantly higher than that of other cities in Hebei, and there is also a certain disparity across cities in Hebei. (2) Under the weight of pure geographical distance, the high-quality economic development of the Beijing–Tianjin–Hebei urban agglomeration does not exhibit spatial correlation. However, there is a clustering effect in the differential relationship of economic development, and the aggregation effect is also significant under the dual influence of economic geography. (3) The collaborative innovation of the Beijing–Tianjin–Hebei urban agglomeration will have an obvious positive impact on the high-quality development of the local economy, namely the direct effect. At the same time, there is also a significant indirect spillover effect, that is, promoting high-quality economic growth in the surrounding areas can promote the overall high-quality economic development level of the urban agglomeration. In this paper the findings about the geographic disparity of high-quality economic development are in line with those of studies by Zhang Minglong [54], Fang Dachun and Ma Weibiao [55]. However, this article is different from the previous research object. Previous scholars used China's provincial level as a sample, while this article gathered in the Beijing Tianjin Hebei urban agglomeration. Furthermore, despite the fact that Ma Chengwen and Xia Jie [56] also came to the conclusion that high-quality economic development has spatial characteristics, in this article, high-quality economic development exhibits different aggregation or dispersion effects in economy and geography, and the conclusion has a certain degree of innovation. The majority of research by Schumpeter [57], Solow [58], Kogan et al [59], and Yuantal [60] has also demonstrated that innovation can support economic growth. This article extends innovation to collaborative innovation, deepening economic growth into high-quality economic development, and broadening previous research conclusions.

This study's findings have significant practical implications for both theory and practice, and they can serve as policy inspiration for the high-quality economic growth of the Beijing–Tianjin–Hebei urban agglomeration. In theory, taking the new development concept of "innovation, coordination, green, openness, and sharing" as the starting point, measuring the level of high-quality economic development in the Beijing–Tianjin–Hebei urban agglomeration, revealing the regular relationship between collaborative innovation and high-quality economic development in urban agglomeration, and analyzing the internal mechanism of the impact of collaborative innovation on high-quality economic development is possible. In practice, its significance lies in assessing the degree of collaborative innovation and high-quality economic development in the Beijing–Tianjin–Hebei urban agglomeration, contrasting the state of high-quality economic development in various cities, examining how collaborative innovation in the Beijing–Tianjin–Hebei urban agglomeration affects high-quality economic development, and proposing replicable and accessible development strategies for other regions.

According to the relevant research conclusions of this paper, the following suggestions are put forward:

Firstly, the Beijing–Tianjin–Hebei urban agglomeration economy has significant differences of high-quality development and collaborative innovation, according to this article. Collaborative development should be combined with characteristic industries to promote development according to local conditions. In the Beijing–Tianjin–Hebei region, coordinated development does not always include imitating or reproducing previously successful experiences and strategies. Due to differences in resource endowment, development level, economic size, population distribution, geographical location, etc. among different cities, blindly seeking the method of "copying homework" is not advisable. Collaborative development means creating a system, mechanism, and development model of collaborative innovation, collaborative management, and mutual support for joint construction, governance, and sharing within the Beijing–Tianjin–Hebei urban agglomeration. The concept of innovation as an important way to achieve high-quality economic development is established, and the entire urban agglomeration is promoted to achieve high-quality development through various paths. Characteristic industries mean that each city needs to explore feasible paths suitable for achieving high-quality development under the guidance of overall macro development concepts and goals, combined with its own characteristics and advantages, with a focus on cultivating a group of pillar industries and leading industries with local characteristics, promoting the accelerated transformation and upgrading of industries in the future. In order to jointly foster high-quality economic development in the area, it is important to strengthen the beneficial interaction and cooperation between diverse industries within the Beijing–Tianjin–Hebei urban agglomeration.

Secondly, based on the results that collaborative innovation can promote high-quality economic development, it is important to increase investment in factors related to collaborative innovation and adhere to the development principles of market leadership and government regulation to support scientific and technological innovation. It is essential to manage the connection between the market and the government well in order to foster collaborative innovation and encourage high-quality economic development. We must adhere to the leading role of the market in resource allocation, increase investment in scientific research personnel, clarify government regulatory parameters and scope, increase fiscal expenditures, and fully leverage the government's role in resource allocation, regulation, integration, and overall planning. In order to encourage high-quality economic development through collaborative innovation, the government should set up an institutional framework and policy instruments that are relatively complete, provide more financial support, and guide and motivate collaborative innovation. For example, providing targeted support through the establishment of special funds, key assistance projects, or encouraging businesses to strengthen technological innovation and independent research and development. The market may have a greater influence on collaborative innovation as development keeps deepening. Enterprises can achieve independent innovation behavior, and the government indirectly intervenes in regulation, resulting in a demonstration effect and driving more enterprises to participate in collaborative innovation.

5.2. Limitations and Future Research

The research on the impact of collaborative innovation in urban agglomerations on high-quality economic development has considerable practical significance, but research on high-quality economic development is still in its infancy, and many issues still need to be explored by the academic community. Here, some limitations and future directions of the research are proposed. First, due to limitations with data collection, the establishment of a system of high-quality economic indicators may encounter some restrictions in the choice of indicators. Second, there may be more influencing aspects and potential interactions surrounding the SDM model's design, and there is still potential for further advancement in the model's construction. Finally, the research presented in this article focuses on the Beijing–Tianjin–Hebei urban agglomeration; nevertheless, the techniques used and the findings could be applied to other urban agglomerations in China. In light of the foregoing, the following areas can be explored and deepened in future research. First off, the meaning of a high-quality economy will continue to be expanded and enhanced as economic development and statistical levels rise continuously. High-quality development indicators could one day be evaluated using a system that is more thorough and scientific. Second, the model setup for collaborative innovation to support high-quality economic development can be more plausible when theoretical research is deepened and spatial econometric methods are improved. Additionally, samples, indicators, and methods can all be further enhanced. Finally, it is concluded that collaborative innovation can support high-quality economic development based on study on the Beijing–Tianjin–Hebei urban agglomeration. This finding can be applied to other urban agglomerations in China, strengthening the government's spending on technological innovation, increasing the investment of scientific research personnel, and enhancing the local level of collaborative innovation, ultimately achieving the goal of improving the high-quality development of the local economy. The method used in this article can be applied to study collaborative innovation and high-quality economic development in other countries' urban agglomerations, providing inspiration for the high-quality economic development of those cities. Relevant indicators can be modified to account for the unique circumstances of each nation.

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Abbreviations

The following abbreviations are used in this manuscript:

HQED	High-quality Economic Development Index
Tsi	Collaborative Innovation
HUM	Population Density
UA	Urbanization
HC	Human Capital
LAB	Labor Force Levels

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