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# FDI driving China's green economic transformation: The "bridge" role of the digital economy

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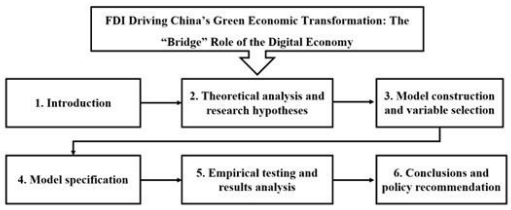
**Graphical abstract**




**Abstract**

China's economy has shifted from high-speed growth to high-quality development, with Foreign Direct Investment (FDI) playing a key role through the transfer of advanced technology and management expertise. This study constructs a three-tier evaluation system to assess high-quality green economic transformation and digital economy development at the provincial level from 2012 to 2023. Using panel entropy methods, 2SLS, and System GMM regression models, the study evaluates the dynamic effects of FDI. An IV-based causal mediation model further explores the digital economy's mediating role. Results show that current-period FDI significantly promotes high-quality green economic transformation, whereas lagged FDI has a negative impact. The digital economy mediates the relationship between FDI and green economic transformation, though this effect is regionally heterogeneous. In the eastern region, both total and indirect effects are negative; in central and western regions, only direct effects are significant. In the northeast, the mediating role of the digital economy is not evident. A threshold model reveals that the digital economy exhibits a single threshold effect—only when digital development surpasses this threshold does FDI's positive impact on transformation significantly increase. This suggests China's digital economy has not yet reached a maturity level sufficient to fully leverage FDI benefits.

**Keywords:** FDI; green high-quality transformation and development; digital economy; IV causal mediation effect model

## 1. Introduction

Since the reform and opening up, Foreign Direct Investment (FDI) has become a crucial means for Chinese enterprises to obtain funds, advanced technology, and access to international markets (Gyamfi *et al.* 2022; Ma *et al.* 2025a). China has continuously expanded its scale of FDI absorption. In the early stages of the reform and opening up, China's actual utilisation of FDI was only US$636 million. By 2002, this figure had reached US$52.743 billion, with China's actual utilisation of foreign capital amount ranking first globally for the first time. The strategy of bringing in foreign capital has played an important role in promoting China's green economic development (Chen, 2022; Zhang *et al.* 2025a; Zeng *et al.* 2025a). Particularly since the introduction of the Belt and Road Initiative in 2013, China's pace in implementing the bringing in strategy has accelerated, and China has gradually become a focal point for transnational investment(Ma *et al.* 2025b; Zeng *et al.* 2025b). Despite the global spread of COVID-19, which cast a shadow over global economic growth, statistics from the *Ministry of Commerce* showed that in 2021, China's actual utilisation of foreign capital reached 1149.36 billion yuan, with a year-on-year increase of 14.9%. This not only achieved double-digit growth but also realised improvements in both the scale and quality of capital introduction. Specifically, the growth in high-tech industries was notable, with a 10.7% increase in foreign capital in high-tech manufacturing and a 19.2% increase in high-tech services (Khurram *et al.* 2024; Zhang *et al.* 2025b). The rapid influx of foreign capital has provided a new impetus for the development of China's high-tech industries. The continuous development of digital information technologies such as the Internet, big data, 5G, and blockchain has become an important driving force for current and future global economic development (Marienko *et al.* 2023; Wu *et al.* 2025a). Against this backdrop, the level of digital economy development has emerged as a key driver for China's high-quality green economic transformation and development (Li *et al.* 2024; Ma *et al.* 2024). Therefore, in the context of a dual-

circulation development pattern, the level of digital economy development plays a significant role in promoting high-quality socio-economic transformation and development in China (Wen *et al.* 2024a, Zhu *et al.* 2023).

China's economy has transitioned from a phase of high-speed growth to one of high-quality green transformation and development (Pan *et al.* 2021). As the economy gradually enters a new stage of quality improvement and efficiency enhancement, regional high-quality green economic transformation and development has become a popular research topic in China (Yang *et al.* 2024; Ma *et al.* 2025c). Scholars have elaborated on the theoretical and practical foundations of China's high-quality green economic transformation and development from various aspects, including the background, driving mechanisms, and supporting elements of high-quality green development (Zeng & Ahmed, 2023; Gong & Zhang, 2023; Ma & Appolloni,2025). Subsequently, researchers have employed various methods to measure the level of high-quality green economic transformation and development in China. These methods include selecting appropriate proxy indicators, such as labour productivity (Ek, 2024; Wen *et al.* 2025b) and total factor productivity (Zhao *et al.* 2022; Zeng *et al.* 2023; Lee & Lee, 2022), as well as establishing comprehensive evaluation indicator systems to measure the level of high-quality green economic transformation and development (Jiang *et al.* 2021; Wang *et al.* 2022).

There is an abundance of research on the impact of FDI on high-quality green economic transformation and development. Studies on the impact of FDI on high-quality green economic transformation and development can be broadly categorised into three areas. First, the impact of FDI on green economic development efficiency. Relevant scholars argued that FDI has both scale and technological effects. Large-scale FDI can bring in production capital, forming economies of scale and promoting capital agglomeration. This, in turn, facilitates the transformation of the host country's industrial structure from labour-intensive to technology-intensive industries (Liu *et al.* 2022; Zhao & Lee, 2024; Wen *et al.* 2025c). Advanced technology significantly enhances total factor productivity (Xiao *et al.* 2022), and these two attributes of FDI promote GDP growth (Liu *et al.* 2001; Khan & Mehboob, 2014; Silajdzic & Mehic, 2016). Second, the impact of FDI on the structure and mode of green economic development (Duan *et al.* 2025). The structure of green economic development is mainly reflected in the distribution of factors, regional development, and industrial structure (Wang *et al.* 2016; Wu & Liu, 2021; Zeng *et al.* 2025c). For example, Luo et al. (2021) found that FDI significantly promotes green high-quality economic transformation and development in China's central and western regions, while the opposite conclusion was drawn for the eastern region, indicating that FDI has significant regional characteristics. Hao et al. (2020) found that the quality of FDI significantly promotes the transformation of China's economic development mode. Third, research on the relationship between FDI and green economic development. The mode of green economic development generally focuses on green development, which requires sustainable development aimed at conserving resources and protecting the environment (Fang *et al.* 2022; Wei *et al.* 2022). Existing studies have explored the impact mechanisms of FDI on economic growth from different perspectives. Some scholars have found that FDI entry is conducive to improving urban environments (Ning *et al.* 2016; Wu *et al.* 2025b), while others argue that FDI is neither conducive to green technological progress nor effective in enhancing green technological efficiency (Yan *et al.* 2025). Therefore, no consensus has been reached on the impact of FDI on green development (Herzer, 2025). Some scholars, from the perspective of spatial heterogeneity, argue that FDI can improve air quality, and that relying on technological innovation to leverage the role of foreign capital in China's green economic development is crucial (Ding *et al.* 2022; Li *et al.* 2025). Other scholars have found that FDI can enhance coordinated economic development (Dong *et al.* 2025), and that with increasing scale, FDI shows an inverted U-shaped relationship with green development efficiency, initially suppressing and then promoting it (Lee *et al.* 2023).

Additionally, scholars have constructed a composite Internet development index in the context of the level of digital economy development era to empirically examine the impact of digital new infrastructure on the inflow of FDI into China and its underlying mechanisms (Xia *et al.* 2024; Abedin *et al.* 2024). They found that the rapid development of the Internet has significantly promoted the inflow of foreign capital (Kolodynskyi *et al.* 2018; Wen *et al.* 2024b; Zeng *et al.* 2025d). Zhu (2025) calculated the level of digital economy development and used data on direct investment in 39 industries in China by US multinational corporations. The study revealed that the digital transformation of host country industries weakens FDI activities in those industries. Cheng et al. (2023) empirically examined from a spatial perspective and found that digital new infrastructure significantly promotes high-quality economic transformation and development in both local and other regions, with significant spillover effects. Iqbal et al. (2023) investigated the impact of FDI on the digital economy development in countries along the Belt and Road and its mechanisms of action. They found that Chinese FDI significantly promotes the level of digital economy development in Belt and Road countries.

In summary, it is evident that scholars have conducted extensive research on the relationship between FDI, the level of digital economy development, and high-quality economic transformation and development. Under the tide of the digital economy era, on one hand, the digital economy enhances the technological synergy of FDI, accelerates the digital transformation of industries, and improves the efficiency of green development; on the other hand, due to the differences in regional digital foundations and development thresholds, the FDI-driven model has become differentiated. The digital economy, leveraging the characteristics such as technology spillover effects, optimized resource allocation, and reduced transaction costs, reshapes the connection between

foreign investment and high-quality development (Zeng *et al.* 2025). However, most studies have focused on the singular impact of FDI or the digital economy on high-quality economic transformation and development, with limited attention to the important mediating role of the level of digital economy development in the promotion of China's high-quality economic transformation and development by FDI. Based on this, this paper used data from 31 provinces (municipalities and autonomous regions) in China from 2011 to 2023 as samples. Two-Stage Least Squares (2SLS), System Generalised Method of Moments (GMM), and Instrumental Variable (IV) causal mediation effect models were employed to address endogeneity and robustness issues. The study empirically investigated the impact of FDI on China's high-quality economic transformation and development, as well as the mediating effect of the level of digital economy development in this process, analysing its causal mechanisms (Zeng *et al.* 2024a; Liu *et al.* 2025). Finally, a panel threshold model was used to explore the threshold role of the digital economy. This was done to provide new ideas and explanations for China to stabilise the scale of FDI, improve the quality of foreign capital utilisation, and expand opening up to the outside world. It also aimed to enrich the theoretical research on the digital economy (Tong *et al.* 2024). Therefore, the main contributions of this paper are as follows: First, it attempts to integrate the digital economy, FDI, and regional high-quality economic transformation and development into a single analytical framework at the theoretical level. It systematically elaborates on the mediating mechanisms and impact effects of the digital economy in the promotion of high-quality economic transformation and development by FDI, which is a valuable addition to existing research on the impact of FDI on high-quality economic transformation and development. Second, using the digital economy as a mediating variable and employing the IV causal mediation effect model, this paper addresses the endogeneity issues present in current mediation effect models, thereby enhancing the reliability of the conclusions. Third, by utilising the panel threshold model to analyse the mediating pathways of the digital economy, this paper provides theoretical support and empirical evidence for China's utilisation of foreign capital and promotion of high-quality economic transformation and development. It also offers new insights for the formulation of relevant policies (Tong *et al.* 2025).

## 2. Theoretical analysis and research hypotheses

China's economy has entered a critical phase of transitioning from high-speed growth to high-quality transformation and development. Gradually shifting towards a stage of quality improvement and efficiency enhancement, the economy has prompted regional high-quality economic transformation and development to emerge as a popular research area. Scholars have elaborated on the theoretical foundations of high-quality economic transformation and development from various aspects, including the background, driving mechanisms, practical orientations, and supporting elements of this developmental shift (Ji *et al.* 2023; Ma & Zhu, 2022; Zeng, 2024). Subsequently, researchers have employed diverse methods to measure the level of high-quality economic transformation and development in China. These methods include: (i) using proxy indicators to measure the level of high-quality economic transformation and development, such as labour productivity as a proxy for the quality of economic growth (Jajri & Ismail, 2010), and total factor productivity as a proxy for economic growth quality (Danquah *et al.* 2014; Dettori *et al.* 2012; Lu *et al.* 2023); and (ii) establishing comprehensive evaluation indicator systems to measure the level of high-quality economic transformation and development (Hu *et al.* 2020; Ye, 2019).

(1) Analysis of the direct pathways through which FDI affects high-quality economic transformation and development

Firstly, the impact of FDI on green economic development efficiency. FDI has both scale and technological effects. The inflow of FDI increases the production capital elements in the host country, thereby expanding the overall economic scale and forming economies of scale that promote capital agglomeration. The inflow of FDI can bring advanced production factors such as production technology and management experience to the host country, thereby improving productivity and labour standards. On one hand, this prompts the host country's industrial structure to upgrade from labour-intensive to technology-intensive industries (Hu *et al.* 2022; Zeng *et al.* 2024b; Li *et al.* 2020). On the other hand, FDI generates technological spillover effects, compelling local firms to imitate and learn from the advanced experiences of foreign enterprises, thereby improving management efficiency and labour productivity, and significantly enhancing total factor productivity (Tan *et al.* 2023). Therefore, FDI inflows significantly promote high-quality economic transformation and growth (Liu *et al.* 2001; Khan & Mehboob, 2014; Silajdzic & Mehic, 2016; Zeng & Lu, 2022).

Secondly, the impact of FDI inflows on the structure and mode of green economic development in the host country. The structure of green economic development mainly includes aspects such as the distribution of factors, regional development, and industrial structure transformation (Liao *et al.* 2021; Wang & Luo, 2020). Since manufacturing industries often have easier access to raw materials and markets, and offer substantial profits, more capital tends to flow into manufacturing firms. These firms expand their production scale and increase their demand for labour, leading to a shift of surplus rural labour towards the manufacturing sector. This change alters the urban-rural dual structure, increases the income level of workers, and improves the consumption structure of residents. Thus, FDI inflows increase the host country's employment level, change the economic dual structure, and optimise the host country's green economic development structure. High-quality FDI also encourages the transformation of local low-end manufacturing industries into high-end manufacturing, and eventually into producer services, thereby optimising the industrial structure and improving domestic capital

flows (Yu & Li, 2020), which in turn promotes high-quality economic transformation and development in the host country.

Thirdly, the promotion of green high-quality economic transformation and development by FDI. The introduction of FDI provides sufficient employment opportunities for the labour force in related industries. A well-established labour training mechanism can enhance workers' employment skills, accelerate the matching efficiency of labour, and shorten job search time, thereby reducing the uncertainty of employment and the unemployment rate (Nguyễn & Phan, 2023). Additionally, the "appropriation effect" of FDI can compel local firms to innovate technologically and adjust management efficiency, thereby enhancing their competitiveness and withstanding fluctuations caused by policy adjustments, market risks, and technological changes, thus strengthening the stability of economic growth. The mode of green economic development generally focuses on green development, which requires sustainable development aimed at conserving resources and protecting the environment (Kasztelan, 2017; Sarkar, 2013). FDI inflows improve the economic risks of local firms and generate linkage effects through capital injection, bringing foreign and local firms closer together. The technological spillover effects of FDI can provide a knowledge base for innovation in local firms, increasing the success rate of technological innovation and thereby promoting regional innovation and development (Lew & Liu, 2016; Shen *et al.* 2024). FDI entry is also conducive to improving urban environments. From a spatial heterogeneity perspective, FDI can improve air quality and reduce environmental pollution (Cheng *et al.* 2018; Lu & Zeng, 2023). Under the dual-circulation strategy of domestic and international markets, leveraging foreign capital to promote China's green economic development through technological innovation is crucial (Zhang k *et al.* 2025). FDI can enhance coordinated green economic development (Qi & Zhang, 2024; Mengchan *et al.* 2025), and as the scale of investment expands, FDI exhibits an inverted U-shaped relationship with green development efficiency, initially suppressing and then promoting it (Zou & Zhang, 2022).

Based on the above analysis, the following hypothesis is proposed:

H1: FDI promotes high-quality economic transformation and development by improving green economic development efficiency and enhancing the structure and mode of green economic development.

(2) Analysis of the indirect pathways through which FDI affects high-quality economic transformation and development in China: the mediating effect of the digital economy

In the context of the digital economy era, the construction and popularisation of information networks have become important channels for China to continuously attract foreign investment (Zhou & Wang, 2014). Although the role of FDI in resource allocation has been widely acknowledged, clarifying how foreign direct investment promotes resource allocation and enhances high-quality economic transformation and development from the perspective of digital economy development still holds significant marginal value (Chen & Xing, 2025). The revolution in information technologies such as the Internet, big data computing, and artificial intelligence has driven the emergence and popularisation of the digital economy. Particularly in the context of the pandemic, these technologies have provided new support and unlimited potential for global economic growth(Wang & Ma, 2024). Countries around the world have been actively engaged in digital construction and have sought international cooperation to continuously improve the level of digital economy development (Wang C *et al.* 2024). Meanwhile, digital economy infrastructure and financial investment have increasingly generated synergistic effects.

Overall, the impact of FDI on high-quality economic transformation and development in China is reflected through the following channels:

The Positive Mechanism through which FDI Promotes the Level of Digital Economy. First, FDI brings advanced technology, which enhances the technological level of host country regions and thereby boosts the development level of the digital economy and promotes high-quality economic transformation and development (Wu *et al.* 2024). According to the theory of comparative advantage, a country transfers its relatively disadvantaged industries that have a comparative advantage in the host country (Wang Z *et al.* 2025). Thus, FDI introduces industries with a comparative advantage into the host country, facilitating industrial upgrading and optimising resource allocation. The inflow of FDI creates a technological gradient between technologically advanced and technologically lagging countries, providing a potential difference for international technology transfer (Yang & Min, 2025; Wang Z *et al.* 2024). The inflow of FDI brings advanced foreign technology and experience, enhancing the host country's technological innovation level. These advanced experiences inevitably promote the improvement of digital technology levels in areas such as blockchain, artificial intelligence, and e-commerce in China (Ilmi, 2017). When FDI introduces advanced digital technology, local digital industry capital in China is further deepened, the total factor productivity (TFP) of the digital technology industry is further updated, and innovation effects are significantly enhanced (Shen *et al.* 2025). This increases the diffusion direction of local technological spillovers, greatly improving local social welfare levels. In some cases, China's digital technology in certain industries even leads international digital technology development, significantly promoting high-quality economic transformation and development (Li *et al.* 2018).

Second, FDI brings advanced technology and other factors that promote the development of the digital economy, thereby reducing corporate operating costs and enhancing high-quality economic transformation and development (Chen *et al.* 2023). The inflow of FDI greatly promotes the development of network information technology, enhancing corporate digital transformation and industrial

digitalisation levels. The development of the digital economy reduces the costs of information collection and collaboration between upstream and downstream enterprises (Sturgeon, 2021; Zou *et al.* 2024), accelerating the integration of factors and knowledge flow between foreign and local firms. The primary purpose of foreign investment in China is to establish large-scale inter-industry cooperation embedded in the production and social networks of host country enterprises. The development of digital technologies such as artificial intelligence and big data means that multinational corporations do not overly rely on low-end labour factors (Das, 2019), thereby compelling an increase in labour quality and production efficiency. Therefore, the rise in factor costs does not directly negatively impact the inflow of FDI (Anyanwu, 2012). The rapid development of digital technology aligns with the purpose of foreign investment in China. Thus, digital platforms enhance the efficiency with which foreign capital finds local partners (Wang *et al.* 2012). According to FDI location theory and new economic geography theory, foreign investment tends to flow to regions with lower trade costs. Therefore, for enterprises, the development of digital technology has economies of scale, which can offset the negative effects of rising factor costs, such as increases in intermediate goods prices. This reduces the variable cost component in total corporate operating costs, lowers corporate operating costs, ensures stable corporate operations, and improves local welfare levels (Baumers *et al.* 2016).

The feedback mechanism of digital economy development in promoting FDI Inflows:

First, the inflow of FDI has spurred the development of digital information technologies such as artificial intelligence and big data in regions. The advancement of digital technologies has, in turn, propelled the growth of the digital finance sector. Digital financial services have broken down spatial and temporal barriers, providing financial support for corporate technological renewal and fostering the development of host country financial markets. A relatively advanced financial market system has not only enhanced the accessibility of financing for both foreign and local firms but has also improved the efficiency and reduced the costs associated with FDI inflows. This is particularly evident in technology-intensive manufacturing and modern service industries. Consequently, the improved financial conditions have optimised the industrial layout in China's central and western regions and in small- and medium-sized cities. The reduction in costs has stimulated the willingness of foreign investors to enter these markets (Yin & Su, 2024). This has also enhanced the capacity of local firms to absorb advanced foreign technology and capital (Deng & Lu, 2022). Given that FDI inflows are significantly motivated by market and knowledge-seeking objectives (Zámborský, 2023), the development of the digital economy and the Internet has significantly promoted FDI inflows (Sinha & Sengupta, 2022).

Second, while the inflow of FDI has promoted the development of the digital economy, it has also exhibited a threshold effect. Digital elements have led the production and manufacturing processes, providing new impetus for manufacturing development. The enhancement of digital technologies has increased the dynamic regulatory efficiency in corporate manufacturing processes, improving both manufacturing and management standards. Firms can now utilise technological channels such as big data and 5G to obtain real-time consumer demands and adjust production scales according to market conditions. This has enabled a transition from mass, standardised production to personalised, intelligent manufacturing. The development of the digital economy has accelerated the rapid growth of intelligent and service-oriented manufacturing in local firms. FDI has increasingly concentrated in high-tech areas, optimising the structure of FDI and facilitating the climb of the manufacturing value chain (Pedro, 2023).

However, for foreign small- and medium-sized enterprises (SMEs), the development of the digital economy has reduced the need for FDI location costs. These firms can now directly enter target international markets and conduct international business activities through digital platforms such as eBay and Amazon, without the need to establish companies in the host country (Eden, 2016). Digital platforms have demonstrated the advantages of low costs and high operational efficiency (Foster & Graham, 2017). Many SMEs can achieve internationalisation through digital trading platforms without active investment. Moreover, highly digitalised multinational corporations tend to invest less overseas compared to traditional multinational corporations (Casella & Formenti, 2019). This has diminished the demand of large digital multinational corporations for traditional markets and tangible resources (Mai, 2020). Therefore, the development of the digital economy exhibits a certain threshold effect. During the rapid development phase of the digital economy, FDI is conducive to its growth. However, as digital technologies advance and digital transformation progresses, multinational operations become more convenient. Firms can even achieve international transactions without engaging in FDI, thereby suppressing the FDI activities of multinational corporations (Fisch & Fleury, 2020).

Based on the above analysis, the following hypotheses are proposed:

H2: FDI inflows promote the development of the digital economy and enhance local welfare levels through positive feedback mechanisms, thereby fostering high-quality economic transformation and development.

H3: When the level of digital economy development is high, it will reduce FDI inflows. The development of the digital economy exhibits a threshold effect in the relationship between FDI and high-quality economic transformation and development.

(3) Indicator system construction for digital economy and high-quality economic transformation and development

Indicator system construction. Digital economy indicator system. Currently, there are two primary approaches to

measuring the level of digital economy development: First, the use of proxy variables for the digital economy, such as the digital economy efficiency coefficient, value-added input in the digital economy industry, the Digital China Index Report's digital economy index, and the global digital economy index released by the Alibaba Research Institute and KPMG (Song *et al.* 2023). Second, the construction of a comprehensive indicator evaluation system for digital economy development (Bruno *et al.* 2023; Han *et al.* 2023). Generally, focusing solely on one or a few aspects of digital economy development indicators may overlook valuable information regarding the overall development of the digital economy (Herman & Oliver, 2023).

Therefore, this study adopts the second approach. Considering the availability and reliability of provincial-level data in China, as well as the new trends and characteristics of digital economy development, a three-tier indicator system for the digital economy is constructed to comprehensively assess the level of digital economy development at the provincial level in China. The secondary indicators are defined as three dimensions: digital infrastructure environment, digital industry employment environment, and digital industry development environment. These secondary indicators are further refined into 10 tertiary indicators. The specific indicators are shown in **Table 1**.

**Table 1.** Measurement and evaluation system for digital economy and high-quality economic transformation and development

| Tier 1 Indicators | Tier 2 Indicators | Tier 3 Indicators | Indicator attributes |
|---|---|---|---|
| Level of development of digital economy | Digital infrastructure environment | Length of fiber optic cable lines (kilometers) | Positive |
| | | Length of long-distance fiber optic cable lines (10,000 km) | Positive |
| | | Internet broadband access ports (10,000) | Positive |
| | | Number of web pages (10,000) | Positive |
| | Digital industry employment environment | Internet broadband access users (10,000) | Positive |
| | | Employed persons in information, software and technology services (10,000 persons) | Positive |
| | | Employed persons in urban units (10,000 persons) | Positive |
| | Digital industry development environment | Total amount of telecommunication business (billion yuan) | Positive |
| | | Internet penetration rate (%) | Positive |
| | | Peking University Digital Inclusive Finance Index | Positive |

*Note: Data were sourced and collated by the author, covering the period from 2011 to 2023.*

**Table 2.** Composition of indicators in the green high-quality economic transformation and development assessment system

| Tier 1 Indicators | Tier 2 Indicators | Tier 3 Indicators | Indicator attributes |
|---|---|---|---|
| Economic Quality Transformation Development Index | Industrial base | Advanced industrial structure[1] | Positive |
| | | Economic contribution of trade volume (total import and export/GDP) | Positive |
| | | Total profit of industrial enterprises above scale[2] | Positive |
| | Factor drivers | Number of internet interfaces | Positive |
| | | Total factor productivity | Positive |
| | Green economic development | General budget revenue of local finance (billion yuan) | Positive |
| | | Gross regional product (billion yuan) | Positive |
| | | Sulfur dioxide removal rate | Positive |
| | | Electricity consumption | Negative |
| | Resident life | Average wage of employed persons in urban units (yuan) | Positive |
| | | Consumer price index (previous year = 100) | Negative |
| | | Disposable income per capita of all residents (yuan) | Positive |
| | | Number of medical and health institutions (number) | Positive |

*Note: The data are collated from the authors, and the data interval of the indicators is 2011-2023.*

*[1]The industry is structured as the ratio of the value added of the tertiary sector to the secondary sector.*

*[2]Total factor productivity is calculated using output as real GDP; input factors are the number of employees, fixed assets (perpetual inventory method), and calculation method: reference to Battese and Coelli's (1995) model, calculated using the latest SFA method.*

Indicator system construction for high-quality economic transformation and development. High-quality economic transformation and development is a multidimensional concept, inherently rich and multifaceted. Similar to the measurement of the digital economy, there are primarily two approaches to measuring high-quality economic transformation and development in China: First, constructing a comprehensive indicator system; and second, using proxy variables such as per capita GDP, total factor productivity (TFP), and the digital inclusive finance index (DIE). Considering the characteristics of high-quality economic transformation and development, this study constructs a three-tier indicator system to comprehensively assess the level of green economic development at the provincial level in China. The secondary indicators are defined across four dimensions: industrial foundation, factor-driven growth, green economic development, and living standards of residents. These

secondary indicators are further refined into 12 tertiary indicators. The specific indicators are shown in **Table 2**.

Measurement of the level of high-quality transformation and development of the economy and the development of the digital economy panel entropy method. This paper uses panel information entropy to construct the evaluation model of digital economy and high-quality economic transformation and development, and the specific calculation steps are as follows: firstly, select the indicators: let there be m cities and n indicators, then qij is the jth indicator of city i (i= 1,2,...,m; j =1,2,...,n); in order to solve the problem of the different units causing the In order to solve the problem of different units, the indicators are standardized, and the absolute values of the indicators are converted into relative values, so that qij = |qij|. The higher the value of the positive indicator the better, the smaller the value of the negative indicator the better, using the following steps to standardize the indicators:

(1) Positive standardization: $q'_{\mathrm{ij}} = \dfrac{q_{\mathrm{ij}} - \min\left\{q_{1i},\ldots,q_{mj}\right\}}{\max\left\{q_{1i},\ldots,q_{mj}\right\} - \min\left\{q_{1i},\ldots,q_{mj}\right\}} + 1$

(2) Negative standardization: $q'_{\mathrm{ij}} = \dfrac{\max\left\{q_{1i},\ldots,q_{mj}\right\} - q_{\mathrm{ij}}}{\max\left\{q_{1i},\ldots,q_{mj}\right\} - \min\left\{q_{1i},\ldots,q_{mj}\right\}} + 1$

(3) Determine the weight of the ith municipality for the jth indicator: let $p_{\mathrm{ij}} = \dfrac{q'_{\mathrm{ij}}}{\sum_{i=1}^{m} q'_{\mathrm{ij}}}$;

(4) Calculate the entropy of the jth indicator , $e_{\mathrm{j}} = -k\sum_{i=1}^{m} q_{\mathrm{ij}} \ln\left(p_{\mathrm{ij}}\right), (i = 1,2,\ldots m; j = 1,2,\ldots,n),$

Where k > 0 and k = ln(m), denotes the adjustment factor, ensuring that 0 < ej < 1;

(5) Calculate the information utility value of the jth indicator: dj= 1-ej (j= 1,2,...,n). The greater the information utility value dj, the greater the importance of the indicator;

(6) Calculate the weight of the jth indicator: $w_{\mathrm{i}} = \dfrac{d_{\mathrm{j}}}{\sum_{j=1}^{n} d_{\mathrm{j}}} \left(j = 1,2,\ldots,n\right)$

(7) Calculate the composite score for the ith city: $s_{\mathrm{j}} = \sum_{i=1}^{m} w_{\mathrm{j}} p_{\mathrm{ij}}, (i = 1,2,\ldots m; j = 1,2,\ldots,n)$ .

Refinement of the TOPSIS method. While the entropy method can address some of the shortcomings of subjective weighting methods, its evaluation results are highly dependent on data accuracy and indicator selection. To mitigate this issue, the Euclidean distance was introduced to measure the relative distance between each indicator scheme and the optimal (or worst) solution, based on the entropy method for weighting. This approach generates a comprehensive evaluation index and re-ranks the results for comparison. By doing so, it fully utilises data information, reduces data loss, and minimises the impact of sample size limitations and reference sequence selection on the results (Yin *et al.* 2020). This method thus provides a more accurate representation of the trends and regional differences in digital economy development and high-quality economic transformation. The specific steps are as follows:

(1) Calculate the weighted normalization matrix for each indicator. $R = \left(r_{\mathrm{ij}}\right)_{m\times n}, r_{\mathrm{ij}} = w_{\mathrm{j}} x_{\mathrm{ij}} (1 \le i \le m, 1 \le j \le n)$ .

(2) Formulate the optimal solution $S_j^+$ and the worst solution $S_j^+$ . $S_j^+ = \max\left(r_{\mathrm{ij}}\right), S_j^- = \min\left(r_{\mathrm{ij}}\right)$ , where 1 ≤ I ≤ m, 1 ≤ j ≤ n.

(3) Calculate the Euclidean distance between each solution and the most solution $sep_i^+ = \sqrt{\sum_{j=1}^{n}\left(S_j^+ - r_{ij}\right)^2}$ , $sep_i^- = \sqrt{\sum_{j=1}^{n}\left(S_j^- - r_{ij}\right)^2}$ .

(4) Calculate the comprehensive evaluation index of each solution. $C_i = \dfrac{sep_i^-}{sep_i^- + sep_i^+}$ , $C_i \in [0,1]$.

## 3. Model construction and variable selection

### *3.1. Variable selection and data description*

Dependent variable: High-quality economic transformation and development (Higd), measured using the indicator system presented in **Table 1**.

### *3.2. Core independent variable*

Foreign direct investment (lnFDI). Represented by the natural logarithm of the stock of foreign direct investment in each province (autonomous region, municipality directly under the central government). Data were sourced from the annual *Statistical Yearbooks of each province*. Investment data include both flow and stock data. This study selected stock data, as the stock of investment can measure the cumulative amount of foreign investment up to a specific point in time, better reflecting the long-term effects of investment and avoiding the issue of net outflows (negative values). The stock of FDI was used to represent foreign direct investment. Given that FDI is typically measured in flow terms, the perpetual inventory method was employed to estimate the stock of FDI, with the calculation formula as follows:

$$\mathrm{FDI}_{it} = (1-k)\mathrm{FDI}_{it-1} + \mathrm{fdi}_{it} \quad (1)$$

Where t denotes the year; $fdi_{it}$ denotes the flow of foreign investment in each province in year t, and k is the economic depreciation rate of FDI stock, which is taken as 9.6% with reference to Whalley & Xian (2010) and others. The estimation formula of FDI stock in the base period is:

$$\mathrm{FDI}_{i0} = \frac{fdi_{i0}}{p+k} \quad (2)$$

### *3.3. Mediating variables*

To investigate the mediating effects of the digital economy under different measurement indicators, two mediating variables were selected: the digital economy (DigE1) and the level of digital financial development (DigE2). The digital economy was measured using the indicator system presented in **Table 3**. The level of digital financial development was represented by the digitalisation index

from the Peking University Digital Inclusive Finance Index for each province.

**Table 3.** Descriptive statistics of variables

| Properties | Symbol | Description | Mean | Standard deviation | Min | Max | Sample |
|---|---|---|---|---|---|---|---|
| Explained variables | *Higd* | High-quality transformational green development of the economy, calculation of the system of indicators obtained | 279 | 0.908 | 0.101 | 0.462 | 0.979 |
| Explanatory variables | ln*FDI* | OFDI stock by province, in logarithms | 279 | 14.764 | 1.695 | 9.980 | 17.893 |
| Mediating variable | *DigE1* | Level of development of the digital economy, calculation of the indicator system obtained | 279 | 0.92051 | 0.1108 | 0.2417 | 0.995 |
| | *DigE2* | Digital Degree Indicator in the Digital Financial Inclusion Index | 279 | 278.400 | 117.673 | 7.58 | 462.230 |
| Control variable | ln*GDP* | Logarithmic GDP by province | 279 | 9.684 | 1.003 | 6.416 | 11.587 |
| | ln*Pop* | Labor endowment, total labor force population in each province taken in logarithms | 279 | 6.010 | 0.891 | 3.148 | 7.633 |
| | ln*Struct* | Logarithmic value of the ratio of tertiary to secondary value added | 279 | -0.070 | 0.406 | -1.643 | 0.658 |
| | ln*Open* | Logarithmic value of the ratio of each province's total exports and imports to its GDP. | 279 | 0.975 | 0.389 | -1.441 | 1.621 |
| | ln*Hracc* | Human capital aggregation is obtained by taking logarithmic values | 279 | -0.040 | 0.298 | -0.811 | 0.636 |
| | ln*Wage* | Logarithmic value of the average value of wages for the urban population in each provincial area | 279 | 1.778 | 0.320 | 1.143 | 2.814 |
| | ln*Gss* | Logarithmic value of student-teacher ratio in colleges and universities in each province | 279 | 2.860 | 0.067 | 2.634 | 3.061 |

**Table 4.** Impact of FDI on provincial high-quality economic transformation and development (Dependent variable: HigD)

| Variables | 2SLS | | System GMM | | Difference GMM | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *L.HigD* | | | 0.317*** | 0.497*** | 0.281* | 0.379*** |
| | | | (0.105) | (0.114) | (0.166) | (0.128) |
| ln*FDI* | 0.101*** | 0.0265*** | 0.033** | 0.128** | 0.056* | 0.208** |
| | (0.029) | (0.009) | (0.016) | (0.051) | (0.034) | (0.106) |
| *L.*ln*FDI* | | | | -0.101** | | -0.123* |
| | | | | (0.0482) | | (0.072) |
| ln*GDP* | -0.179*** | -0.019* | -0.034*** | -0.012 | -0.030*** | -0.016 |
| | (0.064) | (0.010) | (0.010) | (0.008) | (0.011) | (0.011) |
| ln*Hracc* | -0.104*** | -0.044** | -0.027 | -0.063* | -0.059 | -0.148** |
| | (0.037) | (0.022) | (0.030) | (0.037) | (0.041) | (0.074) |
| ln*Wgae* | -0.088 | 0.066* | -0.050*** | -0.028** | -0.066** | -0.063** |
| | (0.055) | (0.036) | (0.016) | (0.014) | (0.029) | (0.027) |
| ln*Struct* | 0.054* | -0.026* | -0.012 | -0.003 | -0.017 | -0.006 |
| | (0.031) | (0.015) | (0.0172) | (0.016) | (0.022) | (0.015) |
| ln*Open* | -0.012 | -0.016 | -0.109*** | -0.036 | -0.094** | -0.046 |
| | (0.029) | (0.010) | (0.029) | (0.027) | (0.039) | (0.031) |
| ln*LaborP* | 0.051 | -0.019 | 0.003 | -0.015 | -0.015 | -0.015 |
| | (0.044) | (0.022) | (0.019) | (0.011) | (0.015) | (0.017) |
| ln*Gss* | 0.954*** | 0.280*** | 0.079 | 0.038 | 0.099 | 0.051 |
| | (0.251) | (0.048) | (0.049) | (0.041) | (0.070) | (0.058) |
| Constant | -1.794** | -0.477* | 0.421* | 0.247 | - | - |
| | (0.765) | (0.247) | (0.232) | (0.209) | - | - |
| Observations | 279 | 248 | 248 | 248 | 217 | 217 |
| Hansen test | - | - | 0.476 | 0.927 | 0.199 | 0.716 |
| AR (1) test | - | - | 0.089 | 0.060 | 0.049 | 0.081 |
| AR (2) test | - | - | 0.129 | 0.944 | 0.586 | 0.810 |

*Note: Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The values in the rows for the Hansen test, AR(1), and AR(2) represent the p-values of the test results, which are the same for the following tables.*

### *3.4. Other control variables*

To mitigate potential endogeneity issues arising from omitted variables and to accurately reflect other factors influencing high-quality economic transformation and development, the following control variables were included: (1) Provincial GDP (lnGDP), measured by the GDP of each province to indicate the level of green economic development; (2) Total Population (lnPop), measured by the total labour force population of each province to represent the endowment of labour resources; (3) Industrial Structure (lnStruct), measured by the ratio of the value added of the tertiary industry to that of the secondary industry to indicate the development of industrial structure in each province; (4) Trade Openness (lnOpen), measured by the ratio of the total import and export volume to the provincial GDP to gauge the level of openness in each province; (5) Human Capital Agglomeration (Hracc). Human capital agglomeration has been identified in prior research as a threshold variable that does not directly affect FDI but influences its development, thus meeting the criteria for an instrumental variable. Following the method of Fu & Gabriel (2012), the degree of human capital agglomeration in each province was measured using location entropy, with the formula as follows:

$$HA_i = \frac{HC_i}{P_i} \Big/ \frac{THC}{P} \tag{3}$$

In the above formula, HCi represents the level of human capital in region I, THC represents the total level of human capital nationwide; Pi represents the total population in region I, and P represents the total national population. The level of human capital was indicated by the number of people with education at the college level or above. (6) Labour Costs (lnWage). Represented by the natural logarithm of the average annual wage of urban employees in each province (municipality). (7) Faculty-Student Ratio in Higher Education Institutions (lnGss). Measured by the ratio of the number of teachers to the number of students in higher education institutions in each province. Except for the human capital agglomeration variable, all other control variables were transformed using natural logarithms. The descriptive statistics of the variables are shown in **Table 3**.

## 4. Model specification

Basic regression model. Based on the analysis above, the following econometric model was constructed to examine the impact of FDI on high-quality economic transformation and development in China. Typically, outward foreign direct investment (OFDI) exhibits a time-lag characteristic, meaning that there is a temporal interval between the initiation of investment activities and their effectiveness. Additionally, considering that high-quality economic transformation and development in the previous period may also influence the current period, the model incorporates the lagged effects by introducing one-period lagged data for both high-quality economic transformation and development and FDI to establish a dynamic panel model, specified as follows:

$$\begin{aligned} Higd_{it} = {} & \alpha_0 + \alpha_1 Higd_{it-1} + \alpha_2 \ln FDI_{it} + \alpha_3 \ln FDI_{it-1} \\ & + \alpha_4 \ln GDP_{it} + \alpha_5 \ln Pop_{it} + \alpha_6 \ln Struct_{it} \\ & + \alpha_7 \ln Open_{it} + \alpha_8 \ln Hracc_{it} + \alpha_9 \ln Wage_{it} \\ & + \alpha_{10} \ln Gss_{it} + \varepsilon_{it} \end{aligned} \tag{4}$$

Where i represents the provinces (municipalities directly under the central government, autonomous regions) in China, and t denotes the year. $Higd_{it}$ and $Higd_{it\text{-}1}$ represent the levels of high-quality economic transformation and development in year t and t-1, respectively. ln$FDI_{it}$ and ln$FDI_{it\text{-}1}$ represent the stock of foreign direct investment in year t and t-1, respectively. $lnGDP_{it}$ represents the GDP of each province in year t. ln$Pop_{it}$ represents the total labour force population of each province in year t. ln$Struct_{it}$ represents the industrial structure of each province. ln$Open_{it}$ represents the level of openness of each province in year t. ln$Gss_{it}$ represents the ratio of the number of teachers to the number of students in higher education institutions in each province in year t. $\varepsilon_{ijt}$ is the random error term.

Mediation effect model. To further investigate the mediating role of the digital economy in the impact of FDI on high-quality economic transformation and development in China, this study employed the Instrumental Variable (IV) causal mediation effect model for mediation analysis. Under the classical analytical framework of traditional mediation effect testing, it is typically assumed that the treatment variable and the mediating variable have an exogenous relationship. The effect of the explanatory variable on the dependent variable through the mediating variable is explored using a stepwise regression coefficient method. However, if FDI and the digital economy are endogenously related, the model may face endogeneity issues arising from reverse causality, thereby significantly undermining the reliability of the regression results. Based on the analysis above, it is reasonable to assume that foreign direct investment introduces new technologies, which may promote the development of China's digital economy, leading to the agglomeration of human capital and technology, and thereby fostering high-quality economic transformation and development. Therefore, to address the endogeneity issue, an IV causal mediation analysis method was established to examine the mediating effect of the digital economy in the impact of FDI on high-quality economic transformation and development, thereby enhancing the credibility and reliability of the regression results. Building on Equation (6) and incorporating the aforementioned mechanism analysis, the following IV causal mediation effect model was constructed:

$$M_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 Z_{it} + \sum \beta_3 \ln X_{it} + \varepsilon_{it} \tag{5}$$

$$Y_{it} = \gamma_0 + \gamma_1 T_{it} + \gamma_2 M_{it} + \gamma_3 Z_{it} + \sum \gamma_4 \ln X_{it} + \xi_{it} \tag{6}$$

Where $M_{it}$ represents the mediating variable, the level of digital economy development in each province; $T_{it}$ is the randomly generated treatment variable; $Z_{it}$ represents foreign direct investment in each province; $X_{it}$ is a set of control variables affecting high-quality economic

transformation and development as in Equation (6); $\xi_{it}$ and $\varepsilon_{ijt}$ is the random error term.

## 5. Empirical testing and results analysis

### *5.1. Basic regression: estimation based on system GMM*

Endogeneity treatment and estimation method selection. On the one hand, considering the potential endogeneity issue that FDI and high-quality economic transformation and development may influence each other, while other control variables are mostly determined by internal factors of each province and do not exhibit significant endogeneity. On the other hand, given that high-quality economic transformation and development and FDI are likely closely related to activities in the previous period, the model incorporates the first-order lagged terms of high-quality economic transformation and development and FDI. This approach can effectively mitigate biases in regression results caused by omitted variables. Since the model involves dynamic short panel data with lagged terms, the system GMM estimation method was employed. In the regression, the first-order lagged terms of high-quality economic transformation and development and FDI were treated as endogenous variables. The system GMM estimation can effectively construct an instrumental variable matrix and use the zero-padding method to treat any beneficial lagged order of endogenous variables as instrumental variables. To address estimation bias and heteroscedasticity in the regression, the two-step method (Two) and robust standard errors (Robust) were used for estimation.

Robustness treatment. To ensure the robustness of the regression results, the difference GMM estimation and instrumental variable (2SLS) regression methods were also employed in the basic regression as robustness checks. The regression results are shown in **Table 4**.

**Table 4** presents the 2SLS regression results using different instrumental variables and controlling for fixed effects in columns (1) and (2). In column (1), following prior research, the total industrial output value of each province from 1993 to 2001 was used as an instrumental variable for OFDI (Yue *et al.* 2022). This was based on two considerations: First, according to the theory of investment development, there is a dynamic correlation between a country's green economic development level and its outward foreign direct investment. Second, the total industrial output value is historical data and does not affect current economic growth quality, making it exogenous. In the 2SLS regression, the F-statistic for the weak instrument variable LM test was 18.501, which is greater than the 10% critical value (16.38). The p-value for the test of underidentification was significant at the 1% level (18.402), indicating that the instrumental variable was valid. In column (2), the one-period lagged value of FDI was used as an instrumental variable. The F-statistic for the weak instrument variable LM test was 810.357, which is greater than the 10% critical value (16.38). The p-value for the test of underidentification was significant at the 1% level (198.516), also indicating that the instrumental variable was valid.

Columns (3)–(4) in **Table 4** show the regression results using system GMM, while columns (5)–(6) present the results using difference GMM. In both the system GMM and difference GMM regressions, the p-values for the Hansen test were greater than 0.1, rejecting the null hypothesis of overidentification of the instrumental variables, which indicates that the instrumental variables were valid. The results of the autocorrelation tests showed that the p-values for AR(1) were significant at the 1% level, while the p-values for AR(2) were greater than the 10% significance level. This indicates that the model residuals exhibited first-order autocorrelation but no second-order autocorrelation, meeting the requirements for using system GMM and difference GMM. After controlling for the endogeneity of the model using fixed-effects OLS, 2SLS instrumental variables, and GMM regression methods, the signs and significance of the coefficients for the core explanatory variables remained largely unchanged, indicating robust regression results. Therefore, the analysis focuses on the regression results using system GMM.

The regression results using 2SLS in column (1) of **Table 4** show that the coefficient for foreign direct investment (lnFDI) is significantly positive, indicating that FDI significantly promotes high-quality economic transformation and development in China. The regression results using system GMM in columns (2)–(3) show that, based on the current-period FDI in column (2), the introduction of the one-period lagged values of provincial high-quality economic transformation and development (L.Highd) in column (2) and FDI (L.lnFDI) in column (3) still results in a significantly positive coefficient for current-period FDI. This indicates that current-period FDI significantly promotes high-quality economic transformation and development in Chinese provinces, thus verifying H1. However, the coefficient for one-period lagged FDI is significantly negative, indicating that previous-period FDI reduces high-quality economic transformation and development in Chinese provinces. Relevant studies suggest that as the level of digital economy development increases, the motivation for FDI inflows gradually shifts towards market-seeking and knowledge-seeking, gradually crowding out resource-seeking FDI and leading to a gradual exit from the Chinese market (Zámborský *et al.* 2023). Therefore, the crowding out of resource-seeking FDI to some extent reduces the level of high-quality economic transformation and development. The withdrawal of FDI has a certain time lag, generally reflected in the previous period. With the development of the digital economy, the motivation for FDI has shifted from "resource seeking" to "market/knowledge seeking". Early low-tech and high-resource-consuming FDI (especially resource-based investment) has gradually withdrawn from the Chinese market. This kind of lagging FDI may come from high-pollution and low-value-added industries. Its withdrawal is accompanied by a contraction in production scale, interruption of technology spillovers, and even the remaining environmental governance costs. Moreover, the "crowding-out effect" of lagging FDI may inhibit local green innovation investment - enterprises that originally relied on foreign capital have fallen into

transformation difficulties due to capital withdrawal, while the newly introduced high-quality FDI has not yet formed a scale, resulting in a short-term decline in the efficiency of the green economy. In terms of coefficients, a 1% increase in current-period FDI enhances the level of high-quality economic transformation and development by 0.128%, while a 1% increase in previous-period FDI suppresses it by 0.101%.

**Table 5.** IV causal mediation effect test for the digital economy (DigE1)

| Stage 1: Regression results for the impact of lnFDI on the digital economy (DigE1) | | | | |
|---|---|---|---|---|
| *DigE1* | Coefficient | P>z | 95% confidence interval | |
| ln*FDI* | 0.041 | 0.047 | 0.001 | 0.082 |
| Stage 2: Regression results on the impact of lnFDI and the digital economy (DigE1) on the high-quality transformational development of the regional economy | | | | |
| *HigD* | Coefficient | P>z | 95% confidence interval | |
| ln*FDI* | 0.020 | 0.006 | 0.006 | 0.033 |
| *DigE1* | 1.732 | 0.002 | 0.651 | 2.812 |
| A test of the mediating effect of digital green economic development | | | | |
| *HigD* | Coefficient (Robust) | P>z | 95% confidence interval | |
| Total effect | 0.091 | 0.001 | 0.036 | 0.147 |
| Direct effect | 0.020 | 0.006 | 0.006 | 0.033 |
| Indirect effect | 0.072 | 0.093 | -0.012 | 0.156 |

**Table 6.** IV causal mediation effect test of the digital economy (DigE2)

| Stage 1: Regression results on the impact of lnFDI on the digital economy (DigE2) | | | | |
|---|---|---|---|---|
| *DigE2* | Coefficient | P>z | 95% confidence interval | |
| ln*FDI* | -86.702 | 0.001 | -137.359 | -36.045 |
| Stage 2: Regression results on the impact of lnFDI and the digital economy (DigE2) on the high-quality transformational development of the regional economy | | | | |
| *HigD* | Coefficient | P>z | 95% confidence interval | |
| ln*FDI* | -0.007 | 0.424 | -0.025 | 0.011 |
| *DigE2* | -0.001 | 0.011 | -0.002 | -0.000 |
| Tests for mediating effects of degree of digital development | | | | |
| *HigD* | Coefficient (Robust) | P>z | 95% confidence interval | |
| Total effect | 0.091 | 0.001 | 0.036 | 0.147 |
| Direct effect | -0.007 | 0.424 | -0.025 | 0.011 |
| Indirect effect | 0.099 | 0.043 | 0.003 | 0.194 |

**Table 7.** Impact of FDI on high-quality economic transformation and development in different provinces

| **Variable** | **Northeast Region** | | **Eastern Region** | | **Western Region** | | **Central Region** | |
|---|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** |
| *L*.ln*HigD* | | 0.027** | | -0.443 | | -0.072 | | 0.612*** |
| | | (0.014) | | (0.502) | | (0.340) | | (0.105) |
| ln*FDI* | -0.033*** | -0.017*** | 0.067** | 0.586** | -0.027 | -0.079 | 0.176*** | 0.275** |
| | (0.006) | (0.005) | (0.026) | (0.288) | (0.020) | (0.143) | (0.052) | (0.111) |
| *L*.ln*FDI* | | 0.042*** | | -0.622* | | 0.075 | | -0.254*** |
| | | (0.008) | | (0.322) | | (0.121) | | (0.078) |
| Control variable | yes | yes | yes | yes | yes | yes | yes | yes |
| Constant | 0.454*** | 0.903*** | -1.605 | - | 1.369*** | 1.080 | -0.110 | 0.333 |
| | (0.077) | (0.097) | (1.192) | - | (0.470) | (2.413) | (0.768) | (0.269) |
| Observations | 24 | 24 | 80 | 80 | 96 | 96 | 48 | 48 |
| Hansen test | - | 1.000 | | 1.000 | | 1.000 | | 1.000 |
| AR (1) test | - | 0.091 | | 0.576 | | 0.488 | | 0.420 |
| AR (2) test | - | 0.631 | | 0.425 | | 0.635 | | 0.235 |

Additionally, the regression results using system GMM show that only key factors influencing FDI, such as human capital agglomeration and regional average wage levels, have a significant inhibitory effect on high-quality economic transformation and development, although their impact is relatively low in terms of coefficients. The effects of other control variables were not significant.

*5.2. Mechanism testing of the mediating effect of the digital economy: based on IV causal mediation analysis*

Traditional mediation effect analysis typically assumes that the treatment variable and the mediating variable have an exogenous relationship. If the treatment variable and the mediating variable are endogenous, the regression results may not be fully reliable. Therefore, we employed the IV

causal mediation analysis method to explore the mediating effect of the digital economy in the relationship between FDI and high-quality economic transformation and development. Similarly, we used the total industrial output value of each province as an instrumental variable to address endogeneity issues in the causal identification process. The regression analysis also employed robust standard errors to ensure the reliability of the results. **Table 5** presents the IV causal regression results with the level of digital economy development as the mediating variable, while **Table 6** shows the IV causal regression results with the digital development index as the mediating variable.

The results of the first-stage regression in **Table 5** show that foreign direct investment (lnFDI) significantly affects digital economy development (DigE1) at the 5% significance level. The results of the second-stage regression indicate that both foreign direct investment and digital economy development significantly influence high-quality regional economic transformation and development (HigD) at the 1% significance level. This confirms that the digital economy plays a partial mediating role in the impact of foreign direct investment on high-quality regional economic transformation and development. It demonstrates that FDI can promote high-quality economic transformation and development through the transmission mechanism of the digital economy, which is consistent with the theoretical analysis presented earlier. Thus, H2 is verified. The effect decomposition results show that the total effect of foreign direct investment on high-quality economic transformation and development is 0.091, of which the direct effect is only 0.020 and the indirect effect is 0.072. The regression results indicate that the increase in the digital economy brought about by foreign direct investment accounts for 78.61% of the total effect.

The results of the first-stage regression in **Table 6** show that foreign direct investment (lnFDI) significantly affects the level of digital economy development (DigE2) at the 1% significance level. The results of the second-stage regression indicate that the digital economy significantly influences the level of high-quality economic transformation and development at the 5% significance level. These results also confirm that FDI can promote high-quality economic transformation and development through the transmission mechanism of the digital economy. The effect decomposition results show that the total effect of FDI on high-quality economic transformation and development is primarily transmitted through indirect effects.

### *5.3. FDI and high-quality economic transformation and development in different economic regions*

Given the varying geographical locations, socio-economic development, natural resource endowments, and market sizes across Chinese provinces, the characteristics of foreign direct investment (FDI) in each province also differ. According to data from the Ministry of Commerce, in 2020, China's actual use of foreign capital reached approximately 1 trillion yuan, with a year-on-year increase of 6.2%. The eastern region saw an 8.9% growth in foreign capital absorption, accounting for 88.4% of the total foreign capital used. Among the major provinces, Jiangsu, Guangdong, Shanghai, Shandong, and Zhejiang experienced growth rates of 5.1%, 6.5%, 6.6%, 20.3%, and 18.3%, respectively. Some provinces in the northeastern and central-western regions also showed significant growth, with Liaoning, Hunan, and Hebei recording increases of 13.7%, 28.2%, and 35.5%, respectively. These figures reveal significant differences in FDI inflows across different regions in China. Therefore, it is worth exploring whether FDI in different economic regions has heterogeneous effects on high-quality economic transformation and development in China. Based on the classification methods in the *Several Opinions of the CPC Central Committee and the State Council on Promoting the Rise of the Central Region*, the *Implementation Opinions on Several Policy Measures for the Western Development Issued by the State Council*, and the report of the 16th National Congress of the Communist Party of China, this study divided China's economic regions into four areas: the eastern, central, western, and northeastern regions[1]. The impact of FDI on high-quality economic transformation and development in different economic regions was examined using 2SLS and system GMM estimation methods with fixed effects controlled. The regression results are shown in **Table 7**.

The regression results in columns (1) and (2) of **Table 7** for the northeastern region indicate that current-period FDI has a significantly negative impact on high-quality economic transformation and development, while lagged FDI has a significantly positive impact. Columns (3) and (4) for the eastern region show that current-period FDI has a significantly positive impact, while lagged FDI has a significantly negative impact. Columns (5) and (6) for the western region reveal that neither current-period nor lagged FDI has a significant impact on high-quality economic transformation and development. Columns (7) and (8) for the central region demonstrate that current-period FDI has a significantly positive impact, while lagged FDI has a significantly negative impact

The regression results in **Table 7** show that the impact of FDI on high-quality economic transformation and development varies significantly across different economic regions, exhibiting a typical east strong, west weak pattern, which is consistent with most existing studies (Li *et al.* 2022; Cao *et al.* 2022). Since the reform and opening up, the eastern and central regions have been relatively economically developed. On the one hand, the east relies on policies such as economic special zones and free trade zones to attract high-tech and high-value-added foreign direct investment (FDI), and is dominated by "service industry + high-tech industry", collaborating with the

[1] The East includes: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. The central part includes: Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan. West includes: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. Northeast includes: Liaoning, Jilin and Heilongjiang.

technological experience of FDI, and having a developed digital economy (such as a high internet penetration rate), which amplifies the efficiency of FDI; on the other hand, the policies in the central and western regions focus on resource development, and FDI is mostly concentrated in low-tech industries. The industrial digitalization lags behind, the digital economy has not reached the threshold, and the absorption capacity is weak, thus resulting in insufficient effect. However, lagged FDI has significantly reduced high-quality economic transformation and development in these regions. This may be because, compared to FDI in developed countries, FDI in China has relatively low technological content and can only drive short-term economic transformation and growth. Over time, the ability of FDI to drive regional economic growth diminishes, and it may lead to other negative impacts, such as environmental degradation, thereby increasing the costs of environmental governance in the eastern and central regions (Bokpin, 2017). Therefore, lagged FDI has a negative impact on high-quality economic transformation and development in the central and eastern regions. In the northeastern region, current-period FDI reduces the level of economic transformation and development, while lagged FDI significantly inhibits it. This is in contrast to the situation in the eastern and central regions. The northeastern region receives relatively little FDI, which does not fully reflect the long-term effects of outward FDI. Thus, lagged outward FDI does not significantly impact high-quality economic transformation and development, and its effect is relatively small (with coefficients of -0.0168 and 0.0417). Similarly, the lack of significant impact of FDI in the western region can be attributed to the relatively low volume of FDI, which does not fully capture the long-term effects of outward FDI.

### *5.4. Heterogeneity of the mediating effect of the digital economy in FDI and high-quality economic transformation and development across different economic regions*

Building on the analysis of the impact of FDI on high-quality economic transformation and development in different economic regions, we further employed the IV causal mediation effect model to examine the heterogeneous mediating effects of the digital economy in the relationship between FDI and high-quality economic transformation and development across different economic regions. The regression results are presented in **Table 8**.

The regression results for the northeastern region in **Table 8** show that neither the level of digital economy development nor the degree of digitalisation, as mediating variables, had significant total, direct, or indirect effects. This indicates that the digital economy in the northeastern region did not play a mediating role in the relationship between FDI and high-quality economic transformation and development. This may be due to the underdevelopment of digital enterprises or industries in the region. There is an imbalance between the types of FDI in the Northeast region and the industrial structure. The FDI in the Northeast is mainly of the resource-seeking type, with a low correlation with the digital economy. Moreover, there are few local digital enterprises and the industrial digital transformation is slow. Due to the fact that FDI has not flowed into the digital economy sector and the local absorption capacity is insufficient, it is impossible to integrate the technological spillovers of FDI through digital technology, resulting in insignificant total effects, direct effects, and indirect effects. Since FDI in the northeastern region is primarily resource-seeking, the mediating effect of the digital economy did not emerge (Hwang, 2023).

For the eastern region, the mediating effect of the digital economy was evident in both the total and indirect effects. However, the level of digital economy development in the eastern region exhibited a negative effect, as indicated by the coefficients. FDI in the eastern region is mainly knowledge and technology-intensive, and the competition in the digital technology field is intense. And the high degree of digitization enables multinational enterprises to enter the market through e-commerce platforms, digital services, etc., reducing the need for physical investment and creating the "digital platform replacing FDI" effect (Zhang G *et al.* 2025). This may be accompanied by negative externalities of knowledge spillovers, which could inhibit the positive effect of FDI on green transformation. However, with the advancement of digital technology, illegal activities such as knowledge and technology theft have dampened the positive impact of FDI on high-quality economic transformation and development (Hwang, 2023).

In the western region, the mediating effect of the digital economy was only observed in the direct effect, with the total effect being insignificant. In comparison, the scale of FDI in the western region is small and it is mainly concentrated in resource-based industries. The digital infrastructure is weak. FDI only affects green development through direct capital injection or traditional technology transfer, thus lacking the "bridging" amplification effect of the digital economy. Moreover, the direct effect was relatively low, as shown by the coefficients. This may be due to the limited inflow of FDI and the relatively low level of digitalisation in the region.

For the central region, only the direct effect was observed, with the total effect remaining insignificant. The direct effect was also relatively low. This is because the industrial structure in the central region mainly features the coexistence of traditional manufacturing and some high-tech industries. The digital economy has initially developed but has not yet achieved a scale effect. The technology spillover of FDI is still mainly in the traditional mode. The intermediary role of the digital economy is only manifested in a few local areas. Therefore, the impact of the digital economy in the central and western regions is only reflected in the direct effect, with a relatively low effect magnitude as indicated by the coefficients.

### *5.5. Threshold effect of the digital economy in the relationship between FDI and high-quality economic transformation and development*

In the theoretical analysis, we discussed how FDI inflows can promote the development of the local digital economy. However, when the digital economy reaches a certain level

of development, the role of digital platforms may inhibit the FDI activities of multinational enterprises. Therefore, the digital economy exhibits a threshold effect. To examine the threshold impact of the digital economy in the relationship between FDI and high-quality economic transformation and development, this study used the digital economy as the threshold variable and first conducted a threshold value test, with the results presented in **Table 9**.

**Table 8.** IV causal mediation effect test of the digital economy across different economic regions (DigE2)

| Area | Effect decomposition | Digital economy development | | Level of digitization | |
|---|---|---|---|---|---|
| | | Coefficient(Robust) | P>z | Coefficient(Robust) | P>z |
| | (1) | (2) | (3) | (4) | (5) |
| Northeast region | Total effect | 1.042 | 0.855 | 1.042 | 0.855 |
| | Direct effect | 0.003 | 0.975 | 0.003 | 0.975 |
| | indirect effect | 1.039 | 0.866 | 1.039 | 0.866 |
| Eastern region | Total effect | -0.817 | 0.005 | -0.817 | 0.005 |
| | Direct effect | 0.060 | 0.438 | -0.647 | 0.656 |
| | indirect effect | -0.876 | 0.030 | -0.170 | 0.926 |
| Western region | Total effect | 0.131 | 0.347 | 0.131 | 0.347 |
| | Direct effect | 0.039 | 0.000 | 0.019 | 0.049 |
| | indirect effect | 0.092 | 0.541 | 0.112 | 0.412 |
| Central region | Total effect | -0.032 | 0.604 | -0.032 | 0.604 |
| | Direct effect | 0.043 | 0.040 | 0.137 | 0.000 |
| | indirect effect | -0.075 | 0.217 | -0.170 | 0.200 |

**Table 9.** Threshold effect test of FDI on high-quality economic transformation and development (Threshold variable: digital economy)

| Threshold type | Level of development of digital economy | | Digitalization index | |
|---|---|---|---|---|
| | F value | P value | F value | P value |
| Single threshold test | 49.86*** | 0.000 | 11.07 | 0.350 |
| Double threshold test | 17.99 | 0.128 | | |

*Note: The p-values and critical values were obtained using the bootstrap method with 500 replications. *** and ** indicate significance at the 1% and 5% levels, respectively.*

**Table 10.** Threshold regression (threshold variable: digital economy)

| Threshold value (*DigE1*) | Coefficient | | Confidence interval | |
|---|---|---|---|---|
| | 0.9353 | | | |
| Other variables | yes | yes | yes | yes |
| explanatory variable (ln*Hig-E*) | 0b._cat#c. Ln*FDI* (*DigE1*≤γ) | 0.029*** | 0.011 | 0.046 |
| | | (0.001) | | |
| | 1._cat#c. Ln*FDI*(*DigE1*＞γ) | 0.031*** | 0.013 | 0.049 |
| | | (0.002) | | |
| Constant | | -0.214 | -0.658 | 0.230 |
| | | (0.225) | | |
| Observations | | 279 | | |
| $R^2$ | | 0.245 | | |

The threshold value test in **Table 9** shows that the level of digital economy development has a significant single threshold value, while the digital index does not exhibit a threshold effect. This may be because the digital index does not comprehensively reflect the level of digital economy development in China. This finding supports the superior use of a constructed index system for measuring digital economy development, as commonly adopted by scholars (Stavytskyy *et al.* 2019). Based on the threshold value test, the following panel threshold model was specified, as shown in Equation (7):

$$lnHigD = \mu_n + \beta_1 \ln FDI_{nt} I\left(DigE_{nt} \le \gamma\right) + \beta_2 \ln FDI_{nt} I(DigE_{nt} \le \gamma) + e_{nt} \quad (7)$$

Where n denotes country, t denotes time, $e_{nt}$ is the residual term; $I(\cdot)$ is the indicative function, when $I(\cdot)=1$ the condition in parentheses holds when otherwise $I(\cdot)=1$. The threshold value divides the samples into low development level of digital economy development (*DigE*≤γ)) and high development level of digital economy development (*DigE* > γ), and the slopes corresponding to different development levels of digital economy in the model are $\beta_1$ and $\beta_2$, respectively. The regression results are shown in **Table 10**. As shown in **Table 10**, when the threshold variable is the level of digital economy development, FDI significantly promotes high-quality economic transformation and development, and a significant threshold effect of the digital economy is observed between the two. Specifically, the threshold value of the digital economy is 0.9353. When the level of digital economy development is below the threshold value of 0.9353, FDI significantly promotes high-quality economic transformation and development. In

terms of coefficients, a 1% increase in FDI below the threshold value promotes high-quality economic transformation and development by 0.0285%. When the level of digital economy development exceeds the threshold value of 0.9353, the impact of FDI on high-quality economic transformation and development remains significant. Above the threshold value, a 1% increase in FDI promotes high-quality economic transformation and development by 0.0310%. The regression results indicate that once the digital economy surpasses the threshold, it enhances the effect of FDI in promoting high-quality economic transformation and development. This suggests that China's current level of digital economy development is not high and is far from reaching a highly developed level. There is no reverse inhibitory effect of the digital economy. Thus, the hypothesis H3 is not fully validated. However, the empirical conclusions of this study are consistent with the actual situation. Therefore, at this stage, improving the level of digital economy development in China is still beneficial for FDI to promote high-quality economic transformation and development.

## 6. Conclusions and policy recommendation

China's economy has transitioned from a phase of high-speed growth to one of green high-quality transformation and development. The impact of FDI on high-quality economic transformation and development has gradually become a popular research area in China. With the rapid development of information technologies such as Internet technology, mobile 5G, big data, and blockchain, research on the digital economy has also attracted increasing attention from domestic scholars. In particular, foreign direct investment has brought advanced technological experience to the development of the digital economy in China, which has to some extent enhanced the level of digital economy development in China. Therefore, this study theoretically elaborated on the pathways through which FDI affects green high-quality economic transformation and development and the mediating effect mechanism of the digital economy. A three-tier indicator evaluation system for the digital economy and green high-quality economic transformation and development was constructed. The panel entropy method was used to measure the levels of digital economy and green high-quality economic transformation and development in Chinese provinces (municipalities directly under the central government, autonomous regions) from 2011 to 2023. The 2SLS, system GMM, and IV mediation effect tests were employed to empirically examine the dynamic impact of FDI on green high-quality economic transformation and development and the mediating effect of the digital economy, overcoming endogeneity and ensuring robustness. The results show that:

First, current-period FDI significantly promotes green high-quality economic transformation and development in Chinese provinces, while lagged FDI reduces it. Relevant studies have shown that as the level of digital economy development increases, the motivation for FDI inflows gradually shifts towards market-seeking and knowledge-seeking, gradually crowding out resource-seeking FDI. Therefore, the crowding out of resource-seeking FDI to some extent reduces the level of green high-quality economic transformation and development. The withdrawal of FDI has a certain time lag, generally reflected in the previous period. In terms of coefficients, a 1% increase in current-period FDI promotes green high-quality economic transformation and development by 0.128%, while a 1% increase in lagged FDI suppresses it by 0.101%.

Second, the IV causal mediation regression results show that FDI significantly affects the level of digital economy development at the 5% level, and both FDI and the digital economy significantly impact green high-quality economic transformation and development at the 1% level. This confirms that the digital economy plays a partial mediating role in the impact of FDI on green high-quality economic transformation and development. The regression results indicate that FDI can promote green high-quality economic transformation and development through the transmission mechanism of the digital economy. The mediation effect decomposition results show that the total effect of FDI in promoting green high-quality economic transformation and development is 0.091, that is, a 1% increase in FDI can enhance green high-quality economic transformation and development by 0.091%. The direct effect is only 0.020, and the indirect effect is 0.072.

Third, the impact of FDI on regional green economic transformation and development varies significantly across different economic regions, showing a typical east strong, west weak pattern. In terms of the mediating effect of the digital economy, neither the total effect, direct effect, nor indirect effect is significant in the northeastern region, whether the digital economy or the level of digitalisation is used as the mediating variable. In the eastern region, a negative total effect and indirect effect are observed. This is because, with the improvement of digital technology levels, illegal activities such as knowledge and technology theft have dampened the positive impact of FDI on green high-quality economic transformation and development. In the western region, the mediating effect of the digital economy is only reflected in the direct effect, with the total effect being insignificant. This may be due to the limited inflow of FDI and the relatively low level of digitalisation in the region. In the central region, only the direct effect is observed, with the total effect remaining insignificant. The direct effect is still relatively low, as indicated by the coefficients. This is because the level of digital development in the central and western regions is relatively low. Relevant studies have shown that FDI in developed regions significantly promotes regional green economic quality growth, while FDI in less developed regions inhibits green economic quality growth.

Fourth, when the threshold variable is the digital economy, FDI significantly promotes green high-quality economic transformation and development, and a significant threshold effect of the level of digital economy development is observed between the two. When the level of digital economy development is below the threshold value of 0.9353, FDI significantly promotes green high-quality economic transformation and development. In

terms of coefficients, a 1% increase in FDI below the threshold value promotes green high-quality economic transformation and development by 0.0285%. When the level of digital economy development exceeds the threshold value of 0.9353, the impact of FDI on green high-quality economic transformation and development remains significant. Above the threshold value, a 1% increase in FDI promotes green high-quality economic transformation and development by 0.0310%. The regression results indicate that once the digital economy surpasses the threshold, it enhances the effect of FDI in promoting green high-quality economic transformation and development. This suggests that China's current level of digital economy development is not high and is far from reaching a highly developed level. There is no reverse inhibitory effect of the digital economy. Therefore, at this stage, introducing green high-quality transformation foreign capital is beneficial for improving the level of digital economy development in China, which in turn enhances the effect of FDI in promoting green high-quality economic transformation and development.

To better optimise the quality of foreign capital introduced into China and enhance the level of green high-quality economic transformation and development, the following policy recommendations are proposed based on the research conclusions of this study:

First, optimise and improve the structure of foreign capital introduced into China, with a focus on advancing information technologies such as the digital economy and digital technologies. The research findings of this study suggest that the digital economy has an effect in promoting the level of high-quality economic transformation and development through FDI. Therefore, in the context of the continuous global development of information technology, screening foreign capital and selecting foreign capital with digital modernisation technologies can not only bring advanced experience to the level of digital economy development in China but also enhance the effect of foreign capital in promoting green high-quality economic transformation and development in China.

Second, optimise the regional differences in foreign capital introduction in China and comprehensively improve the balanced development of high-quality economic transformation across China. Fully utilising China's regional advantages, efforts should be made to advance the level of digital economy development in central and western provinces. The state should provide corresponding policy. In today's rapidly developing global information age, China can enhance the momentum of high-quality economic transformation and development in central and western regions at a lower cost. Offering certain preferential policies to foreign investors in central and western regions will encourage foreign investment in these areas, promote high-quality economic transformation and development in central and western regions, and balance the green economic development gap between central and western regions and the eastern region.

Third, encourage the iteration of domestic information technologies and empower the endogenous driving force of the digital economy. The digital economy not only enhances the effect of FDI in promoting green high-quality economic transformation and development but also reduces corporate operating costs, thereby increasing corporate vitality and regional social welfare. The research findings of this study indicate that although China's digital economy is developing rapidly, it is far from reaching the threshold effect of inhibiting FDI in promoting green high-quality economic transformation and development. Therefore, China should continuously provide supportive policies for domestic enterprises to enhance their passion for innovating digital economy development and support relevant enterprises from an endogenous driving force perspective. This will further develop China's digital economy and ultimately benefit green high-quality economic transformation and development in China.

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