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HOW DOES DIGITAL ECONOMY DEVELOPMENT INFLUENCE FOREIGN DIRECT INVESTMENT INFLOWS?

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Abstract. This study explores the impact of digital economic development (DED) on foreign direct investment (FDI) inflows using panel data from the Yangtze River Delta (YRD) city cluster (2012–2023) and a two-way fixed-effects model. Empirical results demonstrate that DED significantly enhances FDI inflows. These findings remain robust across a series of endogeneity and robustness checks, including instrumental variable (IV) methods, difference-in-differences (DID), dynamic effect models, and propensity score matching-DID (PSM-DID). Mechanism analyses reveal that DED facilitates FDI by driving technological innovation, reducing transaction costs, and expanding consumer markets. Heterogeneity tests indicate that this positive effect is more pronounced in metropolitan areas characterized by robust intellectual property protection, advanced digital infrastructure, and superior economic development. Furthermore, DED exerts the most substantial influence on FDI in the YRD and Beijing–Tianjin–Hebei (BTH) regions. Spatial spillover analyses indicate that while DED stimulates local FDI inflows, it simultaneously diverts investment away from neighboring areas. Ultimately, this paper enriches the theoretical understanding of DED as a crucial determinant in FDI location decisions and offers actionable policy implications for leveraging the digital economy to attract foreign investment and stimulate regional economic growth.

Keywords: digital economic development, foreign direct investment, technological innovation, Yangtze River Delta.

JEL Classification: F21, O33, R11.

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1. Introduction

The digital economy transforms the economic system based on the widespread adoption of digital technology. It not only encompasses a broader scope but also facilitates the creation of new business models and enhances economic efficiency (Böttcher et al., 2024). Specifically, it includes the improvement of digital infrastructure, digital industrialization, and industrial digitalization. Foreign direct investment (FDI) plays a crucial role in economic growth, job creation, export stabilization, and industrial upgrading. However, amid complex geopolitical changes, a "de-Sinicization" trend within global supply chains has emerged. Additionally, rising land and labor costs have squeezed the profit margins of foreign investors. Consequently,

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some low-end manufacturing industries have relocated to Southeast Asia, causing foreign capital utilization in China to decline by 27.1% year-on-year in 2024. Therefore, under these circumstances, a critical question arises: what practical and effective measures can be taken to "stabilize existing foreign investment" and "expand new foreign investment" to achieve stable economic development and high-level opening-up in China? The Yangtze River Delta (YRD) city cluster, a pioneer in China's digital economic development (DED), has seen its DED scale and innovation capabilities become more competitive in attracting FDI. By 2023, the region's DED had exceeded 15 trillion yuan, accounting for over 30% of the national total, while its actual utilization of FDI accounted for more than 40% of the national total. Additionally, the YRD region boasts the largest data center cluster in the country, attracting numerous foreign enterprises to invest in the digital economy sector, such as Amazon AWS's projects in Hangzhou and Nantong, and Siemens' digital transformation factory project in Nanjing. These cases demonstrate the strong appeal of DED to FDI. Therefore, leveraging the role of the DED in promoting FDI, providing an important demonstration for the national "stabilizing foreign investment" efforts, and supporting China's high-quality economic development and high-level opening-up have become a focal point of attention for the Chinese government and various sectors of society. Does DED accelerate FDI inflows to the YRD city cluster? If yes, what are the underlying mechanisms? Furthermore, does this effect vary depending on the external environment (such as intellectual property protection and digital infrastructure) and internal city conditions (such as economic development level and city size)? Although DED has become one of the main pillars of the YRD city cluster and a substantial driver of foreign capital, its specific role in attracting FDI has received limited attention. Therefore, further empirical research is required to address this gap.

The existing literature mainly examines the impact of DED on FDI from a theoretical perspective, categorizing the research into three key aspects. First, the mode through which DED affects FDI. The DED not only changes the quantity and direction of FDI but also reshapes the layout of multinational corporations' branches and governance of global supply chains. As a new production factor, data drives industrial transformation, while digital technologies, resources, and infrastructure boost FDI attraction (Adarov et al., 2022; Ciarli et al., 2021; Casella & Formenti, 2019). Second, DED efficiency influences FDI. DED drives the digital transformation of multinational enterprises by breaking time and space constraints, alleviating information asymmetry, and significantly improving FDI efficiency while reducing investment costs (Peng et al., 2025; Zhan, 2021). Third, the motivation for FDI is influenced by DED. The rapid growth of DED has reduced the traditional reliance on markets and resources, decreasing market- and efficiency-seeking FDI while significantly increasing knowledge- and technology-seeking FDI (Laplume et al., 2016). While these studies offer valuable theoretical frameworks for understanding the influence of DED on FDI, further empirical analyses are required to clarify the involved pathways.

Existing research on the impact of DED on FDI inflows has primarily focused on its direct effects. However, the underlying mechanism has been understudied, and there is no consensus on its direct impact. The generally accepted idea is that DED is a major driver for a country's growth in FDI (Choi, 2010; Desbordes & Wei, 2017; Götz, 2020). These works emphasize that DED brings about efficiency in production, decreases transaction costs, makes the allocation of resources more effective, and promotes innovation capacity, all of which

contribute to making a country more attractive for FDI. Yet, it is also possible that DED can have the opposite effect by limiting FDI (Ko, 2007; Casella & Formenti, 2019; Kim & Aguilera, 2016; Banalieva & Dhanaraj, 2019). The quick pace of digitalization could disrupt established industries and increase competitive pressures on foreign businesses, possibly resulting in fewer FDIs. In fact, the relationship between DED and FDI inflows is quite complex, and the effects depend on the specific country, region, industry, and level of development. Hence, there is a need for more detailed research into how DED influences FDI inflows, combined with analyses of heterogeneity in different contexts, in order to fully understand the link between them.

While they have shed some light on the relationship between DED and FDI, previous researchers have not been able to overcome some of their limitations. Firstly, the majority of these studies have taken a top-down approach without paying much attention to the changes at the city level. The dominance of national or provincial-level data leads to the ignoring of the significant city-level differences in digital infrastructure, industrial structures, and institutional environments. Secondly, the causal analyses are also inconsistent. Although some studies look at technological innovation or transaction costs, they don't develop a comprehensive and systematic framework to include multiple pathways, and hence, they fail to explain the full extent of the role played by DED in FDI inflows promotion. Thirdly, a lot of studies suffered from methodological weaknesses. A significant number of studies didn't sufficiently acknowledge issues of endogeneity and heterogeneity, lacked the use of exogenous policy shocks or multi-method causal inference, or failed to consider the moderating roles of external environments and internal urban characteristics. As a result, the empirical conclusions are not robust, and the existing findings have limited policy implications due to these shortcomings.

The study takes advantage of the data from 2012 to 2023 from the YRD city cluster in China. It develops a DED index and applies a two-way fixed-effects model to scrutinize the impact of DED on FDI inflows. Several endogeneity controls and robustness tests were performed to confirm the reliability of the results. It turns out that DED has a significant positive effect on attracting FDI by fostering technological innovation, cutting transaction costs, upgrading industries, and enlarging consumption. The heterogeneity review demonstrates that this influence is the strongest in metropolitan areas that have a robust intellectual property rights regime, well-established digital infrastructure, and higher levels of economic development. Besides that, this paper investigates the spatial spillover effects of DED on FDI among cities. The research offers a demonstration of the link between DED and FDI inflows and presents significant insights for FDI attraction-oriented policy measures.

An important part of this study's contribution lies in three major areas. Firstly, the originality of the research view. This paper, by setting up a city-level measurement system for DED and FDI inflows, delves into the spatiotemporal evolution features and their mutual impacts. It fills the research gap by going beyond national or regional-level analysis and provides a micro-level perspective for understanding the connection between DED and FDI inflows. Besides, it deals with the problem of influencing FDI inflows and refers to pathways like technological innovation, transaction cost reduction, industrial upgrading, and consumer market expansion. It not only broadens the theoretical scope of DED but also serves as a guide to tapping the potential of digitalization for attracting FDI. Third, there was an improvement in

the research methods. This study conducts a heterogeneity analysis on two levels: the external environment of urban DED (such as intellectual property protection and digital infrastructure) and internal conditions (such as economic development levels and city size). In addition, instrumental variable methods and the exogenous impact of the "Broadband China" policy are used for difference-in-differences and dynamic tests, strengthening the robustness and reliability of the results.

The remainder of this paper is organized as follows. Section 2 reviews the existing literature and presents hypotheses. Section 3 explains the research design, followed by Section 4 that presents the results of this study. Section 5 describes further analyses and Section 6 concludes the paper.

2. Theoretical analysis and hypotheses development

2.1. DED and FDI inflows

According to Coase's (1937) transaction cost theory, when organizational costs within a firm are lower than market transaction costs, firms expand internally to replace market transactions, thereby reducing costs. In the context of DED, multinational corporations use digital technologies to reduce the costs of information acquisition and communication coordination, lowering barriers to FDI and promoting international capital flows. Dunning's (1977) eclectic theory of international production posits that location advantages are key factors for host countries to attract FDI, enabling multinational corporations to achieve higher profits or lower costs in local production and operations. DED has changed the perception of traditional location advantages. In fact, the elements such as data resources, digital infrastructure, innovation capabilities, and digital consumer markets have gradually emerged as the main factors for attracting FDI. Gereffi's (1999) global value chain (GVC) theory highlights that the various activities of a product, such as design, production, marketing, sales, and service, can be geographically separated and performed by different firms in different countries and regions. The rise of DED helps to upgrade industries in developing countries and results in value chain restructuring, and, along with FDI inflows, it defines their qualitative characteristics. Incorporating these theories, this study puts forward the following hypothesis:

H1: *DED has a positive impact on FDI inflows.*

2.2. The influence mechanism of DED on FDI inflows

At the city level, DED may affect FDI inflows in the following ways. One, DED increases the technology level and innovation capacity of the host country; therefore, it is able to attract FDI for technological purposes. Two, through the reduction of transaction costs and the enhancement of investment productivity, DED is capable of attracting the FDI that is derived from the search for efficiency. Three, DED works as a driver of industrial upgrading, thereby producing investment opportunities and attracting FDI-seeking markets. Fourth, DED is also responsible for the generation of new consumer demands; hence, it enlarges consumer markets and attracts market-seeking FDI. The subsequent sections analyze how DED influences FDI inflows by means of these four factors.

(1) Technological innovation

Arvin et al. (2021) and Fang et al. (2022) viewed DED as the driving force behind digital infrastructure and communication technologies development, such as data centers, cloud computing, and the IoT. These create tremendous new opportunities and, at the same time, stimulate FDI inflows. This results in the continuous enhancement of urban innovation and the increase of foreign investors. Brynjolfsson and McAfee (2014) points out that digital technologies, as general-purpose innovations, contribute to widespread technological progress, and at the same time, these innovations radically change business environments, thereby increasing the attractiveness of the host economies to FDI that is knowledge-seeking. Seen from the point of view of multinational enterprises, Mudambi and Swift (2011) underlines that in order to capture knowledge spillovers, foreign firms locate in regions that are characterized by an abundance of talent and a vibrant innovation ecosystem. This, in turn, explains why cities that are digitally advanced receive more foreign capital. More recently, Du and Wang (2024) pointed out that a well-functioning digital infrastructure together with an active digital economy is instrumental in speeding up the flow of information, promoting labor and capital mobility, and enhancing the quality of resource allocation. These factors not only lead to stronger innovation ecosystems but also increase FDI, thereby attracting spillovers. Hence, the present study believes that DED induces FDI inflows by fostering innovation in metropolitan areas.

H2: *DED significantly promotes FDI inflows through promoting technological innovation.*

(2) Transaction cost

Referring to the transaction cost theory (Coase, 1937), DED enhances the productivity of FDI by alleviating the market frictions that occur in cross-border operations. The utilization of big data analytics and cloud platforms helps firms cut down on search and information costs, which are necessary when scouting overseas opportunities (Goldfarb & Tucker, 2019), since they increase transparency. The use of digital communication tools and smart platforms for the coordination of resources across borders reduces the cost levels of collaboration, negotiation, etc. that enterprises must bear when working with foreign counterparts (Meyer et al., 2023). The use of IoT sensing and remote monitoring allows a comprehensive and real-time supervision of the operations of the particular firm abroad, consequently reducing the costs associated with supervision and contract enforcement (Banalieva & Dhanaraj, 2019). Simultaneously, the extensive cloud infrastructure frees up the fixed asset requirements of market entry and, at the same time, allows for the investment models to be more flexible and asset-light (Casella & Formenti, 2019). By continuously lowering transaction costs across the board, DED results in a decrease in entry barriers and operational risks, thus rendering internationalization strategies more feasible and at the same time making a difference in global investment location and market-entry decisions. Therefore, this paper argues that DED, by lowering firms' transaction costs, raises their FDI willingness to enter.

H3: *DED significantly promotes FDI inflows through reducing transaction costs.*

(3) Industrial structure upgrading

From an industrial upgrading viewpoint, DED raises host countries' luring power to FDI by revamping industrial structures so that they can evolve into knowledge-intensive, technology-oriented ones. This is a "digital transformation → industrial upgrading → high-quality FDI" chain of events. Dunning and Lundan (2008) point out that the hidden knowledge that is embedded in DED is a source of locational advantage for MNCs that are in search of strategic assets and improvement of efficiency. DED and technological innovation together create great momentum for industrial upgrading (Liu et al., 2023). On the other hand, the digital economy's phenomenal growth has resulted in the relocation of FDI from the low-end manufacturing to the high-value and technology-oriented sectors, as well as those providing services (Casella & Formenti, 2019), thereby leading to a more optimal sectoral mix. The use of digital technologies, especially when it comes to service digitization, endows FDI with more competitive power and leads to better allocative efficiency (Porter & Heppelmann, 2014). Speaking at the micro level, the collaboration of both digital technologies and consumer demands produces fresh business models and, at the same time, induces the innovation of industrial organizations and strategies. These results, in turn, lead to more FDI (Brynjolfsson & McAfee, 2014); for the most part, industrial upgrading raises the knowledge base of a host economy as well as its industrial capacity. Through this, the multinationals get to have strategic opportunities for capturing technological spillovers, followed by integration into their supply chains that are efficient and entry into emerging markets. This particular path reveals the potential of DED to not only attract FDI of very good quality but also to bring about the optimization of the pattern in the long run. From the perspective of the above-mentioned work, this study proposes that DED leads to an increase in FDI inflows via driving industrial structural reforms.

H4: *DED significantly promotes FDI inflows through upgrading industrial structures.*

(4) Consumption expansion

Promotion of consumption by DED in turn leads to an increase in FDI, with the following three main points: market growth, lessened investment risk, and enhanced market predictability. Firstly, through the creation of new consumer demands and the rearrangement of supply chains, digital industrialization has the effect of direct market elongation and diversification, besides producing great foreign firm attraction opportunities (Li et al., 2023). Secondly, the usage of platform technologies and big data analytics enables businesses to spot consumption patterns and also determine product-market fit more accurately, thus resulting in diminished market uncertainty for FDI newcomers (Goldfarb & Tucker, 2019). Thirdly, digital change in consumption has generated new types of business models, such as e-commerce, online services, etc., which have not only diversified consumption patterns but also increased predictability of demand (Palmié et al., 2022). This serves as the basis for wise resource allocation decisions. The advantage location-wise is given by the large and continually growing consumer market, as proximity to end markets and local demand fulfillment are key factors in multinational investment decisions (Glaeser et al., 2001). The whole process that starts from digital technologies leading to consumption and, finally, consumer markets coming to FDI is

consistent with the international investment theory's market-seeking motive. Following this analysis, the core research hypothesis put forth by the study is the one below:

H5: *DED significantly promotes FDI inflows through expanding consumer markets.*

Figure 1 illustrates the theoretical model.

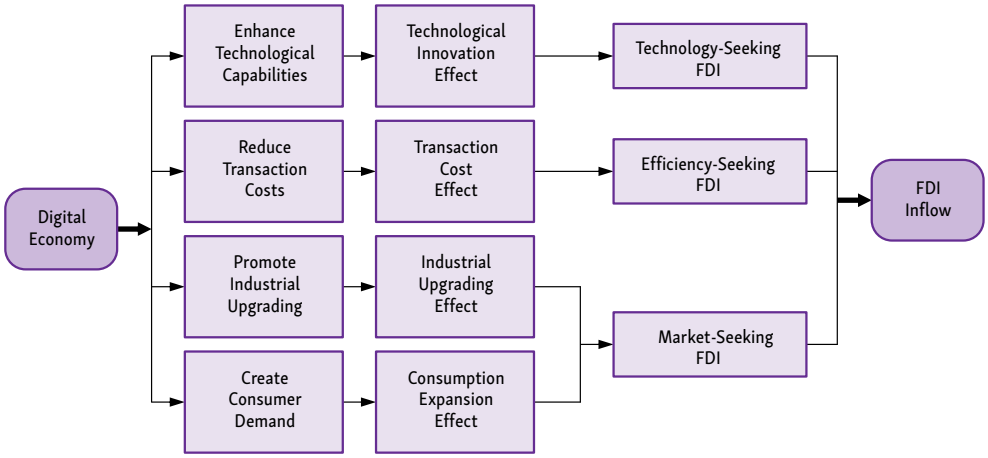


Figure 1. Theoretical model

3. Methodology

3.1. Empirical models

(1) Baseline model

This study examines the impact of DED on FDI inflows in the YRD city cluster using Dunning's (1981) eclectic theory of international production as a theoretical base. This theory stresses that location advantages such as geographical position, FDI policies, natural resources, and market size are the main factors in attracting FDI. Building on this theory, we construct the following baseline regression model, as shown in Equation (1).

$$\ln fdi_{it} = \alpha_0 + \alpha_1 dig_{it} + \sum_{p=2}^{5} a_p X_{it} + \mu_j + \lambda_t + \varepsilon_{it}, \quad (1)$$

where fdi_{it} represents the flow of FDI, dig_{it} measures the level of DED, X_{it} represents the control variables, α_0 is the constant term, α_1 is the regression coefficient for the impact of DED on FDI inflows, a_p represents the regression coefficients for the control variables, μ_j and λ_t denote province and time fixed effects, respectively, ε_{it} is the random error term, i represents the city, and t represents the year. Through this model, the study examines the impact of DED on FDI inflows in the YRD city cluster, with a focus on the economic significance of the coefficient α_1.

(2) Mediation effect models

To test Hypotheses 2–5, we employ the mediation effect models, as specified in Equations (2) and (3), to probe how DED shapes FDI inflows.

$$M_{it} = \beta_0 + \beta_1 dig_{it} + \sum_{p=2}^{5} \beta_p X_{it} + \mu_j + \lambda_t + \varepsilon_{it}; \quad (2)$$

$$\ln fdi_{it} = \lambda_0 + \lambda_1 dig_{it} + \sum_{p=2}^{5} \lambda_p X_{it} + \lambda_6 M_{it} + \mu_j + \lambda_t + \varepsilon_{it}, \quad (3)$$

where M_{it} represents the mediating variable, including technological innovation, transaction cost, industrial structure upgrading, and consumption expansion. Other variables are consistent with the baseline model. Through this mediation effect model, the study explores how DED affects FDI inflows, with a focus on the economic significance and policy implications of the coefficients β_1, λ_1, and λ_6.

3.2. Variable measurement

(1) Dependent variable: FDI

Following Qing et al. (2024), we use the logarithm of a city's FDI amount as a measure of FDI. Since the source data are in US dollars, they must be converted into RMB using the average yearly exchange rate.

(2) Independent variable: DED

This study gets the level of DED by replicating Li et al. (2022), who built an indicator system for this purpose. The system includes three primary indicators: digital economy infrastructure, digital industrialization, and industrial digitalization, in addition to five secondary indicators. Table 1 contains the details.

Digital Economy Infrastructure: This component reflects how widespread and easy to use digital networks and hardware are. The measurement is based on: Internet Penetration Rate (number of internet users per 100 people), which represents a basic level of connectivity and the potential user base for digital services; and Mobile Phone Penetration Rate (number of mobile phone users per 100 people), which measures access to mobile devices, a critical factor for mobile internet and digital applications.

Table 1. Framework for DED evaluation indicators

Primary indicator	Secondary indicator	Indicator description	Attribute
Digital Economy Infrastructure	Internet Penetration Rate	Internet users per 100 people	+
	Mobile Phone Penetration Rate	Mobile phone users per 100 people	+
Digital Industrialization	Number of Internet-Related Employees	Share of employees in information, transmission, computer services, and software industries	+
	Internet-Related Output	Total telecommunications services volume per capita	+
Industrial Digitalization	Inclusive Development of Digital Finance Index	Penetration and usage of digital financial services (e.g., mobile payments)	+

Digital Industrialization: This aspect represents the size and economic contribution of the digital industrial sector. It is determined by the following indicators: Number of Internet-Related Employees (consisting of the share of employees in information, transmission, computer services, and software industries) is the human capital devoted to digital goods and services; and Internet-Related Output (total telecommunications services volume per capita) measures the digital industrial sector's direct economic output.

Industrial Digitalization: This aspect is about the level of digital technology adoption in traditional industries. It is evaluated by a composite index, the Digital Financial Inclusion Index, which measures the penetration and usage of digital financial services (e.g., mobile payments). This index is an indicator of digital technology adoption in finance and, therefore, also of industrial digitization at large.

First, the data are normalized. To eliminate the differences in units and magnitudes between the indicators, the raw data undergo range-based normalization. Let x_{ij} denote the raw value for the j^{th} indicator in the i^{th} city and let X_{ij} denote the normalized value. The processing formula is as follows in Equations (4)–(8).

Positive indicators:

$$X_{ij} = \frac{x_{ij} - \min\left(x_j\right)}{man(x_j) - \min\left(x_j\right)}. \tag{4}$$

Negative indicators:

$$X_{ij} = \frac{man\left(x_{ij}\right) - x_{ij}}{man(x_j) - \min\left(x_j\right)}, \tag{5}$$

where $\min\left(x_j\right)$ and $man\left(x_j\right)$ represent the minimum and maximum values of indicator j, respectively, across all samples.

Next, we compute information entropy. Information entropy E_j for the j^{th} indicator is calculated.

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{n}\left(p_{ij}\ln p_{ij}\right), \tag{6}$$

where $p_{ij} = -\dfrac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}$, and $p_{ij}\ln p_{ij}$ is defined as 0 when $p_{ij} = 0$. n is the number of cities.

Subsequently, the indicator weights are determined. Calculate the weight W_j for each indicator based on information entropy.

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{m}\left(1 - E_j\right)}, \tag{7}$$

where m denotes the total number of indicators.

Finally, a comprehensive DED index is calculated. Using a multi-objective linear weighted function approach, DED_i for each city from 2012 to 2023 is calculated as follows:

$$DED_i = \sum_{j=1}^{m}\left(W_j \times X_{ij}\right). \tag{8}$$

These steps allow the comprehensive development of the digital economy at the prefecture-level city tier within the YRD city cluster to be systematically and objectively evaluated.

(3) Mediating variables

Technological innovation, following Fan and Liang (2025), is proxied by the logarithm of patent applications. Following Song et al. (2024), the marketization index is used as a proxy variable to reflect the connection between market environment and transaction costs. This index covers six aspects: product market development, non-state-owned economy, market services, intellectual property protection, factor markets, and government-market interaction. The marketization index measures market efficiency in terms of transaction costs. Although its broad coverage of institutional features can complicate interpretation, the index remains a reasonable proxy because it comprehensively measures transactional behavior. Industrial structure upgrading, following Szirmai (2012), is measured by the ratio of the tertiary industry's share of GDP to the secondary industry's share of GDP. Consumption expansion, following Liu et al. (2021a), is proxied by the logarithm of total retail sales of consumer goods, with appropriate logarithmic transformations applied.

(4) Control variables

Drawing on the relevant literature on FDI flows, this study selects effective indicators and feasible data to set the following control variables: i) government expenditure, measured by the ratio of public budget spending to GDP; ii) openness level, represented by the ratio of import and export trade volumes to GDP; iii) human capital, measured by the logarithm of the average years of education in the city; and iv) transportation infrastructure, measured by the logarithm of the total freight volume. A summary of variable definitions appears in Table 2.

Table 2. Variable definitions

Variables	Measurement	Symbol	Definitions
Dependent variable	FDI	ln*fdi*	Logarithm of FDI
Independent variable	Digital economy development	ln*dig*	Logarithm of the comprehensive DED index +1
Mediating variables	Transaction costs	ln*market*	Logarithm of marketization level
	Technological innovation	ln*ina*	Logarithm of patent applications
	Industrial upgrading	*ind*	Ratio of tertiary industry's share of GDP to secondary industry's share of GDP
	Consumption expansion	ln*pur*	Logarithm of total retail sales of consumer goods
Control variables	Government expenditure	*fis*	Ratio of local government fiscal expenditure to GDP
	Openness level	*open*	Ratio of import and export trade volume to GDP
	Human capital	ln*hc*	Logarithm of average years of education
	Transportation infrastructure	ln*gt*	Logarithm of total freight volume

3.3. Sample and data sources

This study selects 27 cities in the YRD city cluster from 2012 to 2023 and constructs a panel dataset containing 324 city-year observations. Data sources include the Digital Finance Research Center of Peking University for digital inclusive finance data, the "China City Statistical Yearbook" for digital internet development indicators and the six sub-indicators of the marketization index, the National Population Census Database for city-level human capital data, and the "Statistical Yearbooks" and "Statistical Bulletins" of the provinces and cities in the YRD from 2013 to 2024 for core variables such as FDI, patent applications, total retail sales of consumer goods, and industrial structure upgrading, as well as other control variables. For data that are not explicitly listed, various statistical yearbooks were systematically organized. In terms of data processing, linear interpolation was used to fill in missing data for individual years, and all continuous variables were winsorized at the 1% level on both sides to reduce the impact of outliers on the estimation results.

3.4. Descriptive statistics

Table 3 presents the descriptive statistics of the main variables. After processing, the city-year data refer to the YRD city cluster as a balanced panel from 2012 to 2023. The average DED (ln*dig*) is 0.162, which also agrees with the earlier studies (Chen et al., 2023). The rest of the variables are quite reasonable without too many outliers. Since their standard deviations are all less than 0.1, it means that the data are stable.

Table 3. Descriptive statistics of the study variables

Variable	Obs	Mean	Std. Dev	Min	Max
ln*fdi*	324	2.663	1.106	0.604	5.310
ln*dig*	324	0.162	0.071	0.016	0.327
ln*ina*	324	8.900	1.135	6.260	11.272
ln*market*	324	2.599	0.199	2.081	2.976
ind	324	1.067	0.407	0.417	2.751
ln*pur*	324	7.402	0.983	5.047	9.676
fis	324	0.139	0.042	0.085	0.259
open	324	0.411	0.329	0.049	1.482
ln*hc*	324	2.270	0.067	2.166	2.442
ln*gt*	324	9.970	0.580	8.798	11.844

4. Empirical results and analysis

4.1. Baseline results

From the baseline regression results shown in Table 4, DED has an influence on FDI that is statistically significantly positive. For example, in Columns (1) and (2) of the single variable tests, which do not take into account the provincial fixed effects, the regression coefficient of the DED index (ln*dig*) on FDI (ln*fdi*) gives a significantly positive impact, suggesting that cities

with higher levels of DED clearly have an edge in attracting FDI. Subsequent examination of Columns (3)–(4) reveals that the results of the regression continue to show significance after the inclusion of control variables and fixed effects, with the only exception of city-fixed effects. Most importantly, when being controlled for both province- and year-fixed effects, the regression coefficient of ln*dig* remains at 5.153, and its robust standard error is very significant at the 1% level. This empirical result not only verifies that DED has a significant positive effect on FDI inflows in the YRD city cluster but is also consistent with H1. This result is also consistent with that of Götz (2020). In the YRD, advanced digital infrastructure and dynamic digital activities reduce information acquisition costs and lower market-entry barriers, fostering a favorable operating environment for foreign firms.

Table 4. Baseline results

Variables	(1)	(2)	(3)	(4)
	ln*fdi*	ln*fdi*	ln*fdi*	ln*fdi*
ln*dig*	9.235*** (0.706)	1.508* (0.896)	5.580*** (0.977)	5.153*** (1.035)
Control variables	NO	YES	YES	YES
Province FE	NO	NO	YES	YES
Year FE	NO	NO	NO	YES
City FE	NO	NO	NO	NO
Observations	324	324	324	324
Adj-R^2	0.345	0.630	0.741	0.737

Note: Standard errors are reported in parentheses. ***, and * indicate $p < 0.01$ and $p < 0.1$, respectively. FE represents fixed effects. The same applies to the tables that follow.

4.2. Robustness tests

We conduct robustness tests on four aspects to test the robustness of the research conclusions.

(1) Replacing the dependent variable

Following Burlea-Schiopoiu et al. (2023), this study uses the ratio of FDI to GDP (foreign investment utilization rate) as an alternative measure of the dependent variable (labelled *fdi_gdp*). Column (1) of Table 5 shows that the regression coefficient of the core explanatory variable ln*dig* remains significantly positive, indicating that the baseline conclusion holds, even after changing the measurement method of the dependent variable.

(2) Replacing the independent variable

Following Liu et al. (2021b), this study uses the digital inclusive finance index (ln*dei*) jointly released by the Digital Finance Research Center of Peking University and Ant Financial Services Group as an alternative measure of DED. Column (2) of Table 5 shows that the coefficient on ln*dei* is significantly positive, further verifying the reliability of the baseline conclusion.

(3) Considering the lag effect

Considering that the impact of DED on FDI introduction may have a lagged effect, this study uses the lagged first period of the explanatory variable (L.ln*dig*) for the regression analysis. Column (3) of Table 5 shows that the coefficient of L.ln*dig* remains significantly positive, indicating that the baseline conclusion is robust over time.

(4) Excluding special samples

To exclude the influence of extreme values, this study re-estimates after excluding the sample of Shanghai, a municipality directly under the central government. Column (4) of Table 5 shows that the coefficient of ln*dig* remains significantly positive and consistent with the baseline regression results, indicating that the research conclusions are not affected by the special samples.

Table 5. Robustness tests

Variable	Replacing the dependent variable	Replacing the independent variable	Considering the lag effect	Excluding special samples
	fdi_gdp	ln*fdi*	ln*fdi*	ln*fdi*
	(1)	(2)	(3)	(4)
ln*dig*	8.277*** (2.703)			5.205*** (1.061)
ln*dei*		1.785* (1.010)		
L.ln*dig*			5.963*** (1.129)	
Control variables	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	324	324	297	312
Adj-R^2	0.334	0.719	0.740	0.671

Note: *** and * indicate $p < 0.01$ and $p < 0.1$, respectively.

4.3. Endogeneity tests

(1) Instrumental variable method

Following the approach of Angrist and Kolesár (2024), this study uses a dual instrumental variable strategy to mitigate endogeneity issues. The instrumental variables consist of the first lag of DED level (L.ln*dig*) and per capita mobile phone usage (ln*Info*). L.ln*dig* meets the relevance requirement but may still correlate with current FDI due to path dependence or dynamic accumulation, potentially weakening the exclusion restriction. Similarly, ln*Info* can directly affect FDI by improving informatization and business environment. To mitigate these concerns, we include province- and year-fixed effects and control for key city characteristics. The instrumental-variable diagnostics exceeded the critical thresholds, indicating strong instrument relevance and no weak-instrument problems.

The results of the IV tests are listed in Table 6. First, Column (1) shows that the regression coefficient of L.ln*dig* on the current period's *ln*dig is positive and significant at the 1% level, indicating that the previous period's DED level significantly affects the current period's digital technology development, satisfying the relevance condition of the instrumental variable. Second, Column (2) shows that the coefficient of ln*dig* remains significantly positive at the 1% level in the second-stage regression. Similarly, Column (3) shows a significant positive connection between the instrumental variables ln*Info* and ln*dig*, confirming the close connection between historical communication infrastructure levels and DED. Column (4) further verifies the significant positive characteristics of the ln*dig* coefficient. The instrumental variable regression results consistently indicate that after controlling for endogeneity, the main conclusions of the baseline regression remain robust.

(2) DID dynamic effect analysis

In 2013, the State Council unveiled the "Broadband China" strategy and its implementing plan, and the country set up around 120 "Broadband China" demonstration cities in phases from 2014 to 2016 with a view to speeding up the building of broadband network infrastructures and digital transformation. This policy is regarded as an important foundation for promoting urban digital transformation and corporate digital activities (Wang et al., 2022), thus playing a key role in DED. Based on this policy background, this study constructs a DID model (Equation (9)) and a dynamic effect test model (Equation (10)) for empirical analysis.

$$\ln fdi_{it} = \alpha_0 + \alpha_1 Treat_{it} \times Post_{it} + \sum_{p=2}^{5} a_p X_{it} + \mu_j + \lambda_t + \varepsilon_{it}; \tag{9}$$

$$\ln fdi_{it} = \alpha_0 + \alpha_1 Treat_{it} \times Post\left(n\right)_{it} + \sum_{p=2}^{5} a_p X_{it} + \mu_j + \lambda_t + \varepsilon_{it}, \tag{10}$$

where *Treat* is a treatment group dummy variable, taking the value of 1 if the city is selected as a "Broadband China" demonstration city, and 0 otherwise; *Post* is a time dummy variable, taking the value of 1 after the sample city is selected as a demonstration city, and 0 before; $Post\left(n\right)$ represents the nth period before or after the treatment group or control group sample is selected as a demonstration city, with a research window of 6 years (Imbens & Wooldridge, 2009).

Column (5) of Table 6 shows that the "Broadband China" demonstration city policy has a significant positive effect on FDI, with the coefficient being statistically significant. Column (6) of Table 6 and Figure 2 reveal time-varying characteristics of the policy impact: before becoming a demonstration city, the interaction terms *Treat* × *Post* (–3) and *Treat* × *Post* (–2) for the treatment and control groups are not significant, indicating that the samples satisfy the parallel trend assumption; after the policy implementation, the coefficients of *Treat* × *Post* (0) to *Treat* × *Post* (2) are all significantly positive, indicating that the demonstration city policy significantly improves the level of FDI, and this promotion effect has a sustained impact, but it gradually weakens over time. These dynamic effects suggest that the policy benefits from an improved digital infrastructure, as highlighted by Fang et al. (2022). These findings corroborate the baseline regression results, jointly supporting the core hypothesis H1 that DED has a significant positive impact on FDI.

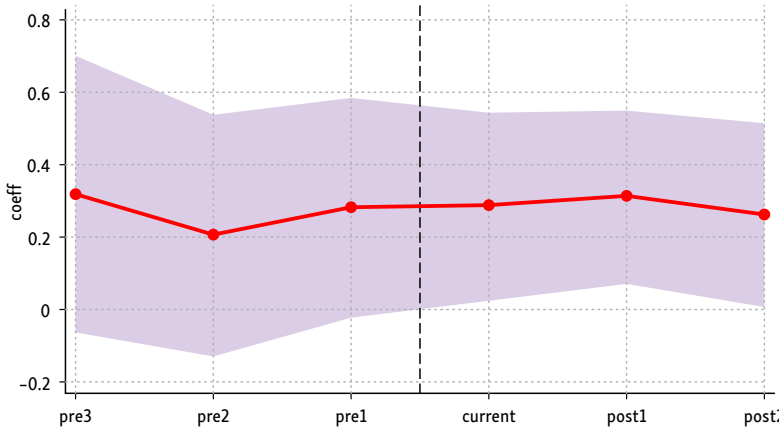


Figure 2. Dynamic effect estimation plot

(3) PSM-DID test

To enhance the reliability of the conclusions, this study also uses the propensity score matching difference-in-differences method (PSM-DID) to alleviate potential selection bias. Specifically, following Huang and Zhang (2025), we first calculate the propensity scores of each sample city based on city characteristic variables using a logit model. Cities selected as "Broadband China" demonstration cities are treated as the treatment group, while the remaining cities are the control group. In the year before policy implementation, one-to-one nearest neighbor matching (without replacement) and a 0.1 standard caliper were used for matching, ensuring that the treatment and control groups had comparable key characteristics. After matching, the treatment and control group cities show high similarity in characteristics such as digital technology innovation, making the research design closer to a quasi-natural experiment. Column (7) of Table 6 displays the PSM-DID estimation results, showing that the coefficient for the interaction term is 0.168 and statistically significant, meaning that the designation of a city as a "Broadband China" demonstration city highly influences the increase of FDI inflows. Thus, this result supports the first-line regression and traditional DID estimation results and demonstrates once again the ability of DED to promote FDI, while also adding more strength to our study's conclusions.

4.4. Mechanism tests

(1) Technological innovation

To test the mechanism through which DED affects FDI via technological innovation, this study uses the logarithm of patent applications (ln*ina*) as a proxy for technological innovation in the mediation effect analysis. Columns (1) and (2) of Table 7 present the results of the mediation effect test. Column (1) shows that the regression coefficient of DED on patent applications is 4.757 and significant at the 1% level, indicating that DED significantly promotes technological innovation in the YRD city cluster. Second, Column (2) shows that the regression coefficient of patent applications (ln*ina*) on FDI is 0.325 and is significant at the 1% level. The Sobel test

Table 6. Endogeneity tests

Variables	Instrumental variable				DID dynamic effect		PSM-DID
	ln*dig*	ln*fdi*	ln*dig*	ln*fdi*	ln*fdi*	ln*fdi*	ln*fdi*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L.ln*dig*	0.898*** (0.049)						
ln*Info*			0.133*** (0.011)				
ln*dig*		6.640** (1.377)		13.525*** (2.425)			
Treat × *Post*					0.255*** (0.094)		0.168* (0.078)
Treat × *Post* (–3)						0.318 (0.196)	
Treat × *Post* (–2)						0.207 (0.171)	
Treat × *Post* (–1)						0.282* (0.156)	
Treat × *Post* (0)						0.286** (0.133)	
Treat × *Post* (1)						0.312** (0.123)	
Treat × *Post* (2)						0.262* (0.130)	
First-stage F Statistic	332.95		138.99				
Cragg-Donald Wald F Statistic		730.80		147.61			
Kleibergen-Paak rk LM Statistic		59.77		75.22			
Control variables	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	NO	NO	NO
Year FE	YES	YES	YES	YES	YES	NO	YES
Observations	297	297	324	324	324	324	119
Adj-R^2	0.947	0.634	0.867	0.595	0.640	0.633	0.694

Note: ***, **, and * indicate $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

yielded a Z-statistic of 3.673, significant at the 1% level. This finding validates the existence of a statistically significant mediating effect. This finding confirms that DED enhances regional technological innovation capabilities, thereby attracting more FDI, and supports the technological innovation mechanism of H2 that DED significantly enhances the attractiveness of the YRD city cluster to FDI through technological innovation.

(2) Transaction cost

To verify the mechanism through which DED attracts FDI by reducing transaction costs, this study uses the marketization index (ln*market*) as a proxy for transaction costs to test the mediation effect. Columns (3) and (4) of Table 7 present these results. Column (3) indicates that the regression coefficient of DED (ln*dig*) on the marketization index (ln*market*) is 0.658 and is significant at the 10% level, suggesting that DED significantly enhances marketization. Column (4) shows that the coefficient of the marketization index (ln*market*) on FDI is 0.889 and is significant at the 1% level. Furthermore, the Sobel test results show that the Z-statistic of 1.661, which is significant at the 10% level. This empirical finding confirms that DED reduces transaction costs, improves market efficiency, and thereby attracts efficiency-seeking FDI, supporting the transaction cost mechanism of H3 that DED significantly promotes FDI inflows in the YRD city cluster by reducing transaction costs.

(3) Industrial structure upgrading

This study conducts a mediation effect analysis to examine how DED influences FDI through industrial structure upgrading. Columns (5) and (6) of Table 7 provide the results. Column (5) reveals that the regression coefficient of DED (ln*dig*) on industrial structure upgrading (*ind*) is 1.127 and highly significant at the 1% level. This means that DED has a strong and positive impact on the industrial structure upgrading in the YRD city cluster. Column (6) shows that the coefficient of industrial structure upgrading on FDI is –0.075 and not statistically significant. The Sobel test provides no evidence of the mediation effect, given the Z-statistic of –0.455, implying that industrial structure upgrading is not a significant channel. The measure used probably captures a mixed upgrading effect: an increase in the service sector's share may come from both traditional and high-end services. While technology-driven, high-value services tend to attract high-quality FDI, the growth of traditional services might weaken this positive influence.

(4) Consumption expansion

For the purpose of checking the channel through which DED attracts FDI via consumption expansion, in this paper, the logarithm of total retail sales of consumer goods (ln*pur*) is adopted as a proxy for consumption expansion to perform mediation effect test. Columns (7) and (8) of Table 7 show the test outcomes. Initially, Column (7) reflects that the regression coefficient of the DED level (ln*dig*) on consumption scale (ln*pur*) is 2.573 and the degree of statistical significance is 1%. This discloses that DED has a significant positive effect on the expansion of consumer markets. Next, Column (8) tells us that the regression coefficient of consumption scale (ln*pur*) on FDI (ln*fdi*) is 0.201, and the degree of statistical significance is 1%. Further, the findings of the Sobel test show that Z-statistic is 2.092, which is statistically significant at 5% level. This result of empirical analysis supports the idea that DED creates new consumer demand and expands the market size, which in turn attracts market-seeking FDI. Hence, it supports H5. In essence, this means that DED notably increases the attractiveness of the YRD city cluster for FDI through the consumption expansion channel.

In general, the mechanism channel analysis shows that the major routes through which DED attracts FDI are technological innovation and consumption market expansion. Besides,

the role of reducing transaction costs has been only marginal, and the influence on industrial structure upgrading is even negligible. Such results can also be seen in Arvin et al. (2021), who highlight that ICT connectivity leads to innovation and hence to higher FDI inflows. Also, Li et al. (2023) underline the demand-expansion effects of digital platforms. The digital economy in the YRD, as shown by big names like Alibaba and Pinduoduo, has led to the digital transformation of the traditional industries, to the formation of globally competitive industrial clusters, and to the provision of significant opportunities to foreign firms for collaborative innovation and the large, dynamic consumer market.

Table 7. Mechanism tests

Variable	Technological innovation		Transaction costs		Industrial upgrading		Consumption expansion	
	ln*ina*	ln*fdi*	ln*market*	ln*fdi*	ind	ln*fdi*	ln*pur*	ln*fdi*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln*dig*	4.757*** (0.988)	3.606*** (1.023)	0.658* (0.348)	5.662*** (1.348)	1.127*** (0.367)	5.237*** (1.053)	2.573*** (0.812)	4.635*** (1.041)
ln*ina*		0.325*** (0.057)						
ln*market*				0.889*** (0.255)				
ind						–0.075 (0.162)		
ln*pur*								0.201*** (0.072)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	324	324	243	243	324	324	324	324
Adj-R^2	0.773	0.762	0.418	0.756	0.757	0.736	0.796	0.743
Sobel Test		3.673*** (0.421)		1.661* (0.352)		–0.455 (0.185)		2.092** (0.248)

Note: ***, **, and * indicate $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

5. Further analysis

5.1. External environment heterogeneity

(1) Intellectual property protection

As a core civil right in the modern economic system, the level of intellectual property protection is significantly and positively correlated with the efficiency of patent commercialization. A sound intellectual property protection mechanism is not only an institutional guarantee for enterprises to obtain market returns through technological innovation but also a key factor affecting the construction of innovation ecosystems in the DED era (Teece, 2018; Liu et al., 2023). Based on this, this study proposes that strengthening intellectual property protection

can enhance the exclusivity of digital patent rights, thereby promoting the commercialization of digital technological innovation achievements and increasing the attractiveness of FDI. Drawing on Wu and Yang (2025), this study measures the strength of regional intellectual property protection using the number of intellectual property cases concluded by city courts (*IPPC*) with data sourced from the PKULAW judicial case database. Based on the median intellectual property protection strength each year, the sample cities are divided into high and low protection strength groups, and separate regression analyses are conducted. The empirical results, as shown in Columns (1) and (2) of Table 8, indicate that the regression coefficient of the DED-level variable ln*dig* is significantly larger in the high protection-strength city group, suggesting that the attraction effect of DED on FDI is more pronounced in cities with stronger intellectual property protection.

To further assess the moderating role of intellectual property protection, this study introduces an interaction term between DED and intellectual property protection (ln*dig* × ln*IPPC*). As Column (3) of Table 8 shows, the interaction coefficient is 0.563 and is significant at the 1% level. This finding confirms that stronger intellectual property protection enhances the positive impact of DED on FDI inflows. This result provides empirical support for reinforcing intellectual property protection to enhance the digital economy's capacity to attract investments.

(2) Digital infrastructure

In the field of DED research, scholars emphasize the critical role of digital infrastructure, arguing that the development of DED highly depends on the level of digital infrastructure in its ecosystem, and urban economic growth also requires well-developed digital infrastructure as a foundation (Brynjolfsson & McAfee, 2014). Based on this, this study hypothesizes that a well-developed digital infrastructure can promote technological progress and enhance informatization levels, driving high-quality urban economic development and thereby attracting FDI. Following Kolko's (2012) research method, this study uses the ratio of the number of Internet access ports to the resident population in each city as a basis, dividing the sample into digital infrastructure-developed and underdeveloped regions using the median method and conducting empirical tests separately. The empirical analysis results, as shown in Columns (4) and (5) of Table 8, indicate that in digital infrastructure-developed regions, the DED level (ln*dig*) and FDI (ln*fdi*) show a significant positive correlation, and the regression coefficient is significantly higher than that in digital infrastructure-underdeveloped regions. The implication here is that a highly developed digital infrastructure can enhance the capability of DED to attract FDI, thereby giving a stronger push to urban economic growth.

To examine the digital infrastructure's role, this research adds an interaction variable between DED and digital infrastructure (ln*dig* × *SZJC*). The 6th column of Table 8 reveals that the coefficient for the interaction term is 0.777, which shows significance at the 5% level. This result implies that the upgrading of digital infrastructure greatly intensifies the effect of DED in attracting FDI. It indeed signifies the importance of digital infrastructure in FDI attraction and supports the strategic deployment of digital infrastructure to enhance foreign investments.

Consideration of external environmental differences shows that intellectual property protection levels and digital infrastructure technology affect how the digital economy attracts FDI. This supports the views of Liu et al. (2023), who mentioned that digital innovation

requires strong intellectual property protection systems, and it also agrees with Brynjolfsson and McAfee (2014), who recognized the key role of digital infrastructure in economic growth at the regional level. YRD cities such as Shanghai and Suzhou have been able to lure a large amount of FDI in R&D and high-tech sectors, essentially through the development of intellectual property protection mechanisms and top-notch digital infrastructure.

Table 8. External environment heterogeneity analysis

Variable	ln*fdi*					
	Strong intellectual property protection	Weak intellectual property protection	Moderating effect of intellectual property protection	Well-developed digital infrastructure	Under-developed digital infrastructure	Moderating effect of digital infrastructure
	(1)	(2)	(3)	(4)	(5)	(6)
ln*dig*	7.818*** (1.826)	3.190** (1.389)	0.941 (1.632)	5.107*** (1.558)	0.832 (1.583)	3.911*** (1.143)
ln*dig* × ln*IPPC*			0.563*** (0.174)			
ln*dig* × *SZJC*						0.777** (0.314)
Group differences	4.628** (P < 0.05)			4.275** (P < 0.05)		
Control variables	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Observations	155	169	314	156	167	324
Adj-R^2	0.795	0.396	0.756	0.585	0.610	0.741

Note: *** and ** indicate $p < 0.01$ and $p < 0.05$, respectively.

5.2. Internal conditions heterogeneity

Prior research has identified that the impact of FDI inflow can be different for each region, including its size (Du et al., 2023). Thus, we assume that the attraction effect of DED on FDI might be even more obvious in the cities that are more economically developed and bigger in size.

(1) Economic development level

In line with Rodrik et al. (2004), per capita GDP is used here as the proxy for the level of regional economic development. The total research sample is divided into two groups of high and low economic development by sample median, and regression and comparative analyses are carried out separately. As per the empirical findings shown in Columns (1) and (2) of Table 9, a very interesting thing is the location-based heterogeneity in the positive relationship between the levels of DED (Department of Economic Development) and FDI

(Foreign Direct Investment); that is, the cities that are economically better off experience a stronger enhancement effect of DED on FDI as compared to the economically lower cities. This means that the economic development level of a region is a crucial moderator changing the impact of DED on FDI attraction effects.

(2) City size

Following Xu et al.'s (2019) classification of city size. Based on the average annual population at the end of the year, a three-tier classification system has been built. If a city has a population of less than 3 million on average annually, it is considered to be a small city; similarly, medium-sized cities are those that have populations between 3 and 5 million, while large cities are those that have populations above 5 million. According to the empirical findings in Columns (3) to (5) of Table 9, it turns out that the effect of the level of DED on FDI varies with the size of the city. If we take a sample of only the large-sized cities, then the results for the DED reveal a significant increase in FDI, with the regression coefficient being statistically significant at the 1% level of significance. On the other hand, taking the samples of cities that are medium- and small-sized, we find that this impact is not statistically significant. Therefore, it can be concluded that because of superior digital infrastructure, industrial clusters, and policy advantages, large cities are more able to attract FDI due to DED.

In advance of an investigation into the variations within the groups, it is found that economic development and city size are the major factors that moderate the influence of DED on FDI significantly, which is in line with the results of Du et al. (2023). It also indicates that the location choices of FDI are hierarchical in nature: cities having stronger economies and bigger populations are more able to tap into benefits arising from digital investment attractions. In the YRD city cluster, major cities like Shanghai, Nanjing, and Hangzhou are at the forefront of this development as they are making the most of their highly developed industrial systems, abundant talent pools, and geographical advantages.

Table 9. Internal conditions heterogeneity analysis

Variable	ln*fdi*				
	High economic development level	Low economic development level	Large cities	Medium cities	Small cities
	(1)	(2)	(3)	(4)	(5)
ln*dig*	6.268*** (1.150)	5.480*** (1.737)	2.752*** (0.806)	1.826 (1.786)	0.492 (1.438)
Control variables	YES	YES	YES	YES	YES
Fixed effects	YES	YES	YES	YES	YES
Observations	156	168	60	120	44
Adj-R^2	0.827	0.561	0.947	0.751	0.663

Note: *** indicates $p < 0.01$.

5.3. Heterogeneity analysis

This study also looks at the regional differences in how DED influences FDI by extending the analysis firstly to the whole country and secondly to three major city clusters: Beijing–Tianjin–Hebei (13 cities), the Pearl River Delta (9 cities), and Chengdu–Chongqing (16 cities).

Table 10 shows that the impact of DED on FDI differs considerably from one region to another. The coefficients of the digital economy index (ln*dig*) are 5.153 and 5.735, respectively, in the city clusters of the YRD (Column 1) and Beijing–Tianjin–Hebei (Column 3). Both being significant at the 1% level implies that the FDI-stimulating effect in these highly developed clusters is very strong. On the other hand, the coefficient for the national sample (Column 2) is 0.648, which, though positive, is much smaller, implying that the digital economy's attraction for FDI is more evident in the advanced, highly urbanized regions. The Pearl River Delta (Column 4) also shows a positive impact, as the coefficient of 1.566 is significant at the 1% level. However, the magnitude of its impact is still less than the above-mentioned regions. In the Chengdu–Chongqing city cluster (Column 5), the coefficient is negative (–0.165), and its value is not statistically significant. This probably stems from the fact that the region's digital infrastructure is quite underdeveloped and industrial transformation is ongoing. What this implies is that the digital economy's potential as an FDI magnet has not yet been tapped.

In short, the digital economy is capable of attracting FDI but across locational discontinuities ("regional gradient"). The FDI effect is maximum in the regions of YRD and Beijing–Tianjin–Hebei that have a well-developed digital infrastructure and industrial systems. At the whole country level, it has a positive impact but of a small magnitude. On the other hand, in the Chengdu–Chongqing area with an underdeveloped DED, there has been no significant attraction effect. Likewise, Wei et al.'s (2022) study on the spatial heterogeneity in FDI distribution showed that the digital economy's role in increasing investment is dependent on regional development conditions. So, the policymaking should be region-specific rather than the "one size fits all" approach. The leading regions ought to stay ahead by continuously enhancing their digital ecosystems, while the less developed regions should work first on their digital infrastructure and institutional environments so that they may be able to attract more FDI.

Table 10. Heterogeneity of China's four major city clusters

Variable	ln*fdi*				
	Yangtze River Delta	Nationwide	Beijing–Tianjin–Hebei	Pearl River Delta	Chengdu–Chongqing
	(1)	(2)	(3)	(4)	(5)
ln*dig*	5.153*** (1.035)	0.648 (0.441)	5.735*** (1.524)	1.566*** (0.359)	–0.165 (0.629)
Control variables	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	NO	YES
Year FE	YES	YES	YES	NO	YES
Observations	324	3360	156	108	192
Adj-R^2	0.737	0.475	0.781	0.606	0.550

Note: *** indicates $p < 0.01$.

5.4. Spatial spillover effect

To more precisely capture the spatial linkages of DED on FDI, this paper uses the geographic inverse distance matrix (W1) as the main spatial weight matrix and tests the geographic inverse distance squared matrix (W2) to see if the results hold true and also to address the issue of a single distance criterion that may cause measurement bias.

(1) Spatial correlation analysis

Spatial autocorrelation was measured with Global Moran's I index to check if DED and FDI show spatial clustering. Table 11 presents Moran's I values plus the respective levels of the significance of FDI (ln*fdi*) and DED (ln*dig*) over the 2012–2023 period. For the two spatial matrices, the majority of ln*dig*'s and ln*fdi*'s Moran's I values were both positive and significant at least at the 10% level. This demonstrates a powerful spatial correlation within the YRD city cluster. DED was seriously clustered, with Moran's I gradually increasing from 2020, in line with spatial linkages strengthening. Even if for some years the FDI was not significant, it showed a spatial dependence pattern overall. Such findings act as a good basis for the next spatial econometric analyses.

Table 11. Annual global Moran's I for key indicators

Year	Inverse distance matrix W1		Inverse distance square matrix W2	
	ln*fdi*	ln*dig*	ln*fdi*	ln*dig*
2012	0.094***	0.036**	0.216***	0.106**
2013	0.057***	0.021**	0.147***	0.081**
2014	0.034**	0.002	0.108**	0.051
2015	0.009	0.007	0.061	0.063
2016	0.013*	0.027**	0.070	0.098**
2017	0.015*	0.042***	0.077*	0.120**
2018	0.008	0.023**	0.064	0.084*
2019	0.012*	0.059***	0.076*	0.155***
2020	0.014*	0.090***	0.078*	0.216***
2021	0.022**	0.110***	0.094**	0.255***
2022	0.004	0.126***	0.055	0.286***
2023	–0.013	0.138***	0.028	0.308***

Note: ***, **, and * indicate $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

(2) Spatial spillover effects analysis

After confirming the existence of spatial dependence, the authors implemented a two-way fixed-effects SAR model to determine how DED affects FDI locally (direct effect) and in other regions (indirect effect). The appropriateness of the SAR model was established by LM, Hausman, and LR tests.

Table 12 details the spatial spillover effects. It can be seen that DED (ln*dig*) exerts a statistically positive direct effect on local FDI, since the estimated coefficients were 4.731 and 4.870 at the 1% level, regardless of the spatial weighting matrix chosen. Consistency in the

results with the base regression ones was observed, which further validated the importance of DED in attracting local FDI. On the other hand, indirect effects are significantly negative, indicating a "siphoning effect." Within the YRD city cluster, DED has not created strong regional synergy or diffusion; on the contrary, it has attracted FDI to core cities like Shanghai and Nanjing. This situation comes to light as city centers possess better digital infrastructure, high-quality financial resources, and mature industrial ecosystems, while surrounding cities are lacking in financial support, innovation capacity, and digital foundation. They have limited capability to attract or keep foreign investments. As a result, the main direction of the flow of resources and investment is from "center to the periphery." The significantly negative spatial autoregressive coefficient (ρ) in all models also points out that FDI interactions in the region are competitive rather than complementary.

In summary, whereas DED makes local areas more attractive for FDI, its effects at the moment in terms of spreading benefits evenly are quite limited. This is owing to the fact that digital resources and foreign capital in the YRD's city cluster are distributed very unequally.

Table 12. Spatial spillover effects analysis

Variable	Effect	Inverse distance matrix W1	Inverse distance square matrix W2
		ln*fdi*	ln*fdi*
		(1)	(2)
ln*dig*	Direct effect	4.731*** (0.999)	4.870*** (0.997)
ln*dig*	Indirect effect	–2.455*** (0.598)	–1.560*** (0.423)
ln*dig*	Total effect	2.276*** (0.581)	3.311*** (0.743)
Spatial rho		–1.035*** (0.239)	–0.457*** (0.119)
Control variables		YES	YES
Province FE		YES	YES
Year FE		YES	YES
Observations		324	324
R-sq: overall		0.756	0.768

Note: *** indicates $p < 0.01$.

6. Conclusions and policy implications

6.1. Conclusions

The YRD city cluster is the leading DED engine in China. It is dramatically accelerating the birth of a DED global hub through policy coordination, industrial city clusters, and innovation ecosystems, thereby creating new opportunities and growth pathways for FDI. Using panel data from the YRD city cluster over the period 2012 to 2023, this paper employs the entropy rights method to create a composite DED index, quantifies the level of DED, analyzes

its impacts on FDI, and explores the determinants and factors of heterogeneity. The main summaries are as follows.

(1) Both the benchmark regression and robustness checks indicate DED as a powerful factor for FDI attraction, making foreign capital utilization more effective in the YRD city cluster. Besides, being a "Broadband China" pilot city has a favorable dynamic effect on FDI, although the effect tends to wane over time.

(2) Mechanism analyses demonstrate the two-fold nature of DED in FDI attraction: First, it has a positive impact on technology and market growth, and second, it reduces transaction costs. The total mediating effect is, however, only slightly effective. The industrial upgrading mechanism did not achieve the significance level, probably because the indicators for the industrial structure are not adequate in distinguishing traditional from high-end services.

(3) Heterogeneity analysis of the exterior environment as well as the internal conditions of urban DED, it appears that DED's ability to attract FDI is higher in cities that have both a strong intellectual property protection system and a developed digital infrastructure. Besides, cities with a high level of economic development and medium-sized cities tend to be more capable of promoting FDI inflows through DED. The metropolitan-level heterogeneity analysis further demonstrates that the positive influence of DED on FDI differs quite markedly from one region to another. The YRD and Beijing–Tianjin–Hebei (BTH) metropolitan areas show the most extensive impacts, while the Pearl River Delta area experienced a relatively weaker investment attraction. Rather, the Chengdu–Chongqing metropolitan area, where digital infrastructure and industry are in transition, shows a negligible effect on promotion. From the standpoint of spatial spillover effects, while DED pushes local FDI inflows, it also shows a "siphoning effect" on surrounding areas, thereby laying bare the internal imbalances in digital resource allocation and the foreign investment distribution within the YRD region.

(4) The YRD city cluster's digital economic traits are, in fact, comparable to those of the European Union, ASEAN, and Latin American countries. For instance, EU member states are able to attract high-quality foreign investment items through better digital infrastructure and intellectual property protection; ASEAN countries use e-commerce and digital payment systems to reduce transaction costs and expand consumer markets; and Latin American nations improve their investment environments through digital regulation and open data policies. The YRD region in China has strong institutional advantages in digital industrialization and digital financial systems; however, there are still several aspects that can be improved, such as the regional coordination and alignment with international digital governance frameworks.

6.2. Theoretical contributions

This study makes theoretical contributions as follows. (1) Based on the literature, it develops a system to measure DED and FDI inflows at the city level, which uncovers their spatial and temporal evolution characteristics and impact relationships from a more micro perspective. (2) In this paper, the explanation of how DED impacts FDI inflows is given systematically in

four aspects: (i) technological innovation, (ii) reduction of transaction costs, (iii) upgrading of industrial structure, and (iv) expansion of consumption. The findings serve to deepen the theoretical discussions of DED and, at the same time, open up a new avenue for promoting FDI through DED. (3) To thoroughly examine the influence of DED on the attraction of FDI inflows, a heterogeneity analysis has been conducted by looking at two aspects: the external environment, i.e., the protection of intellectual property and digital infrastructures of urban DED, and internal conditions, i.e., economic levels and city size, thus offering a theoretical basis as well as practical examples for policy-making towards the simultaneous development of DED and FDI inflows.

6.3. Policy implications

For the YRD city cluster, the following policy recommendations are proposed.

First, promote the coordinated development of digital infrastructure and industries. Building on regional strengths and inspired by the EU's Digital Single Market, enhance connectivity in terms of 5G, computing power, and AI infrastructure to facilitate data flow and collaboration along the digital industrial chain and boost regional FDI spillovers. Considering the heterogeneity of city clusters, adopt differentiated strategies: advanced networks for mature city clusters, such as the YRD and BTH, and basic network expansion for developing city clusters, such as Chengdu–Chongqing, to strengthen their attraction to FDI.

Second, enhance the transmission mechanism of the DED on FDI inflows. Strengthen the deep integration of DED and real industries at the technical level, deepen digital industry chain collaboration, activate digital consumption and business models, innovate digital financial support systems, and amplify the synergistic effects of each link through policy coordination.

Third, strengthen intellectual property and digital innovation protection mechanisms. Align with international high-standard regulatory frameworks to establish mechanisms for protecting digital innovation outcomes and distributing associated benefits, thereby attracting technology-intensive and R&D-driven FDI. Drawing on the collaborative frameworks between the OECD and WIPO regarding digital patents and data ownership, cultivate an internationally recognized digital innovation ecosystem.

Fourth, promote regional coordination and South-South cooperation. Leveraging the RCEP and Belt and Road mechanisms, strengthen DED's cooperation with ASEAN and Latin American countries. Advance connectivity in digital technology standards, cross-border e-commerce, and smart manufacturing to establish a high-quality FDI network driven by DED.

6.4. Limitations and future research

Several directions for further research include exploring the connection between DED and FDI quality to broaden the research scope, constructing enterprise-level DED measurement indicators to examine the gravitational effect of DED on FDI inflows from a micro perspective, and separately examining the impact effects of different dimensions within the DED index system on FDI inflows.

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