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Digital Economy, Industrial Structure, and Coordinated Development of the Two-way FDI: An Empirical Study Based on the Beijing-Tianjin-Hebei Region

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ABSTRACT

With the sustained attention of the academic community on the digital economy, this paper aims to delve into the impact of digital economy development on the coordinated development of inward foreign direct investment (IFDI) and outward foreign direct investment (OFDI) against the backdrop of the current global economy, focusing on the Beijing-Tianjin-Hebei region of China, building upon previous academic achievements. Through literature review and empirical data analysis, this paper reveals the effects of digital economy development on optimizing industrial structure, coordinating the two-way FDI development, and the spatial spillover effects of the two-way FDI coordination at the urban level. The research findings indicate that the rise of the digital economy not only significantly promotes the coordinated development of the two-way FDI but also plays a significant positive role in the upgrading of industrial structure in the Beijing-Tianjin-Hebei region, with both the digital economy and bilateral FDI coordination exhibiting significant positive spatial spillover effects.

KEYWORDS

Digital Economy; Industrial Structure; the Two-way FDI Coordination; Beijing-Tianjin-Hebei region

1. INTRODUCTION

With the advancement of technologies such as the Internet, big data, cloud computing, and artificial intelligence, the world economy is gradually undergoing digital transformation (Liu et al., 2021a, b). In the rapidly changing global economic environment and increasingly complex international economic landscape, the rise of the digital economy has become one of the important engines driving economic growth and industrial structural reform (Latif et al., 2018; Jiang and Jia, 2022). Especially against the backdrop of intensified downward pressure on the global economy, the digital economy has defied the trend (Bulturbayevich et al., 2020) and has become a key tool for stabilizing economic growth and achieving economic recovery in various countries (Xue et al., 2022). Digital technology's resilience plays a crucial role in economic recovery (Popkova et al., 2022; Wang et al., 2022), and it also provides important insights for China's strategic measures to achieve a new development pattern of domestic and international "dual circulation" (Bressanelli et al., 2018).

Since the 21st century, the scale of inward foreign direct investment (IFDI) and outward foreign direct investment (OFDI) has been increasing year by year, significantly driving the economic development of countries worldwide (Yao and Wei, 2007; Mehic, Silajdzic, and Babic-Hodovic, 2013; Nwaogu and Ryan, 2015; Rehman, 2016; Hayat, 2018; Aust, Morais, and Pinto, 2020). IFDI and OFDI, as important forms of international economic links, have far-reaching impacts on the economic development of various countries (Fu and Lin, 2021). For a long time, China, as one of the main

destinations for many countries' foreign direct investment, has attracted a large amount of IFDI investment in manufacturing, services, and high-tech fields. IFDI has brought advanced technology, management experience, and capital, driving the growth and industrial upgrading of the Chinese economy. Meanwhile, with the rapid rise of the Chinese economy, Chinese enterprises have also actively expanded outward investment, involving manufacturing, energy, infrastructure, finance, and other sectors, not only promoting the internationalization of Chinese enterprises but also strengthening China's influence globally.

The coordinated development of China's IFDI and OFDI is crucial to achieve the dual circulation of domestic and international markets, serving as a key foundation for China to construct a comprehensive open pattern and undergo a "second transformation". It helps to address the internal and external imbalances of the Chinese economy, enabling China to better adapt to the new economic normalcy (Huang and Li, 2021). The significance of the two-way coordination between IFDI and OFDI is reflected in various aspects such as promoting economic structural optimization, facilitating bilateral technological exchange, expanding global markets, and driving deep integration of industrial chains.

At the national level, China's two-way FDI has preliminarily formed a trend of coordinated development. However, in the shoes of different regions, the coordination extent is different. These differences are directly related to the industrial structure, degree of openness, and capital elements of each region, and are also closely related to the level of local digital economic development (Zhang and Wang, 2022). The digital economy refers to a series of economic activities that utilize digitized information as a key production factor, modern internet as an important carrier, and information technology as an effective means. The idealized digital economy strives to achieve "zero-cost" and impacts economic operation through pathways by improving total factor productivity, optimizing industrial structure, promoting technological innovation, and reducing transaction costs (Chi and Shi, 2022). The emergence of the digital economy has created numerous new commercial opportunities, not only promoting the growth of cross-border service trade but also becoming an important consideration for international investment location choices (Tao and Zhang, 2022).

The Beijing-Tianjin-Hebei urban agglomeration, as an important regional economic cluster in China, is currently at a crucial period of vigorous development in the digital economy and optimization and upgrading of industrial structure. This region boasts abundant resources, developed economy, high level of technological innovation, and urbanization. However, it also faces challenges such as unbalanced urban development and sluggish regional economy (Ding, 2020). As an economic circle centered on China's capital, the Beijing-Tianjin-Hebei region not only bears the important task of China's economic development but also attracts keen attention from international investors. Therefore, in-depth research on the coordinated development of the digital economy, industrial structure, and two-way FDI is of great significance for comprehensively understanding the economic development pattern of the Beijing-Tianjin-Hebei region and promoting economic transformation and upgrading.

Furthermore, the digital economy's significant impact on industrial restructuring, quality development, and innovation (Zhang and Zhai, 2023; Zhao et al., 2020; Han et al., 2019) is widely acknowledged. Given China's proactive high-level opening-up policy and the pursuit of high-quality coordinated development through both attracting inward and promoting outward investment, it's clear that studying solely the unidirectional effects of IFDI and OFDI is insufficient. Instead, there's a need to explore the interactive effects between IFDI and OFDI, as well as the digital economy's role in this bidirectional coordination.

This paper calculates the two-way FDI coupling degree in various cities within the Beijing-Tianjin-Hebei region and examines the interactive relationship between the digital economy and bidirectional FDI coordination. This paper also analyzes the role of industrial structure in this process. Through

literature review, data analysis, and empirical research, the paper elucidates the direct effects of the digital economy on bidirectional FDI coordination and its industrial and spatial spillover effects.

2. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

The concept of the digital economy was first proposed by Bowman (1996). It refers to the emerging economic form that utilizes digital technology, and information and communication technology (ICT) to drive economic development and growth. It encompasses digitized processes of production, distribution, exchange, and consumption, including but not limited to e-commerce, digital payments, big data analytics, and artificial intelligence. The rise of the digital economy not only disrupts traditional industries but also creates a series of new business models and opportunities (Lu, 2018). Nowadays, the concept of the digital economy has gained worldwide recognition, and countries have seized the opportunities it offers, actively competing for market share.

The flourishing digital economy is closely intertwined with the coordinated development of two-way FDI (Fan et al., 2022). It provides fresh impetus and direction for international investment, enhancing its attractiveness and efficiency through efficient information dissemination, digitalized production methods, and innovation-driven characteristics. This emerging economic form fosters interaction in international investment, playing a crucial role in promoting investment balance and optimization in the global economy (Lu and Fang, 2022). The innovation and efficient production methods brought about by the digital economy positively impact the development of bidirectional FDI, strengthening the level of coordinated development (Chai and Li, 2023). In short, digital economy promotes balanced and stable growth in international investment, profoundly shaping the current global investment landscape and providing strong support for further integration and development of international investment. Therefore, this paper mainly validates the impact of the digital economy on bidirectional FDI coordination from three aspects: direct effects, transmission effects, and spatial spillover effects, and proposes research hypotheses.

2.1. Direct Effects of the Digital Economy on the two-way FDI Coordination

The digital economy presents a significant advantage in attracting foreign investment. Not only does it directly drive local economic growth, but it also enhances the country’s international competitiveness (Yao and Xiong, 2023), thereby attracting more investment. Digital economy becomes an important consideration for foreign investors when choosing investment locations, as evident from the perspective of attracting Inward Foreign Direct Investment (IFDI). Regarding Outward Foreign Direct Investment (OFDI), the digital economy similarly plays a crucial role (Yang and Fu, 2024), facilitating regions in achieving high-quality development, enhancing overall productivity, and promoting innovation capabilities. Therefore, these results would enhance the region's international competitiveness and consequently elevate its OFDI capabilities and levels (Peng et al., 2023). In summary, the cost advantage of the digital economy mainly lies in efficiency improvement, process optimization, reduced labor input, accelerated information dissemination, and innovation. Based on these cost advantages, the digital economy can drive businesses to engage in international operations more effectively. Consequently, this paper proposes the first hypothesis:

Hypothesis H1: The digital economy has a significant positive impact on the coordinated development of the two-way FDI.

2.2. Industrial Transmission Effects of the Digital Economy on the Two-way FDI Coordination

The rise of the digital economy has brought about opportunities for renewal and transformation in traditional industries (Zuo et al., 2020). Through the application of digital technology, not only can efficiency be improved and processes optimized in some traditional industries, but also a batch of

new business areas can be explored and developed. According to existing literature, digital transformation can drive industrial structures towards higher value-added and more innovative directions (Xu and Zhou, 2021). Moreover, the digital economy itself has shaped a series of emerging industries involving technologies such as artificial intelligence, big data, and cloud computing, which may become the vanguard of industrial structural upgrades. However, the rise of the digital economy may also pose challenges to certain traditional industries, especially those struggling to adapt to digital trends, which may have adverse effects on certain industries in the short term (Xiao and Zhou, 2021). For example, during the process of digitalization, some traditional industries may find it difficult to adapt rapidly due to limitations in technological infrastructure, investment, or talent.

Therefore, the digital economy may not directly promote the structural upgrade of these industries, and its development may exacerbate resource imbalances. Some regions can easily get an access to digital technology, talent, and investment, while others may face disparities, leading to industrial structural upgrades in some areas but potentially producing opposite effects in others (Chen et al., 2023)."Nevertheless, it may also compel regions to plan for the development of related industries, thereby driving digital transformation in those industries.

Furthermore, the Beijing-Tianjin-Hebei urban agglomeration has distinct unbalance. Despite being closely connected, the development among cities in the Beijing-Tianjin-Hebei region is noticeably uneven. Beijing, as the capital and political center of China, boasts higher economic strength and development level, whereas the development level of cities within Hebei Province is relatively lower (Wang and Zhang, 2022). In order to coordinate the development of the Beijing-Tianjin-Hebei urban agglomeration, the central government has adopted policies and strategies for the integrated development of the capital economic city cluster. In addition to promoting the strategy of integrated development of the Beijing-Tianjin-Hebei region, the government has also established new areas such as Xiong'an New Area to regulate and balance the development disparities among these cities, aiming to promote economic synergy, optimize resource allocation, and reduce regional development gaps (Fang, 2014). While the government employs regional integration measures to mitigate this imbalance, the "siphoning effect" of large cities in attracting talent overwhelms the government's intention to achieve a talent outflow effect centered on the capital.

In conclusion, the transformation brought about by the digital economy may promote the coordination of bidirectional FDI, but it may also be constrained by the market demand for new technologies and services, as well as hindered by the influence of the international competitive environment on the level of bidirectional FDI coordination. Based on the above analysis, this paper proposes the second hypothesis:

Hypothesis H2: The industrial structure has a moderating effect on the impact of the digital economy on bidirectional FDI coordination, and the direction of this moderating effect remains to be studied.

2.3. The Spatial Spillover Effects of the Digital Economy on the two-way FDI Coordination

From the spatial perspective of economic development, the economic growth of a region is influenced by three main factors: the Multiplier Effect (ME) within the region, the Spillover Effect (SE) between regions, and the Feedback Effect (FE) between regions (Round, 1985). The Multiplier Effect within a region refers to the output growth resulting from the interaction among different sectors within the region. The Spillover Effect between regions refers to the one-way impact of output growth in one region on the economic development of another region. The Feedback Effect represents the impact of changes in final output in one region on other regions, which then influences the original region itself through economic cycles.

The digital economy, through efficient information transmission, effectively reduces the costs associated with the distance in time and space, enhancing the connectivity of economic activities

between regions. This phenomenon, as mentioned by Zhao et al. (2020), highlights the spatial spillover effect of the digital economy.

The development of the digital economy drives the expansion of industrial linkages and value chains (Song, 2024). Surrounding cities may become complementary links to the central city in the industrial chain due to the development of industries related to the digital economy, enabling nearby areas to play a more important role in two-way FDI coordination. Additionally, the development of the digital economy often promotes cooperation and interaction between regions (Tian and Zhang, 2024). Surrounding cities may establish cooperative mechanisms (Zhang and Shi, 2023), collectively promote policies related to the digital economy, thereby influencing bidirectional FDI coordination, and building cooperative advantages within and outside the region (Lu et al., 2021). Moreover, the expansion of the digital economy may also lead to closer business and market connections. Adjacent cities and regions may gain more business opportunities and markets due to their proximity to digital economic centers, attracting more two-way FDI inflows. Based on the above analysis, this paper proposes the third hypothesis:

Hypothesis H3: The digital economy can positively promote the two-way FDI coordination development in neighboring cities through its spatial spillover effects.

3. MODEL CONSTRUCTION AND VARIABLES EXPLANATION

3.1. Model Construction

Since the values of the two-way FDI coupling coefficient calculated in this paper range from 0 to 1, indicating the characteristic of the dependent variable being partioned, a Tobit panel model is constructed in this study to verify the direct effect of the digital economy on bidirectional FDI coordination:

$$D_{it}(IO) = \alpha_0 + \alpha_1 DIG_{it} + \alpha_2 X_{it} + \varepsilon_{it} \quad (1)$$

In equation (1), $D_{it}(IO)$ represents the index of bidirectional FDI coordination, DIG_{it} denotes the level of digital economy development, X_{it} stands for the set of control variables, ε_{it} represents the random disturbance term, and i and t represent cities and years respectively.

In addition to the direct effect, this paper attempts to further investigate the potential industrial transmission effect of the digital economy on the two-way FDI coordination. This paper conducts a mediation analysis with industrial structure as the intermediary variable. The specific steps are as follows: on the basis of the significant direct effect model (1), building regressions of the digital economy on industrial structure and of the digital economy and industrial structure on bidirectional FDI coordination respectively, and the models are equation (2) and (3). The existence of the mediation effect is judged by the significance change of regression coefficients.

$$STRU_{it} = \beta_0 + \beta_1 DIG_{it} + \beta_2 X_{it} + \varepsilon_{it} \quad (2)$$

$$D_{it}(IO) = \gamma_0 + \gamma_1 DIG_{it} + \gamma_2 STRU_{it} + \gamma_3 X_{it} + \varepsilon_{it} \quad (3)$$

Furthermore, this paper constructs a spatial econometric model to examine the potential spatial spillover effects of the digital economy and bidirectional FDI. Given that the Spatial Durbin Model (SDM) can simultaneously consider the spatial correlation of both the dependent and explanatory variables, it is adopted as the fundamental spatial econometric model in this paper. The model is as follows:

$$D_{it}(IO) = \theta_0 + \theta_1 DIG_{it} + \rho_1 WD_{it}(IO) + \rho_2 WDIG_{it} + \theta_3 X_{it} + \mu_{it} + v_{it} + \varepsilon_{it} \quad (4)$$

In equation (4), ρ_1 represents the coefficient of the spatial lag of bidirectional FDI coordination, ρ_2 denotes the coefficient of the spatial lag of the digital economy, ρ_1 and ρ_2 respectively measure the extent and direction of the impact of bidirectional FDI coordination and the digital economy in neighboring cities on the dependent variable. Meanwhile, Wrepresents the spatial weight matrix. In this paper, the regression results of the economic distance matrix are considered as the primary analysis basis. The formula for calculating the economic distance is as follows:

$$W_{ij} = \begin{cases} \frac{1}{|\overline{Y_i} - \overline{Y_j}|}, & i \neq j \\ 0, & i = j \end{cases}$$

$\overline{Y_i}$ and $\overline{Y_j}$ respectively represent the average GDP of cities i and j during the period from 2000 to 2022.

3.2. Variables Explanation

Dependent Variable: the Two-way FDI Coordination Level ($D_{it}(IO)$).

In physics, coupling is used to represent the degree of interaction between two or more systems. This paper adopts a coupling model derived from physics to measure the level of the two-way FDI coordination. The coupling model is as follows:

$$C_{it}(IO) = \frac{IFDI_{it} \cdot OFDI_{it}}{(\alpha IFDI_{it} + \beta OFDI_{it})^{\gamma}} \quad (5)$$

In equation (5), $C_{it}(IO)$ represents the bidirectional FDI coupling coefficient, indicating the level of the two-way FDI coordination. A larger value of $C_{it}(IO)$ indicates a higher coupling degree between IFDI and OFDI, indicating a stronger interaction and mutual influence between them. i and t denote cities and years respectively, while $IFDI_{it}$ and $OFDI_{it}$ represent the IFDI and OFDI flows in city i during year t. α and β denote the undetermined weights for IFDI and OFDI. Given the national emphasis on both "attracting inward investment" and "going global", the values of α and β are equally set to 0.5. The adjustment coefficient γ follows the setting standards proposed by Chinese scholar Huang Lingyun (2018), with γ set to 2.

However, according to the definition of coupling in physics, coupling only reflects the degree of interaction between subsystems, but may neglect the actual development levels of the subsystems. Thus, it is possible to observe a relatively high coupling degree between IFDI and OFDI, while their actual respective development levels are not very high. Therefore, this paper follows the approach proposed by Chinese scholars Zhang Jifeng (2022) and Tu Niansong (2023), introducing a coordinated development index:

$$D_{it}(IO) = (C \cdot T)^{1/2} \quad (6)$$

In equation (6), $D_{it}(IO)$ is defined as the coupling coordination degree of bidirectional FDI, C is the coupling degree calculated in equation (5), where T is the comprehensive investment index, denoted as $T = \frac{(IFDI+OFDI)}{2}$. Combining equations (5) and (6), we can calculate the formula for the coupling coordination degree of bidirectional FDI as follows:

$$D_{it}(IO) = \left[\frac{IFDI_{it} \cdot OFDI_{it}}{(IFDI_{it} + OFDI_{it})}\right]^{1/2} \quad (7)$$

Therefore, $D_{it}(IO)$ is the dependent variable defined in this paper: the level of the two-way FDI coordination, which ranges from [0, 1]. Referring to the classification criteria of Zou Zhiming (2021) and Zhang Jifeng (2023), $D_{it}(IO)$ is considered to have a low coordination level if it is less than 0.4 ($D_{it}(IO) \epsilon$ [0, 0.4)), a moderate coordination level if it is at the range from 0.4 to 0.6($D_{it}(IO) \epsilon$ [0.4-

0.6]), and a good or higher coordination level if it exceeds 0.6 ($D_{it}(IO) \epsilon$ (0.6, 1]). In short, the larger the index of the two-way FDI coordination level, the more significant its role.

It needs to be emphasized that in this paper, the IFDI and OFDI data in equation (7) are not simply IFDI and OFDI data from the original data source. Based on the principles of data rationality, representativeness, and accessibility, and referring to the research of Xu Jing et al. (2021), a bidirectional FDI evaluation index system is constructed from the dimensions of scale and effect. The purpose is to more accurately reflect the level of bidirectional FDI. Table 1 presents the bidirectional FDI evaluation index system.

Table 1. The Two-way FDI Evaluation Index System

Primary Indicators	Secondary Indicators	Tertiary Indicators	Weights
IFDI	Scale	IFDI Flow	0.518
		Per Capita IFDI Flow	0.363
	Effect	Share of IFDI Flow in GDP (IFDI/GDP)	0.119
OFDI	Scale	OFDI Flow	0.425
		Per Capita OFDI Flow	0.366
	Effect	Share of OFDI Flow in GDP (OFDI/GDP)	0.209
Note: The weights are calculated using Stata 18.0.			

Combining the two-way FDI evaluation index system (Table 1) and the formula (equation 7) for calculating the two-way FDI coordination level, the final result of the bidirectional FDI coordination level in the Beijing-Tianjin-Hebei region is calculated in Table 2.

Table 2. Measurement Results of the Coordinated Level of Two-Way FDI in the Beijing-Tianjin-Hebei Region

	BJ	TJ	TS	SJZ	QHD	HD	XT	BD	ZJK	CD	CZ	LF	HS
2000	0.418	0.007	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.009	0.000	0.000	0.000
2001	0.319	0.013	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2002	0.257	0.022	0.002	0.003	0.004	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.003
2003	0.200	0.037	0.006	0.011	0.017	0.004	0.008	0.008	0.006	0.005	0.007	0.008	0.011
2004	0.148	0.062	0.021	0.037	0.049	0.014	0.021	0.022	0.017	0.016	0.021	0.022	0.041
2005	0.123	0.061	0.052	0.088	0.115	0.033	0.053	0.059	0.040	0.033	0.047	0.060	0.068
2006	0.085	0.071	0.045	0.060	0.081	0.024	0.039	0.050	0.032	0.024	0.037	0.048	0.045
2007	0.134	0.115	0.047	0.057	0.072	0.030	0.037	0.052	0.035	0.024	0.036	0.049	0.046
2008	0.224	0.111	0.048	0.053	0.069	0.026	0.034	0.051	0.024	0.024	0.034	0.043	0.042
2009	0.216	0.172	0.073	0.108	0.120	0.047	0.063	0.104	0.039	0.031	0.068	0.098	0.091
2010	0.268	0.210	0.109	0.125	0.155	0.072	0.093	0.144	0.048	0.056	0.089	0.140	0.125
2011	0.318	0.222	0.102	0.122	0.136	0.072	0.082	0.127	0.045	0.037	0.083	0.124	0.124
2012	0.367	0.278	0.115	0.143	0.153	0.079	0.084	0.130	0.053	0.037	0.093	0.133	0.137
2013	0.502	0.348	0.155	0.166	0.182	0.093	0.107	0.148	0.064	0.053	0.110	0.162	0.163
2014	0.589	0.608	0.196	0.179	0.206	0.108	0.126	0.147	0.071	0.084	0.118	0.153	0.167
2015	0.729	0.497	0.185	0.143	0.200	0.105	0.103	0.122	0.075	0.071	0.112	0.139	0.140
2016	0.761	0.773	0.261	0.241	0.299	0.163	0.170	0.186	0.120	0.120	0.170	0.211	0.192
2017	0.676	0.445	0.203	0.185	0.256	0.124	0.151	0.176	0.089	0.080	0.151	0.144	0.178
2018	0.633	0.439	0.239	0.113	0.183	0.163	0.137	0.221	0.112	0.107	0.121	0.144	0.147
2019	0.655	0.474	0.241	0.123	0.190	0.185	0.142	0.232	0.169	0.090	0.128	0.155	0.154
2020	0.591	0.350	0.099	0.122	0.186	0.121	0.142	0.223	0.169	0.087	0.128	0.149	0.154
2021	0.621	0.404	0.219	0.272	0.270	0.177	0.106	0.193	0.118	0.073	0.176	0.203	0.185
2022	0.604	0.454	0.248	0.318	0.213	0.139	0.037	0.095	0.040	0.013	0.139	0.153	0.152

Note: The results are calculated using Stata 18.0., BJ refers to Beijing City, TJ refers to Tianjin City, TS refers to Tangshan City, SJZ refers to Shijiangzhuang City, QHD refers to Qinghuangdao City, HD refers to Handan City, XT refers to Xingtai City, BD refers to Baoding City, ZJK refers to Zhangjiakou City, CD refers to Chengde City, CZ refers to Cangzhou, LF refers to Langfang, HS refers to Hengshui.

The core explanatory variable: Digital Economy (DIG_{it}). This study follows the approach of Chinese scholar Zhao Tao (2020), using internet penetration rate, internet-related employment, internet-related output, mobile internet users, and inclusive development of digital finance as second-level indicators. Specifically, indicators such as internet users per hundred people, the number of professionals in computer services and software, per capita telecommunications revenue, mobile phone users per hundred people, and China's Digital Inclusive Finance Index are used as third-level indicators to construct the Composite Development Index of the Digital Economy. Each indicator is standardized based on the range, and then the entropy method is applied to obtain the Digital Economy Development Level Index for each city and year. Table 3 shows the evaluation indicator system of the Digital Economy Development Level:

Table 3. Evaluation Indicator System of Digital Economy Development Level

Primary Indicators	Secondary Indicators	Tertiary Indicators	Weights
Digital Economy Development Level Comprehensive Index	Internet penetration rate	internet users per hundred people	0.123
	internet-related employment	he number of professionals in computer services and software	0.129
	internet-related output	per capita telecommunications revenue	0.127
	mobile internet users	mobile phone users per hundred people	0.123
	inclusive development of digital finance	China's Digital Inclusive Finance Index	0.499

Note: The weights are calculated using Stata 18.0.

According to the evaluation indicator system of digital economy development level, the digital economy level indices of various cities in the Beijing-Tianjin-Hebei region in different years were calculated using Stata software, as shown in Table 4:

Table 4. The digital economy development level in the Beijing-Tianjin-Hebei region

	BJ	TJ	TS	SJZ	QHD	HD	XT	BD	ZJK	CD	CZ	LF	HS
2000	0.091	0.006	0.170	0.082	0.077	0.051	0.045	0.065	0.073	0.082	0.061	0.090	0.071
2001	0.108	0.000	0.206	0.072	0.074	0.066	0.057	0.064	0.054	0.079	0.079	0.075	0.092
2002	0.120	0.006	0.250	0.089	0.085	0.065	0.061	0.052	0.089	0.059	0.052	0.104	0.083
2003	0.137	0.017	0.226	0.089	0.079	0.126	0.063	0.111	0.098	0.076	0.082	0.094	0.099
2004	0.137	0.030	0.300	0.092	0.080	0.081	0.105	0.123	0.096	0.086	0.113	0.092	0.099
2005	0.164	0.033	0.291	0.115	0.099	0.101	0.086	0.119	0.093	0.107	0.106	0.120	0.112
2006	0.168	0.039	0.326	0.091	0.138	0.093	0.093	0.110	0.093	0.096	0.142	0.123	0.123
2007	0.197	0.043	0.332	0.154	0.118	0.156	0.146	0.142	0.115	0.115	0.164	0.117	0.134
2008	0.196	0.041	0.354	0.101	0.119	0.143	0.169	0.125	0.158	0.174	0.113	0.175	0.120
2009	0.210	0.050	0.355	0.147	0.166	0.141	0.151	0.155	0.121	0.169	0.108	0.148	0.148
2010	0.235	0.059	0.391	0.172	0.167	0.154	0.160	0.153	0.151	0.121	0.131	0.172	0.172
2011	0.229	0.103	0.384	0.200	0.168	0.205	0.166	0.160	0.135	0.169	0.212	0.158	0.142
2012	0.330	0.176	0.482	0.246	0.250	0.239	0.232	0.220	0.165	0.258	0.242	0.245	0.242
2013	0.414	0.236	0.526	0.231	0.254	0.246	0.224	0.271	0.277	0.247	0.215	0.254	0.272
2014	0.434	0.278	0.700	0.395	0.369	0.386	0.382	0.396	0.386	0.400	0.337	0.340	0.376
2015	0.485	0.324	0.818	0.392	0.432	0.307	0.446	0.429	0.370	0.339	0.335	0.342	0.340
2016	0.516	0.333	0.772	0.407	0.408	0.414	0.359	0.366	0.355	0.349	0.415	0.366	0.316
2017	0.573	0.378	0.798	0.455	0.426	0.362	0.376	0.401	0.405	0.406	0.449	0.357	0.414
2018	0.630	0.433	0.793	0.419	0.374	0.407	0.425	0.426	0.435	0.437	0.411	0.370	0.410
2019	0.675	0.467	0.878	0.484	0.503	0.432	0.476	0.397	0.434	0.501	0.430	0.432	0.518
2020	0.699	0.494	0.872	0.494	0.503	0.457	0.431	0.544	0.532	0.471	0.500	0.402	0.481
2021	0.746	0.541	0.901	0.490	0.404	0.446	0.534	0.506	0.475	0.392	0.423	0.434	0.492
2022	0.755	0.560	0.938	0.541	0.573	0.424	0.511	0.404	0.426	0.464	0.524	0.500	0.472

Mediating variable: Industrial structure ($STRU_{it}$). This paper measures industrial structure by using the ratio of the output value of the tertiary industry to that of the secondary industry.

Control variables: (1) Economic development level (PGDP), measured by the per capita GDP of each city; (2) Economic openness level (OPEN), measured by the trade dependence ratio of each city, which can be calculated by the total import and export volume; (3) Human capital (Human), measured by the number of higher education institutions in each city; (4) Capital stock (K), measured by the fixed asset investment of each city; (5) Technological innovation (Tec), represented by the amount of financial expenditure on scientific activities in each city; (6) Government support (Gov), represented by the total financial expenditure of each city; (7) Financial development (Fina), measured by the year-end loan balance of each city. To reduce the fluctuation range between variables, logarithmic transformation is applied to all control variables in this paper.

3.3. Data Source

To ensure respect for the originality of the data, this paper provides a description of the data sources used. The China Inclusive Finance Index is sourced from the "Peking University Inclusive Finance Index (2011-2022)". The data for measuring the coordination of two-way FDI is obtained from the "China City Statistical Yearbook" and the "China Outward Investment Bulletin", while data for other variables of cities are sourced from the "China City Statistical Yearbook," "Beijing Statistical Yearbook," "Tianjin Statistical Yearbook," "Hebei Statistical Yearbook," as well as the statistical bulletins on the national economy and social development of prefecture-level cities. The descriptive statistics of each variable are shown in Table 5.

Table 5. Variables Description

	Variables	Mean	Standard Error	Min	Max
Dependent Variable	$D_{it}(IO)$	0.1309	0.1418886	0.0001039	0.7725183
Core Independent Variable	DIG_{it}	0.2733	0.1916	0.0001	0.9380534
Mediating Variable	$STRU_{it}$	0.8513	0.1797	0	1
Control Variable	lnPGDP	10.317	0.8657	8.497875	12.64834
Control Variable	lnOPEN	8.1940	1.7649	4.555332	12.69059
Control Variable	lnHuman	2.2836	1.0857	0	4.836282
Control Variable	lnK	0.4925	0.1725	0.1824588	0.8518423
Control Variable	lnGov	0.1327	0.0567	0.0433266	0.3378256
Control Variable	lnTec	0.0018	0.00261	-0.0000276	0.0127818
Control Variable	lnFina	0.7361	0.2813	0.2583551	2.057018

Note: The data sources were compiled by the authors and computed using Stata 18.0.

4. EMPIRICAL ANALYSIS

4.1. Analysis of Direct Effect

This paper employs the random panel Tobit model for regression. The results indicate that the likelihood ratio test passes the significance test at the 1% level, suggesting that the random effects panel Tobit model outperforms the mixed model. Regression results are shown in Table 6. In columns (1) and (2), the coefficient of the core explanatory variable, digital economy, is significantly positive at the 1% level, indicating that the digital economy can promote the coordinated development of two-way FDI, validating hypothesis H1.In addition, after incorporating the control variables, the coefficient of PGDP is significantly positive at the 1% level, indicating that the higher the economic development level of a city, the higher its coordinated level of two-way FDI. And the coefficient of Gov is significant at the 5% level, suggesting that government support can significantly promote the coordinated development of two-way FDI in various cities in the Beijing-Tianjin-Hebei region. The substantial government expenditure enhances urban infrastructure construction, fosters a favorable investment environment, and effectively promotes the coordinated development of two-way FDI.

However, the coefficients of capital stock (K) and financial development (Fina) are significantly negative at the 1% and 5% levels, respectively, contradicting the results presented in some existing literature (Zhang Jifeng and Wang Hongrui, 2022). The possible reason may indicate that the Beijing-Tianjin-Hebei region relies more on regional and domestic capital, leading to a reduced dependence on two-way FDI from external countries. This may suggest that the region is inclined to use internal resources or domestic investment to meet its funding needs, resulting in a lower level of coordination for external two-way FDI. In other words, if the capital stock within the cities is relatively abundant, there may be a greater reliance on local capital for investment. With better local financial development, local residents are more likely to trust local financial products and thus prefer local financing, leading to a decrease in the reliance on two-way FDI.

Table 6. Regression Results of Direct Effects and Transmission Effects

	(1)	(2)	(3)	(4)
	$D_{it}(IO)$	$D_{it}(IO)$	$STRU_{it}$	$D_{it}(IO)$
Variables	Direct Effect		Industrial Transmission Effect	
DIG_{it}	0.446***	0.296***	1.610***	0.257***
	(0.0235)	(0.0491)	(0.190)	(0.0517)
$STRU_{it}$				0.0244*
				(0.0135)
lnPGDP		0.0964***	0.255***	0.0893***
		(0.0170)	(0.0656)	(0.0171)
lnOPEN		-0.00114	-0.0779***	0.000355
		(0.00721)	(0.0283)	(0.00710)
lnHuman		0.0141	-0.00550	0.0105
		(0.00997)	(0.0501)	(0.00981)
lnK		-0.120***	-0.775***	-0.0958***
		(0.0181)	(0.0736)	(0.0223)
lnTec		-0.00143	-0.0195	-0.00136
		(0.00934)	(0.0341)	(0.00930)
lnGov		0.0534**	0.458***	0.0421*
		(0.0244)	(0.0925)	(0.0246)
lnFina		-0.0349***	0.0660	-0.0376***
		(0.0128)	(0.0479)	(0.0127)
sigma_u	0.0937***	0.0354***	0.543***	0.0312***
	(0.0188)	(0.00982)	(0.117)	(0.00882)
sigma_e	0.0707***	0.0638***	0.228***	0.0638***
	(0.00296)	(0.00271)	(0.00959)	(0.00270)
Constant	0.00905	-0.929***	-0.880	-0.888***
	(0.0271)	(0.193)	(0.794)	(0.191)
LR chi2	253.96***	23.59***	268.25***	19.91***
N	299	299	299	299

Note: The regression results were computed using Stata 18.0, where *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.2. Analysis of Industrial Transmission Effect

To confirm the industrial transmission effect of the digital economy on bilateral FDI coordination, this study employs a mediation effect model for empirical testing. The specific steps are outlined as follows:

1) Regressing the digital economy on the level of bilateral FDI coordination;

2) Regressing the digital economy on industrial structure;

3) Regressing the digital economy and industrial structure on the level of bilateral FDI coordination.

The results of the mediation model regression are presented in columns (3) and (4) of Table 6. Column (2) has already established the significant promoting effect of the digital economy on bilateral FDI coordination. Column (3) demonstrates the significant promoting effect of the digital economy on industrial structure. Subsequently, the intermediary variable of industrial structure is incorporated into the regression equation to assess the impact of the digital economy on bilateral FDI coordination.

Upon observing the significance of the intermediary variable coefficient and the change in the coefficient value of the digital economy, it is concluded that in column (4), after including the intermediary variable, the coefficient of the intermediary variable of industrial structure is significantly positive. Moreover, the coefficient item of the digital economy development level, the core explanatory variable, decreases compared to column (2). This indicates a partial mediation effect of industrial structure, signifying that part of the impact of the digital economy on bilateral FDI coordination is realized through industrial transmission effect. Thus, Hypothesis H2 of this study is confirmed.

4.3. Analysis of Spatial Spillover Effects

Before conducting spatial econometrics, this study first examines whether there is spatial autocorrelation among the research objects. The study uses Moran's I spatial autocorrelation index to make this determination. Based on the calculation of the two-way FDI coordination using an economic distance matrix, this study finds that the two-way FDI coordination exhibits spatial positive correlation at the 1% significance level. After conducting LM tests and Hausman tests, the study opts to employ the random effects spatial Durbin model (SDM) for analysis. The specific regression results are presented in Table 7.

Table 7. Regression Results of Spatial Panel Model

	SDM		SLM	
Variables	Economic distance	Spatial proximity	Economic distance	Spatial proximity
Rho	0.646***	0.227***	0.642***	0.248***
	(0.0518)	(0.0685)	(0.0539)	(0.0629)
DIG_{it}	0.108**	0.107**	0.176***	0.262***
	(0.0530)	(0.0519)	(0.0358)	(0.0431)
$W*DIG_{it}$	0.165**	0.152*		
	(0.0694)	(0.0807)		
lnPGDP	0.0360*	0.0337**	0.0153	0.0298*
	(0.0213)	(0.0169)	(0.0131)	(0.0160)
lnOPEN	0.0125**	0.0124**	0.0100*	0.0108
	(0.00559)	(0.00596)	(0.00533)	(0.00697)
lnHuman	0.0156*	0.0136**	0.00855	0.00650
	(0.00817)	(0.00657)	(0.00742)	(0.00855)
lnK	-0.250***	-0.190***	-0.212***	-0.246***
	(0.0389)	(0.0480)	(0.0402)	(0.0472)
lnGov	0.128	0.283*	0.189	0.241
	(0.166)	(0.168)	(0.125)	(0.147)
lnTec	-7.444**	21.12***	8.674***	17.53***
	(3.339)	(2.976)	(3.106)	(3.418)
lnFina	0.0178	-0.0975***	-0.0246	-0.0533**
	(0.0270)	(0.0330)	(0.0176)	(0.0212)
lgt_theta	-1.446***	15.21	-0.256	0.0361
	(0.323)	(922.8)	(0.470)	(0.581)
sigma2_e	0.00173***	0.00346***	0.00245***	0.00356***
	(0.000153)	(0.000285)	(0.000221)	(0.000307)
Constant	-0.251	-0.347**	-0.172*	-0.290**
	(0.178)	(0.155)	(0.0983)	(0.118)
Observations	299	299	299	299
R-squared	0.762	0.820	0.785	0.786
Number of id	13	13	13	13

Note: The regression results were computed using Stata 18.0, where *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The estimation results from columns (1) of Table 7 indicate that in the regression based on the economic distance matrix, the coefficient of the spatial lag term for the dependent variable, the two-way FDI coordination level, is significant at the 1% level. This suggests a positive spatial spillover effect of the two-way FDI coordination development in neighboring cities on the two-way FDI coordination development in the central city, implying that the two-way FDI coordination development in the central city can enhance the bilateral FDI coordination level in its neighboring cities. Additionally, the coefficient of the spatial lag term for the core explanatory variable, digital economy, is significant at the 5% level. This indicates a positive spillover effect of the digital economy in neighboring cities on the bilateral FDI coordination development in the central city, suggesting that the digital economy can promote the two-way FDI coordination level in neighboring cities of a given city in Beijing-Tianjin- Hebei region.

To test the robustness of the regression results, this study used a 0-1 matrix of geographic adjacency instead of the economic distance matrix for estimation. The results in column (2) in Table 7 indicate that the direction of the main explanatory variables remains unchanged, although the significance level has slightly decreased, the results are still statistically significant. Furthermore, the study presents the Spatial Lag Model (SLM) with random effects for comparison. The results show that the direction and significance of the main explanatory variables remain unchanged, there are only some changes in the magnitude of the coefficients. This indicates that the Spatial Durbin Model (SDM) used in this study to estimate the promotion of the two-way FDI coordination in neighboring cities through spatial spillover effects of the digital economy is robust.

4.3. Robustness Check

Given that the spatial weight matrix based on economic distance may affect the robustness of the econometric results, this study adopted a 0-1 adjacency matrix and conducted spatial panel regression. As shown in Column (2) of Table 7, apart from some changes in coefficients, there were no significant alterations in the direction and significance of the results. This indicates that the spatial spillover effects exhibit good robustness.

In addition, this study employs a standardized measure of digital economy development, replacing the previous digital economy development level (DIG_{it}), to analyze both the direct and mediation effects. It can be observed from Table 8 that the regression results remain significant, and the conclusions drawn are consistent with those of the baseline regression analysis, but there were slight changes in the coefficients of the respective variables.

Furthermore, the robustness test results of the industrial structure variables in Table 8 are consistent with the baseline regression. However, some variables, such as capital stock (K) and financial development (Fina), are significantly negative at the 1% level, contradicting some previous literature. The possible reason for this discrepancy could be that the Beijing-Tianjin-Hebei region relies more on internal capital or domestic investment, leading to a decrease in dependence on external bilateral FDI inflows. This may imply that the region is more inclined to use regional internal resources or domestic investment to meet its capital needs. If the capital stock within the city is relatively abundant, there may be a greater reliance on local capital for investment. Moreover, with better local financial development, local residents may have more trust in local financial products, thus preferring local financing, which may inhibit the development of bilateral FDI coordination.

Table 8. Robustness Check for Direct and Mediated Effects Regression

	(1)	(2)	(3)	(4)
	$D_{it}(IO)$	$D_{it}(IO)$	$STRU_{it}$	$D_{it}(IO)$
Variables	Direct Effect		Industrial Transmission Effect	
DIG_{it}	0.0855***	0.0566***	0.309***	0.0493***
	(0.00450)	(0.00941)	(0.0365)	(0.00990)
$STRU_{it}$				0.0244*
				(0.0135)
lnPGDP		0.0964***	0.255***	0.0893***
		(0.0170)	(0.0656)	(0.0171)
lnOPEN		-0.00114	-0.0779***	0.000355
		(0.00721)	(0.0283)	(0.00710)
lnHuman		0.0141	-0.00550	0.0105
		(0.00997)	(0.0501)	(0.00981)
lnK		-0.120***	-0.775***	-0.0958***
		(0.0181)	(0.0736)	(0.0223)
lnGov		0.0534**	0.458***	0.0421*
		(0.0244)	(0.0925)	(0.0246)
lnTec		-0.00143	-0.0195	-0.00136
		(0.00934)	(0.0341)	(0.00930)
lnFina		-0.0349***	0.0660	-0.0376***
		(0.0128)	(0.0479)	(0.0127)
sigma_u	0.0937***	0.0354***	0.543***	0.0312***
	(0.0188)	(0.00982)	(0.117)	(0.00882)
sigma_e	0.0707***	0.0638***	0.228***	0.0638***
	(0.00296)	(0.00271)	(0.00959)	(0.00270)
Cons	0.131***	-0.848***	-0.440	-0.817***
	(0.0263)	(0.197)	(0.816)	(0.194)
Obs	299	298	298	298
id	13	13	13	13

Note: The regression results were computed using Stata 18.0, where *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5. CONCLUSION

Through empirical analysis of the digital economy, industrial structural upgrading, and the two-way FDI coordination, this paper draws the following conclusions:

Firstly, the rise of the digital economy has brought significant impacts on the two-way FDI coordination in the Beijing-Tianjin-Hebei region. Under the impetus of the digital economy, the proliferation of digital technologies in the region has enhanced the investment environment, attracting more domestic and foreign enterprises to invest in emerging industries and innovation fields. Digital economy innovation has facilitated the digital transformation of enterprises, strengthened the competitiveness of the industrial structure in the Beijing-Tianjin-Hebei region, and attracted more capital inflows. The digitalization process has also promoted cooperation and exchanges among enterprises inside and outside the region, driving collaboration and win-win situations in investment projects. Overall, the digital economy has injected new momentum into the growth of the two-way

FDI in the Beijing-Tianjin-Hebei region, enhanced the region's position in the global investment market, and promoted economic diversification and innovative development.

Secondly, the vigorous development of the digital economy has prompted significant changes in the industrial structure of the Beijing-Tianjin-Hebei region. Traditional industries have revitalized in the process of digital transformation, utilizing advanced technologies to enhance productivity and quality, and optimizing supply chain management. Meanwhile, emerging industries such as digital technology, the internet, and artificial intelligence have rapidly grown, becoming new drivers of economic growth and promoting diversified and innovation-driven development of the industrial structure. The rapid rise of the digital economy has also led to changes in talent demand, prompting adjustments in the education system and vocational training to meet the technological requirements of new industries. This digitalization impact has also generated a spillover effect within the region, where differences in digitalization levels and industrial structure development among different cities mutually promote each other, forming a trend of coordinated regional economic development. Therefore, the digital economy has brought about a new development pattern and opportunities for the industrial structure of the Beijing-Tianjin-Hebei region, providing new impetus for sustained economic growth and innovation in the region. Additionally, the digital economy will also positively influence the coordinated development of bilateral FDI by promoting industrial structural upgrading.

Thirdly, the rise of the digital economy has promoted the optimization and expansion of the industrial chain within the region, accelerating the vigorous development of emerging industries, thereby driving economic growth in surrounding cities and generating certain spatial spillover effects. The introduction of the two-way FDI not only enhances the industrial level and competitiveness of cities within the region but also creates opportunities for cooperation and win-win outcomes between regions, strengthening resource complementarity and cooperation among cities. These effects drive technological innovation and talent aggregation, promoting the coordinated development of the entire Beijing-Tianjin-Hebei region, making urban development within the region more inclusive and complementary, and further enhancing the overall international competitiveness of the region.

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