



# OPEN Endowing urban business environments with an intelligent brain: empirical evidence from cities in western China

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As globalization advances, establishing a fair, efficient, and convenient business environment is vital to enhancing international competitiveness. Smart city development, as a new urban innovation model, drives digital transformation. It also improves market conditions, and speeds up urban reforms. Therefore, it is particularly important to examine how less developed regions can utilize smart city policy (SCP) to improve their business environment. This study is grounded in institutional theory, information economics, and the theory of competitive advantage. Using panel data from 82 cities in western China spanning 2006 to 2021, it treats SCP as a quasi-natural experiment and applies a multi-period difference-in-differences model. The research examines the link between smart city development and regional business environments, while also exploring the underlying mechanisms. The findings reveal that SCP have significantly improved the business environment in western China, which remains robust even after a series of robustness tests. The effects of SCP are particularly pronounced in megacities and in cities with higher levels of human capital, stronger financial support, and more advanced digital infrastructure. Moreover, SCP fosters a market-oriented, internationalized, and law-governed business environment, while Fintech further amplifies this positive impact. Additionally, SCP exhibits a significant spillover effect. These findings offer valuable insights for policymakers seeking to enhance the business environment in less developed regions.

**Keywords** Smart city policy, Business environment, Spatial spillover effect, Fintech

In 2002, the World Bank launched the Doing Business project, introducing the concept of the business environment for the first time. The project defined the business environment as a set of external conditions that enterprises cannot control but that significantly impact their entire lifecycle. Following this, the World Bank established a business environment evaluation system to comprehensively rank the business environments of different countries. In May 2023, the World Bank introduced the B-READY framework, a new system designed to assess the legal framework and regulatory quality of business environments. According to the 2024 report based on this framework, the top ten economies with the best business environment indices include Singapore, Estonia, Georgia, Rwanda, Hungary, Portugal, Czechoslovakia, Bulgaria, Hong Kong (China), and New Zealand. Notably, the ranking features few developing countries or emerging markets, highlighting a significant gap. For emerging markets, optimizing the business environment has become a critical issue for enabling markets to play a decisive role in resource allocation and enhancing international competitiveness.

As the largest developing country, China ranked 91st in the comprehensive business environment index in 2005. However, in the World Bank's 2020 Doing Business Report, China's ranking surged to 31st place, making it one of the top ten economies with the most significant improvements in the business environment globally. The western region of China, due to geographical constraints, economic development disparities, and institutional limitations, has struggled with inefficiencies in its soft institutional environment. In recent years, while the overall business environment in western China still lags that of the central and eastern regions, its improvement has been more pronounced than in the central and eastern regions<sup>1</sup>.

On the one hand, this progress can be largely attributed to the Chinese government's policies and initiatives aimed at optimizing the business environment and promoting economic development. Table 1 provides a

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Year	City	Policy
2021	Chongqing	Chongqing business environment optimization regulations
2020	Gansu	Measures on implementing the business environment optimization regulations
2021	Xinjiang	Implementation measures for the business environment optimization regulations in Xinjiang Uyghur autonomous region
2020	Guangxi	Guangxi Zhuang autonomous region business environment optimization regulations
2021	Guizhou	Guizhou province business environment optimization regulations
2020	Yunnan	Yunnan province business environment optimization measures
2020	Ningxia	Deepening “delegation, regulation, and service” reform to optimize the business environment in Ningxia Hui autonomous region
2021	Qinghai	Qinghai Province Business Environment Optimization Regulations
2018	Shaanxi	Shaanxi province business environment optimization regulations
2021	Sichuan	Sichuan province business environment optimization regulations
2020	Tibet	Tibet autonomous region 2020 business environment optimization work plan
2021	Inner Mongolia	Inner Mongolia autonomous region business environment evaluation implementation measures (Trial)

**Table 1.** Statistical analysis of local regulatory measures aimed at optimizing the business environment.

detailed overview of these policy measures. On the other hand, China’s smart city pilot program has expanded to 290 cities, forming a new urban model in the Smart City 2.0 era. Among the 94 cities in western China, 37 have been designated as smart city pilots, accounting for nearly 40% of the region. As an innovative model of urban development<sup>2</sup>, smart cities leverage intelligent computing technologies to enhance the intelligence, coordination, and efficiency of key urban infrastructure and services. Additionally, smart city development has significantly improved urban ecological efficiency, and the policy effects have strengthened over time<sup>3</sup>. When measuring urban ecological efficiency, key indicators typically include resource inputs, economic benefits, and environmental impacts, all of which are closely linked to the business environment. This suggests that smart city development plays a crucial role in optimizing the business environment.

From the perspective of institutional economics, institutions serve as effective constraints on economic behavior. Their core function is to reduce transaction costs and institutional uncertainty, thereby improving institutional efficiency and enhancing economic performance<sup>4</sup>. SCP as a form of institutional reform, are not merely about building digital infrastructure; more importantly, they represent a systemic transformation of governance models and institutional arrangements<sup>5</sup>. By leveraging digital technologies such as big data, cloud computing, and artificial intelligence, smart city improves information structures and governance capacity across multiple dimensions. This, in turn, helps optimize market operations and regulatory order, providing institutional support for the enhancement of the business environment.

Based on the above analysis, this study empirically examines the impact of SCP on the optimization of the business environment in western China from 2006 to 2021. To understand how smart city policies affect the business environment, this study integrates insights from institutional economics, information economics, and the theory of national competitive advantage. Based on these perspectives, it constructs an analytical framework centered on the core mechanisms of marketization, internationalization, and legal institutionalization. Additionally, it investigates whether SCP and business environment optimization interact positively from the perspective of Fintech advancement. Finally, a spatial model is constructed to examine the spillover effects of smart city program on the business environment.

This research makes several key contributions: First, for emerging economies, optimizing the business environment has become a critical factor in enhancing international competitiveness and capturing global market share. China, as a leader in business environment reforms, serves as a benchmark for other emerging economies seeking to improve their local business environment. By analyzing the business environment in western China, this study offers valuable insights and lessons for other developing economies worldwide. Second, Existing research primarily qualitatively analyzes smart city development, lacking empirical validation to assess how smart cities impact economic practices<sup>6</sup>. China launched its first batch of smart city pilot projects in 2012, followed by a second and third batch in 2013 and 2014, respectively. As a result, 37 cities in western China were eventually selected as smart city pilots. Leveraging the gradual rollout of SCP, this study empirically investigates how smart cities, through digital infrastructure development, contribute to business environment optimization and economic growth. Finally, Existing research primarily examines how the business environment influences macroeconomic development<sup>7,8</sup> and corporate operations<sup>9,10</sup>, but few studies explore the driving factors behind business environment optimization. Western China, with underdeveloped infrastructure and weak institutional frameworks, faces significant challenges in both hardware and software support for business-friendly policies. However, SCP enhances digital infrastructure, attracts skilled talent, and fosters business environment optimization. By simultaneously improving hardware environment and software environment, smart city program contributes to economic growth in western China.

## Policy background and theoretical analysis

### Smart city policy

The concept of smart cities was initially proposed to address the various challenges brought by urban sprawl in Western countries. Smart city development is built on digital technology as its core foundation, with the primary goal of enhancing interconnectivity and intelligence within urban operational systems, thereby

fostering a new model of urban innovation and development. As the digital era unfolds, countries worldwide have launched smart city development strategies aimed at optimizing urban governance, improving resource allocation efficiency, and enhancing residents' quality of life. In 2004, South Korea introduced the "U-Korea" development strategy, dedicated to building an eco-friendly, digitalized, and seamlessly mobile-connected smart city. In 2006, the European Union initiated the European Smart Cities Network, and in June of the same year, Singapore formulated a ten-year plan, "Intelligent Nation 2015," to advance the nation's smart city infrastructure. In 2009, the city of Dubuque established the first smart city in the United States, leveraging IoT technology to interconnect various public resources and integrating big data analytics to intelligently address the diverse needs of residents. China first introduced the "smart city" concept in 2009, and in 2012, the Ministry of Housing and Urban-Rural Development issued the "Interim Administrative Measures for National Smart City Pilot Programs", announcing the first batch of 90 pilot smart cities at the county level. By 2017, 95% of provincial-level cities and 76% of county-level cities had either formulated or implemented smart city development plans. As of today, China has launched more than 500 smart city pilot programs, exceeding the total number in all other regions worldwide. Compared with traditional urban development policies, SCP take a more human-centric approach by deeply integrating artificial intelligence with sustainable economic development. As a result, SCP have become a key policy tool driving China's green economic growth (Guo et al., 2022). Current research on smart cities primarily focuses on three core areas: (1) The impact of smart city development on the ecological environment. (2) The role of smart city development in fostering technological innovation. (3) The contribution of smart city program to improving economic and ecological efficiency.

First, the green industrial park theory suggests that reducing energy consumption through intelligent resource management and industrial symbiosis can drive the green transformation of industries. Studies have shown that smart city development significantly reduces urban carbon emissions<sup>11</sup>, improves energy efficiency<sup>6</sup>, and enhances urban green total factor productivity<sup>12</sup>, ultimately contributing to higher levels of urban green and low-carbon development<sup>2</sup>. Most research finds that smart cities, supported by information and communication technology (ICT) applications, reduce urban energy consumption through multiple channels, particularly in smart transportation and smart grid systems<sup>13</sup>. Moreover, ICT technology enables demand-side management and low-carbon scenario design through smart monitoring systems and data visualization technologies<sup>14</sup>. Second, according to Porter's hypothesis, smart city development fosters technological innovation, particularly in energy-saving and clean production technologies, which enhance resource efficiency and reduce pollution emissions. The systemic governance framework of smart cities, especially through cross-departmental collaboration and multi-stakeholder participation, has effectively promoted urban innovation and transformation<sup>15</sup>. Caragliu<sup>16</sup> further argues that SCP not only directly impact smart city-related technologies but also generate technological spillover effects, facilitating broader technological innovation through technology cooperation and localized applications. Finally, Fromhold-Eisebith<sup>5</sup> emphasizes that SCP are not merely technology-driven urban solutions but also processes that drive governance transformation. While SCP may not always fully achieve their technological objectives, they can still promote sustainable urban development through institutional reforms. Similarly, Nam et al.<sup>17</sup> argue that smart cities should not be viewed solely as a technological concept but rather as a broader socio-economic development strategy. Since urban green development, technological innovation, and economic growth contribute to an improved business environment, smart city development plays a crucial role in optimizing the business environment.

### theoretical analysis

Institutional theory posits that institutions function as constraints on the behavior of economic actors. Their core role is to reduce transaction costs and institutional uncertainty, thereby enhancing institutional efficiency and economic performance<sup>4</sup>. SCP as a form of institutional reform<sup>5</sup>, represent not only the development of digital infrastructure but also a systemic transformation of governance arrangements. By applying advanced digital technologies such as big data, cloud computing, and artificial intelligence, SCP improve the quality and accessibility of market information<sup>18</sup>, mitigating moral hazard and adverse selection. Through the creation of data-sharing platforms, SCP reduce information asymmetries between financial institutions and enterprises, lowering transaction costs and uncertainty. At the same time, they establish more efficient and accessible communication channels for cross-border trade, thereby reducing communication and logistics costs. The development of digital infrastructure not only enhances trade facilitation but also contributes to the expansion of international trade<sup>19</sup>. Moreover, SCP strengthen institutional performance through the construction of digital governance platforms, intelligent regulatory systems, and information-sharing mechanisms. These tools help mitigate information asymmetries between governments and market participants, improve policy implementation efficiency, and reduce enforcement costs. As a result, SCP enhance institutional predictability and transparency, support the standardization of market operations, and create a business environment that is more convenient, efficient, and equitable. Based on this, the study proposes the following research hypothesis.

**Hypothesis 1** SCP promote the optimization of the urban business environment.

Smart city is not merely the accumulation of digital infrastructure; rather, it constitutes a profound process of institutional transformation. By enabling technological empowerment, institutional restructuring, and governance enhancement, smart cities promote the improvement of the urban business environment across multiple dimensions. To systematically analyze the underlying mechanisms, this study draws upon information economics, the theory of competitive advantage, and institutional economics, constructing an analytical framework centered on three key pathways: marketization, internationalization, and legal institutionalization.

First, according to information economics, the non-rivalrous nature of information implies that information sharing can enhance overall market welfare<sup>20</sup>. When information search costs are high, market participants

are less able to make optimal decisions. Smart cities address this problem by developing digital platforms—such as big data systems and blockchain networks—that promote market-wide information sharing. These platforms reduce the information costs faced by financial institutions and mitigate information asymmetry. As a result, reduced asymmetry between banks and enterprises lowers firms' borrowing costs, decreases banks' operational risks, and improves the efficiency of financial resource allocation, thereby fostering a more effective and accessible market environment<sup>18</sup>.

Second, the theory of national competitive advantage suggests that firm competitiveness is shaped not only by internal capabilities but also by the surrounding institutional and infrastructural context<sup>21</sup>. Smart cities support the construction of cross-border digital infrastructure—such as smart ports and international data exchange platforms—which improves customs efficiency, reduces transaction costs, and creates new trade opportunities<sup>19,22</sup>. Furthermore, the emergence of digital trade regulations provides firms with a more predictable and supportive institutional framework. The interplay of digitalization, connectivity, and globalization also enhances cities' ability to attract international capital and enterprises.

Finally, Acemoglu and Robinson<sup>23</sup> argue that inclusive institutions are central to long-term economic development, while extractive institutions are more prone to rent-seeking and corruption. Smart city construction fosters inclusive governance through the integration of digital technologies with public administration. Platforms such as “Internet+Government Services” enhance citizen oversight and participation by enabling open access to government data and the digital supervision of administrative procedures<sup>24</sup>. These initiatives increase institutional transparency, improve regulatory efficiency, and help curb corruption<sup>25</sup>. Moreover, they strengthen the rule of law by enhancing legal accountability for both government and businesses, thereby cultivating a business environment that is fair, transparent, and conducive to sustainable growth. Based on this, the study proposes the following hypothesis. The mechanism proposed is illustrated in Fig. 1.

**Hypothesis 2** SCP influence the business environment by advancing marketization, legal institutionalization, and internationalization.

The innovation diffusion theory describes the process through which a new idea or concept is disseminated and adopted. As of now, only two-fifths of cities in western China have been selected as pilot cities for smart city development, and their digital transformation fosters local technological innovation. Compared with earlier communication technologies, the information technologies used in smart cities are better equipped to transcend geographical distance<sup>26,27</sup>. First, population mobility and the convenience of intelligent transportation in these pilot cities, technological talent is likely to migrate to neighboring cities, facilitating knowledge and technology spillovers from central cities to surrounding areas. Second, this spillover effect is not only reflected in technology and infrastructure development but may also profoundly influence regional economic development models. As smart city program advance, the experience and resources accumulated by central cities in digital economy, smart manufacturing, and technology services will gradually diffuse to surrounding regions through industrial collaboration and supply chain linkages, thereby promoting regional industrial upgrading and economic integration. Thus, SCP not only directly enhance the economic vitality of central cities but also stimulate high-quality development in surrounding cities through spillover effects, ultimately optimizing the overall regional business environment.

**Hypothesis 3** SCP generate positive spatial spillover effects.

## Methodology

### Regression model

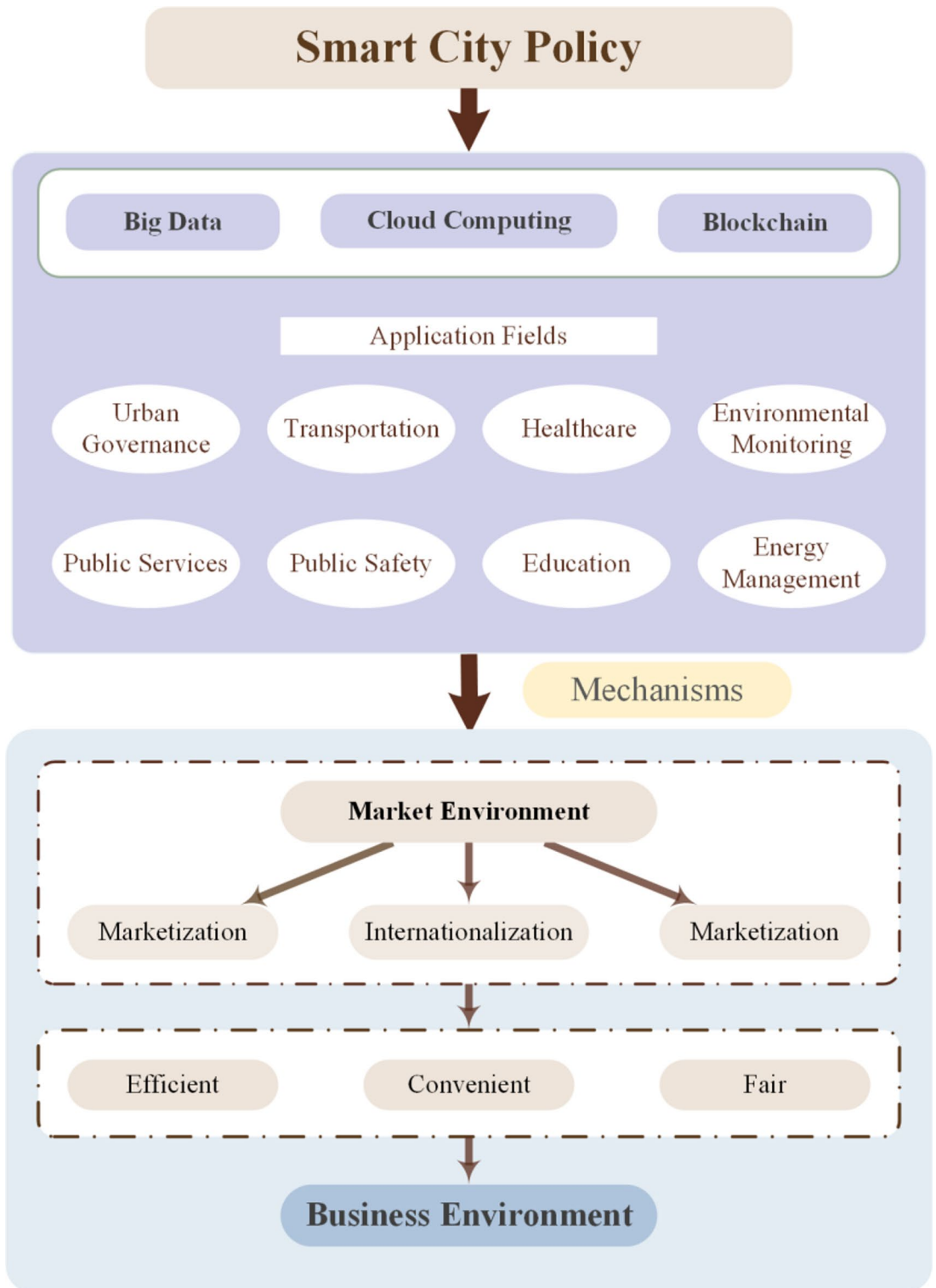
The impact of SCP on the business environment includes time effects that evolve over time and policy treatment effects resulting from the implementation of specific policies. This study focuses primarily on examining the policy treatment effects of smart city program on the urban business environment. The difference-in-differences (DID) model is particularly effective in distinguishing between these two effects, providing a robust analysis of the treatment effects caused by the implementation of SCP while also helping to mitigate potential endogeneity issues. The specific model structure is as follows:

$$BE_{i,t} = \beta_0 + \beta_1 SCP_{i,t} + \beta_2 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

Here,  $i$  represents the city, and  $t$  represents the year. The dependent variable,  $BE_{i,t}$ , denotes the business environment of city  $i$  in year  $t$ .  $SCP_{i,t}$  is a dummy variable that equals 1 if city  $i$  is selected as a national smart city pilot in year  $t$  or any subsequent years, and 0 otherwise. The coefficient  $\beta_1$  measures the impact of smart city development on the business environment. A positive and significant  $\beta_1$  indicates that smart city development enhances the urban business environment, while a negative and significant  $\beta_1$  suggests that it worsens the business environment.  $X_{i,t}$  represents a series of control variables, including urban economic density, urbanization rate, expenditure on education level, fiscal investment effort, Internet penetration rate, economic development.  $\mu_i$  and  $\lambda_t$  capture city fixed effects and time fixed effects, respectively.  $\varepsilon_{i,t}$  represents the random error term.

To better verify the mechanism by which SCP impacts the business environment, this study adopts the research methodology from<sup>28</sup>. This method effectively avoids endogeneity issues commonly found in traditional mechanism analyses, thereby making the test results more robust and persuasive. The study establishes Eq. (2) as follows:

$$M_{i,t} = \beta_0 + \beta_3 SCP_{i,t} + \beta_4 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$



**Fig. 1.** Research framework diagram. The diagram outlines the overall structure and methodology of the study.

Here,  $M_{i,t}$  represents the mechanism variable, while the meanings of the other variables remain consistent with those in Eq. (1). Together, Eqs. (1) and (2) constitute the mechanism testing model. The coefficients of the key explanatory variables in Eqs. (1) and (2) are denoted as  $\beta_1$  and  $\beta_3$ , respectively. If both  $\beta_1$  and  $\beta_3$  are statistically significant, the proposed mechanism pathway is confirmed. Furthermore, this study seeks to determine whether Fintech plays a moderating role in the relationship between SCP and the business environment. Therefore, we establish Eq. (3) as follows:

$$BE_{i,t} = \beta_0 + \beta_5 SCP_{i,t} + \beta_6 X_{i,t} + \beta_7 Z_{i,t} * D_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (3)$$

Here,  $Z_{i,t}$  represents the moderating variable, and  $\beta_7$  denotes the coefficient of the interaction term between the moderating variable and the core explanatory variable, which reflects the regulatory role of Fintech on policy effects. The meanings of the other variables remain consistent with those in Eq. (1). If  $\beta_7$  is statistically significant, it indicates that the moderating effect holds. SCP has driven technological progress and facilitated resource agglomeration. Cities with higher administrative rankings leverage their capacity to concentrate resources and technology, generating regional spillover effects that influence the emission reduction performance of neighboring areas<sup>11</sup>. Based on this premise, we construct a spatial econometric model to examine whether SCP exerts a spatial spillover effect on the business environment. Accordingly, we formulate Eqs. (4)–(6).

$$BE_{i,t} = \beta_0 + \theta W + \beta_8 SCP_{i,t} + \beta_9 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (4)$$

$$BE_{i,t} = \beta_0 + \gamma W BE_{i,t} + \beta_{10} W SCP_{i,t} + \beta_{11} X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (5)$$

$$BE_{i,t} = \beta_0 + \gamma W BE_{i,t} + \beta_{12} W SCP_{i,t} + \rho W SCP_{i,t} + \beta_{13} X_{i,t} + \beta_{14} W X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (6)$$

Equation (4) represents the Spatial Error Model (SEM). It assumes that unobservable factors exhibit spatial correlation. This correlation is transmitted through the error term to identify the impact of spatial variables on the measured space. In this model,  $\theta$  denotes the spatial error coefficient, which captures the extent to which the unobserved characteristics of neighboring areas influence the local business environment.  $W$  represents the spatial weight matrix, which based on the reciprocal of geographic distance. Equation (5) corresponds to the Spatial Autoregressive Model (SAR). In this model, it is assumed that a city's business environment is influenced not only by its own SCP but also by the business environment levels of neighboring cities.  $\gamma$  denotes the coefficient of the spatially lagged dependent variable, reflecting how the business environment of neighboring areas affects the local business environment.  $W BE_{i,t}$  represents the weighted average influence of the business environment of neighboring cities, and  $W SCP_{i,t}$  represents the weighted average impact of the neighboring cities' smart city policies. Equation (6) represents the Spatial Durbin Model (SDM). It is employed to capture both the direct effect of SCP on the local business environment and the spatial spillover effects on neighboring regions. Here,  $\rho$  denotes the coefficient of the spatial lag term of the SCP, reflecting the extent to which the promotion of SCP in neighboring areas indirectly impacts the local business environment.  $W X_{i,t}$  captures the influence of neighboring cities' characteristics on the local outcomes.

The prerequisite for constructing a spatial econometric model to examine whether SCP has a spatial spillover effect on the business environment is to first verify the spatial correlation of the business environment. To achieve this, we employ Moran's I index to analyze the spatial correlation of the business environment. The calculation formulas for Moran's I are presented in Eqs. (7)–(9).

$$Moran's I = \frac{\sum_{a=1}^n \sum_{b=1}^n (BE_a - \overline{BE}) (BE_b - \overline{BE})}{S^2 \sum_{a=1}^n \sum_{b=1}^n W_{ab}} \quad (7)$$

$$S^2 = \frac{1}{n} (BE_a - \overline{BE}) \quad (8)$$

$$\overline{BE} = \frac{1}{n} BE_a \quad (9)$$

$S^2$  represents the variance of BE,  $\overline{BE}$  denotes the mean value of BE, and  $n$  is the number of sample cities. If the Moran's I index is greater than 0, it indicates a positive spatial correlation between provinces, whereas a value less than 0 suggests a negative spatial correlation. To further analyze spatial relationships, we construct a geographical distance matrix, denoted as  $W$ , which is formulated as shown in Eq. (10).

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (10)$$

$d_{ij}$  represents the distance between city  $i$  and city  $j$ , where  $(x_i, y_i)$  and  $(x_j, y_j)$  are the geographical coordinates of city  $i$  and city  $j$ , respectively.

## Variable description

### Business environment

Scholars have varied approaches to constructing and measuring the business environment index system. To more comprehensively and accurately assess the business environment, the number of indicators included in the index system has increased, and the methods of measurement have become more complex. The World Economic Forum ranks countries' business environments based on the average of the Global Competitiveness Index, which was developed by Martin and Elsa through a stepwise weighted approach. The World Bank employs the "frontier distance method", while other scholars have utilized methods such as weighted averaging, principal component analysis, factor analysis, and entropy methods<sup>1,24,29–31</sup>. As China increasingly emphasis on optimizing business environment, Chinese economic research institutes have launched the "China Urban Business Environment Assessment" research project. Drawing on the indicator design by Li and Yin et al.<sup>29,32</sup> and the "China Urban Business Environment Evaluation" project team from the Economic Research Institute of Management World, this study constructs a business environment evaluation system based on six key dimensions—public

services, human resources, market environment, innovation environment, financial services, and government environment—along with 18 secondary indicators. The entropy weight method assigns weights based on data variability. The smaller the entropy of an evaluation index, the greater the degree of variation, which means more information is provided, thus increasing the weight of the comprehensive evaluation. Since the business environment indicators consist of multiple components, the entropy weight method can avoid the interference of subjective human judgment, effectively enhancing the objectivity of the overall evaluation. The process involves first calculating the weights of tertiary indicators under each secondary indicator, then using these weights to compute the comprehensive scores of the secondary indicators. Next, the process is repeated to calculate the comprehensive scores of the primary indicators, and finally, the overall business environment score is obtained through the same method. The specific process and results are as follows:

*Step 1* Standardizing the raw data for comparability which ensure the comparability of different indicators. To prevent the occurrence of  $\ln 0$ , a small constant (0.00000001) is added to the data. For positive indicators, Eq. (11) is applied. For negative indicators, Eq. (12) is used. Here,  $i$  represents the sample size, and  $j$  represents the number of indicators.

$$X_{ij}' = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}} + 0.00000001 \quad (11)$$

$$X_{ij}' = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}} + 0.00000001 \quad (12)$$

*Step 2* Calculating the entropy value of each indicator.

$$r_{ij} = \frac{X_{ij}'}{\sum_{i=1}^{304} X_{ij}'} \quad (13)$$

$$e_j = -\frac{1}{\ln 304} \sum_{i=1}^{304} r_{ij} \ln r_{ij} \quad (14)$$

*Step 3* Calculating the weight of each indicator.

$$w_j = \frac{1 - e_j}{\sum_{j=1}^n 1 - e_j} \quad (15)$$

*Step 4* Calculating the comprehensive score for each sample.

$$F_i = \sum_{j=1}^n w_j X_{ij}' \quad (16)$$

Based on the above calculation method, the weight distribution of the regional business environment indicator system is presented in Table 2. Table 3 lists the business environment scores and rankings of the provincial capital cities in the western region for the years 2006 and 2021. From Table 3, it can be observed that while all cities have experienced a significant improvement in their business environment scores, the rankings of some cities have declined. This suggests that despite progress, the relative competitiveness of certain cities has weakened compared to others in the China's western region.

#### Smart city policy

China first proposed the concept of smart cities in 2009 and officially introduced SCP which piloted in 90 prefecture-level and county-level cities in 2012. In this study, smart city pilot is treated as a quasi-natural experiment. Given that this study focuses on western China, the evaluation of the treatment effect of SCP is primarily based on cities in this region that were selected as smart city pilots between 2012 and 2014. To examine the impact of SCP, this study constructs a dummy variable, which comprises two components: (1) a treatment dummy variable (treated), where cities designated as smart city pilots are assigned to the treatment group (treated = 1), while non-pilot cities constitute the control group (treated = 0); and (2) a time dummy variable (time), where time = 1 if the year in which a city is selected as a pilot and all subsequent years, otherwise time = 0.

#### Control variables

In selecting control variables, we focus on factors that have a significant impact on the business environment but are not yet included in the business environment evaluation index system. Drawing on the findings of Li and Clarke et al.<sup>32,33</sup>, we incorporate additional city-specific characteristics that may influence the business environment to minimize the potential impact of omitted variable bias. These control variables include urban economic density, urbanization rate, expenditure on education level, fiscal investment effort, Internet penetration rate, economic development. The definitions of the key variables are presented in Table 4. Additionally, a correlation analysis was conducted for the control variables. As shown in Fig. 2, darker colors indicate a stronger positive correlation, while lighter colors indicate a stronger negative correlation. Some variables exhibit negative correlations, others show positive correlations, and certain variables display no significant correlation with each other.

Primary indicators	Weight(%)	Secondary indicators	Weight(%)	Tertiary indicators	Weight(%)
Public services	0.14	Natural Gas Supply	0.41	Gas supply capacity (10,000 tons)	
		Water Supply	0.25	Public water supply capacity (10,000 cubic meters)	
		Electricity Supply	0.20	Industrial power supply capacity (10,000 kilowatt-hours)	
		Medical Conditions	0.14	Medical and health services (hospital beds per 10,000 people)	
Human resources	0.12	Human Resource Reserve	0.88	Number of students enrolled in higher education institutions (people)	0.62
		Labor Cost	0.12	Number of employees in registered work units at year-end (people)	0.38
Market environment	0.10	Economic Indicator	0.15	Regional GDP per capita (RMB)	0.33
				Total fixed asset investment (RMB10000)	0.67
		Imports & Exports	0.62	Actual utilization of foreign capital in the current year (RMB10000)	0.65
				Number of newly signed contracts in the current year (unit)	0.35
Enterprise Structure	0.23	Number of large-scale industrial enterprises (unit)			
Innovation environment	0.29	Innovation Investment	0.44	Science and technology expenditure (RMB10000)	
		Innovation Output	0.56	Number of invention patents granted (unit)	
Financial services	0.20	Industry Scale	0.39	Number of employees in the financial industry (10000people)	
		Financial Services	0.61	Year-end loan balance of financial institutions (RMB)	
Government environment	0.15	Government Expenditure	0.37	General budgetary expenditure (RMB10000)	
		Government Revenue	0.63	General budgetary revenue (RMB10000)	

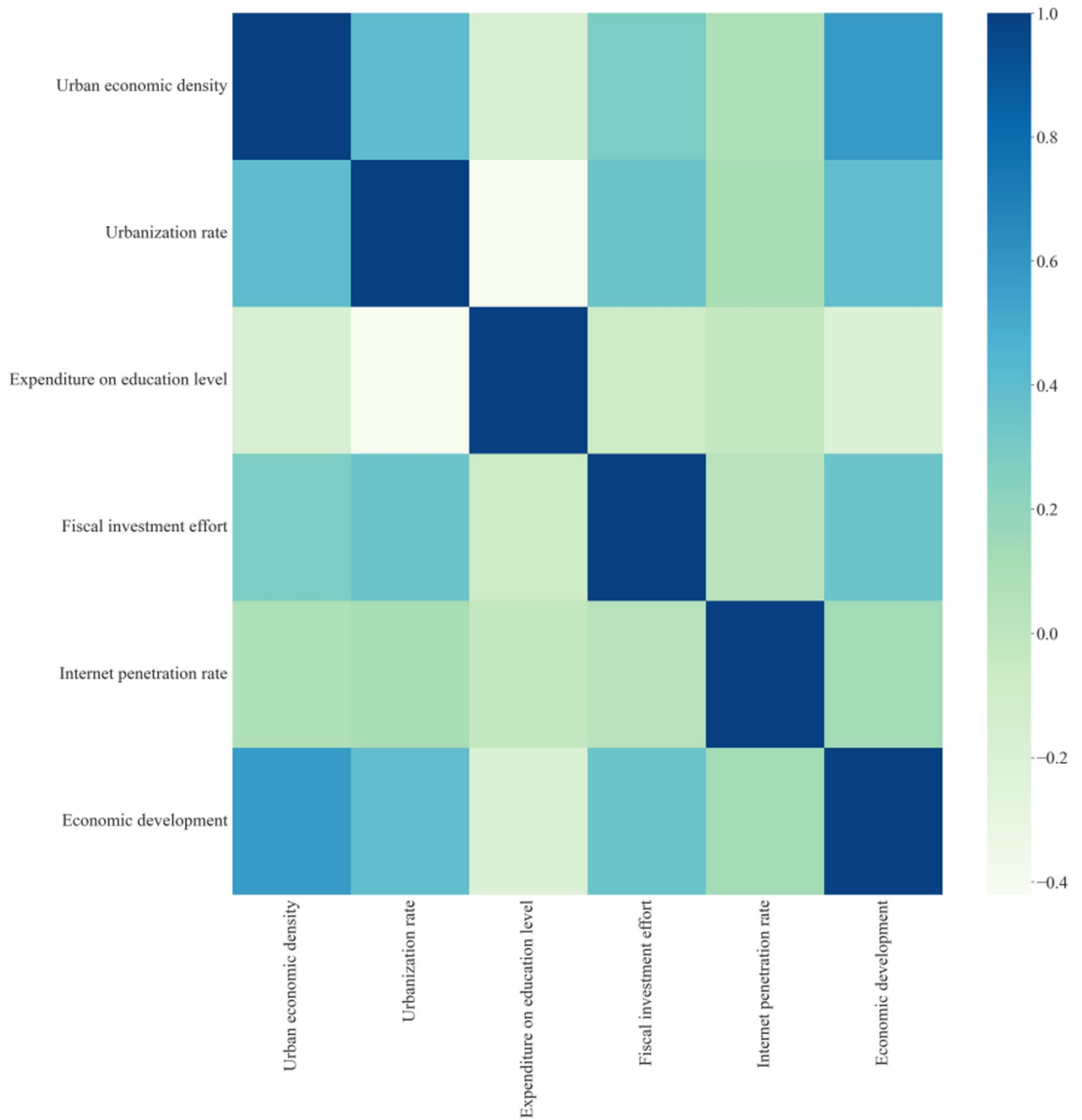
**Table 2.** Business environment indicators. The indicators for constructing the business environment were calculated using the entropy weight method.

City	2006	Rank	2021	Rank
Chongqing	0.1666	1	0.7531	2
Chengdu	0.1499	2	0.7797	1
Xi'an	0.1026	3	0.5044	3
Ürümqi	0.0913	4	0.1761	7
Kunming	0.0622	5	0.2602	4
Nanning	0.0540	6	0.1900	6
Guiyang	0.0534	7	0.2096	5
Lanzhou	0.0441	8	0.1112	9
Hohhot	0.0363	9	0.1345	8
Yinchuan	0.0240	10	0.0828	11
Xining	0.0233	11	0.0917	10

**Table 3.** Business environment scores and rankings of provincial capital cities.

Variable (unit)	Definition	Mean	Max	Min
Business environment	BE	0.049	0.780	0.001
Smart city policy	SCP	0.251	1	0
Urbanization rate (%)	Proportion of urban residents in the total population	49.336	99.87	15.279
Urban economic density (%)	Regional GDP per unit of administrative land area	9.233	138.940	0.089
Expenditure on education level (%)	Share of education expenditure in the local public budget	17.913	37.743	0.001
Fiscal investment effort (%)	Share of fixed asset investment in the local public budget	430.336	1632.051	8.511
Internet penetration rate (%)	number of internet users as a share of the total population	1.948	24.538	0.000
Economic development (RMB 10,000)	Logarithm of actual GDP	15.630	19.089	13.021
Marketization index (RMB 10,000)	Total outstanding RMB loans at financial institutions by year-end	4.09e + 07	9.18e + 08	822,787
Internationalized index (%)	total imports and exports as a percentage of regional GDP	22.371	2487.773	0.000
Legal institutionalization index (%)	Frequency of references to digital economy policies	0.002	0.037	0.000
Fintech (%)	Digital finance index	2.373	6.745	0.000

**Table 4.** Descriptive statistics. The definitions of the main variables in this study are provided, along with calculations of their mean, maximum, and minimum values.



**Fig. 2.** Correlation matrix of control variables. Heatmap of the correlation coefficients of control variables in the baseline regression.

*Mediating and moderating variables*

This study examines the mechanism through which smart city development policies enhance the business environment by fostering a market-oriented, globally integrated, and law-governed market system. It also explores the moderating effect of Fintech on the relationship between SCP and the business environment. To measure Fintech, this study utilizes the Digital Financial Inclusion Index compiled by the Peking University Internet Finance Research Center. This index that based on data provided by Ant Financial assesses the level of Fintech at the provincial and city levels across China (excluding Hong Kong, Macau, and Taiwan). The index is employed as a proxy variable for Fintech development and has been normalized for analysis.

**Data source**

This study selects 82 cities in western China from 2006 to 2021 as the research sample, resulting in a total of 1312 observations. Considering data availability and reliability, we exclude data prior to 2006 due to its limited

representativeness and do not include post-2021 data due to substantial missing values. Consequently, we conduct empirical analysis using data from 2006 to 2021. For variables with minor missing values, we employ interpolation methods for imputation. The business environment is measured using the entropy method, incorporating six dimensions and 18 indicators. The primary data sources include the China Urban Statistical Yearbook, the China Environmental Statistical Yearbook, and the Wind Database. The rule of law indicator is derived through web scraping and systematic compilation of policy documents published by prefecture-level governments. Specifically, we assess the presence of digital economy-related keywords in these documents, ultimately determining the indicator based on the proportion of relevant keywords to the total word count.

## Results and discussions

### Baseline regression results

We use Eq. (1) to examine the relationship between SCP and the business environment with the regression results presented in Table 5. In Column (1), no regional characteristic variables are controlled, and a fixed-effects model is not applied. Column (2) controls for regional characteristics while incorporating city fixed effects, but without year fixed effects. Column (3) controls for regional characteristics and simultaneously includes both city and year fixed effects. Across all specifications, the regression results consistently indicate a significant positive impact at the 10% level. This suggests that the development of smart cities effectively enhances the urban business environment, providing empirical support for Hypothesis 1.

On one hand, SCP provide assurance that market participants operate in a fair and equitable competitive environment by building digital government platforms that enable information sharing and intelligent supervision. At the same time, the extensive use of IoT-enabled big data, artificial intelligence, and blockchain technologies in smart cities not only enhances government governance capacity and efficiency<sup>34</sup> but also establishes communication bridges between the government, enterprises, and citizens, thereby promoting government-society cooperation<sup>24</sup>. Moreover, smart cities are not limited to intelligent governance but also encompass a smart economy, smart transportation, smart living, and a smart environment. The multidimensional application of ICT improves the quality and efficiency of urban services, reduces corporate costs, and further optimizes the business environment<sup>35</sup>.

On the other hand, smart city systems drive urban technological innovation and transformation by fostering collaboration among governments, enterprises, and universities<sup>5,15</sup>, thereby enhancing urban competitiveness<sup>36</sup>. Meanwhile, intelligent resource management facilitates the rational allocation of energy, reduces energy

	(1)	(2)	(3)	(4)
	BE	BE	BE	BE
did	0.030*** (9.730)	0.006** (2.059)	0.005* (1.857)	
Urbanization rate		0.000** (2.219)	0.000** (2.347)	0.001** (3.159)
Urban economic density		0.396*** (28.105)	0.410*** (28.175)	0.410*** (28.507)
Expenditure on education level		0.015 (0.484)	0.012 (0.375)	0.0018 (0.059)
Fiscal investment effort		-0.003*** (-4.234)	-0.003*** (-3.858)	-0.003*** (-4.109)
Internet penetration rate		0.000* (1.652)	0.000* (1.730)	0.001*** (2.612)
Economic development		0.008* (1.924)	0.000* (1.730)	-0.008** (-2.564)
did (ln (GDPpc) < 10.771)				0.001 (0.076)
did (ln (GDPpc) > 10.771)				0.008** (2.471)
Constant	0.042*** (5.421)	-0.113* (-1.828)	0.080 (1.035)	0.120*** (2.655)
City fixed effects	No	No	Yes	Yes
Year fixed effects	No	Yes	Yes	Yes
N	1312	1312	1312	1312
R <sup>2</sup>	0.071	0.547	0.549	0.546

**Table 5.** Baseline regression results. The first column presents results without control variables and fixed effects. The second columns show results with time fixed effects. The third column includes both control variables and a model with dual fixed effects. The fourth column presents the results of threshold regression. The brackets represent t value. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively.

consumption, and drives the green transformation of industries, ultimately improving the level of urban green and low-carbon development. Increased technological innovation, industrial upgrading, and optimized resource allocation enhance urban ecological efficiency, which further contributes to the optimization of the business environment<sup>3</sup>.

This study first employs a multi-period DID model with fixed effects to examine the linear relationship between SCP and the business environment. Compared to the traditional DID approach, the multi-period DID method offers greater applicability by accommodating the staggered implementation of policies over time, while effectively controlling for unobservable individual fixed effects and time trends, thereby enhancing estimation accuracy and external validity. Initially, a linear analysis based on fixed effects was conducted, and subsequently, a panel threshold regression was introduced as a supplementary test, using the logarithm of per capita regional GDP as the threshold variable. The results show that the estimated threshold value is 10.771. Column (4) of Table 5 indicates that the policy effect is insignificant when financial support is below the threshold, whereas the effect becomes significantly positive once financial support exceeds the threshold.

## Robustness test

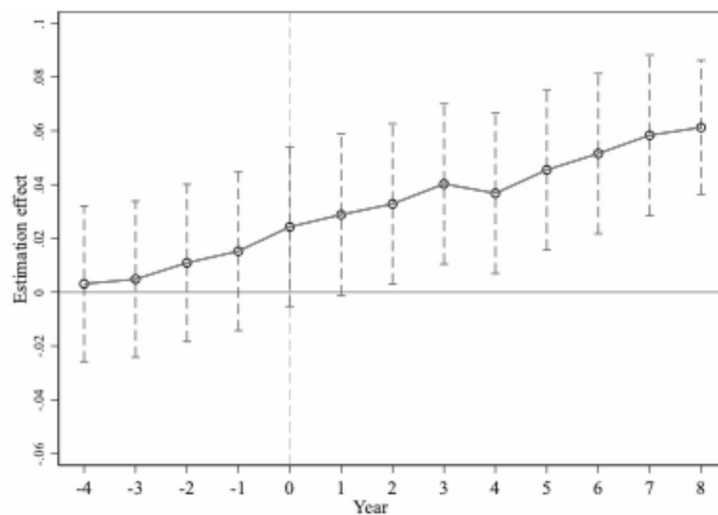
### Parallel trend test

To ensure the validity of the DID model, this study conducts a parallel trend test to verify whether the business environments of the treatment and control cities exhibited similar time trends before being selected as smart city. Since not all SCP were launched in the same year, we focus exclusively on cities selected as pilots in 2012 to test the parallel trend assumption. By excluding cities designated as pilots in 2013 and 2014, we ensure that the treatment group remains relatively homogeneous, allowing for a more precise assessment of the parallel trend. We incorporate dummy variables representing five years before and eight years after the policy implementation into the model, using the earliest period as the baseline<sup>37</sup>. As shown in Fig. 3, prior to the launch of smart city program, the regression coefficients for the business environment remain close to zero and are statistically insignificant, indicating no meaningful difference between the treatment and control groups. However, starting from the second year after SCP implementation, the regression results become significantly positive at the 95% confidence level. This confirms that our research design passes the parallel trend test. Figure 3 and Table 6 further illustrates that from the second year onward, the business environment in treatment cities improves significantly relative to the control group, showing a divergence that continues to expand over time. This pattern aligns with the long development cycles of smart city infrastructure and technological innovation, suggesting that the policy effects exhibit a lagged response. The supplementary materials provide supplementary results of the parallel trends test under the 90% confidence interval. The results indicate that the parallel trend hypothesis is not rejected.

This table reports the results of the parallel trends test along with the corresponding p-values.

### Placebo test

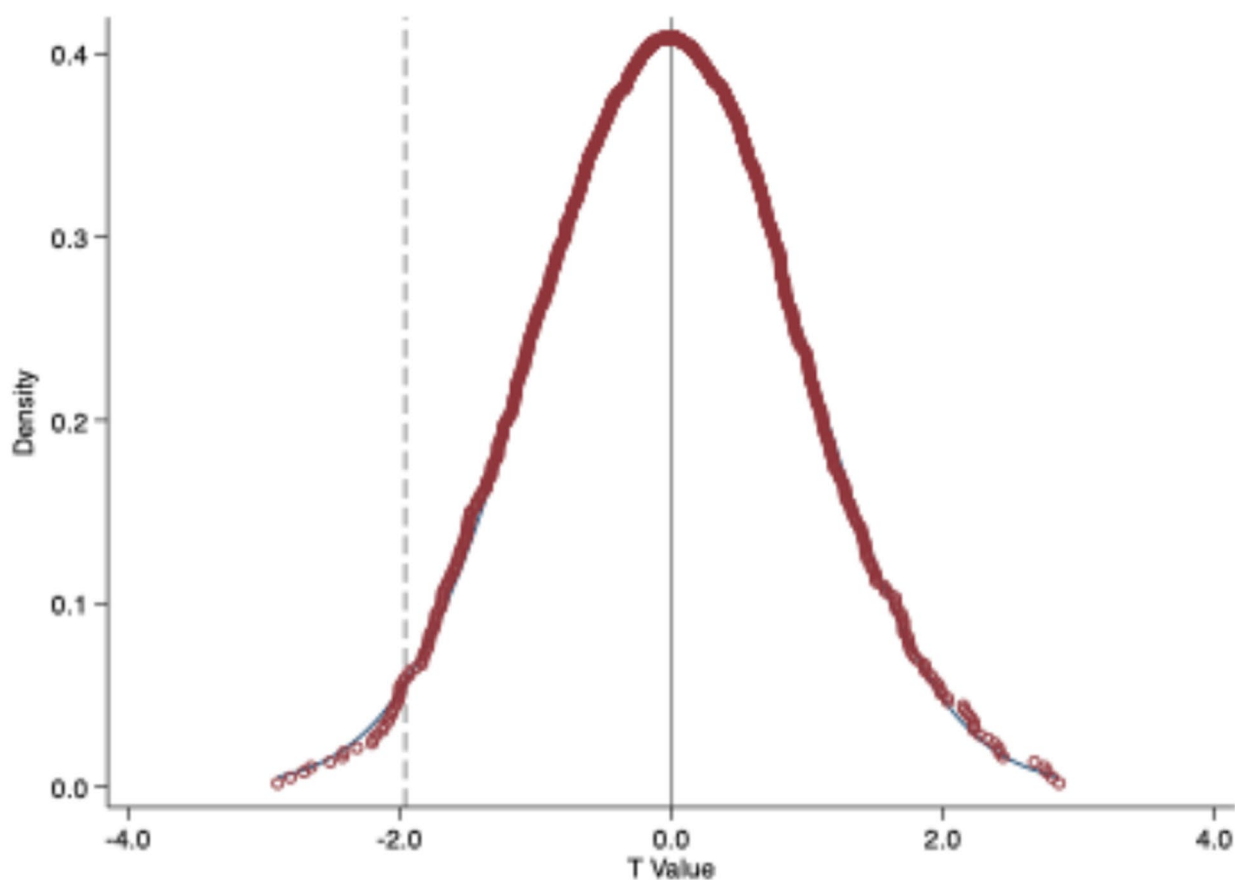
To mitigate the potential impact of unobservable factors on the business environment, this study constructs a “placebo treatment group” by repeatedly randomizing the treatment group variable and rerunning the regression 1000 times as a placebo test. We examine the kernel density distribution of the estimated BE coefficients to determine whether the randomized estimates are centered around zero and whether they significantly deviate from the actual values. If the placebo treatment group also exhibits a significant treatment effect, it may suggest issues with sample selection or an improperly defined control group. As shown in Fig. 4, the Y-axis represents the



**Fig. 3.** Parallel trend test. This figure shows that before SCP, there is no significant difference in the business environment between treatment and control cities. From the second year onward, the business environment in treatment cities improves significantly, with the gap widening over time.

Time	BE	p-value
Before 4	0.005	0.741
Before 3	0.006	0.721
Before 2	0.012	0.461
Before 1	0.017	0.301
Current	0.027	0.096
After 1	0.031	0.055
After 2	0.036	0.023
After 3	0.044	0.006
After 4	0.039	0.015
After 5	0.047	0.004
After 6	0.054	0.001
After 7	0.061	0.000
After 8	0.061	0.000

**Table 6.** Parallel trend test.



**Fig. 4.** Placebo test. This figure shows the kernel density of estimated coefficients for randomly assigned treatment groups. The t-values of the BE coefficients follow a normal distribution, mostly ranging between  $-2.0$  and  $2.0$ , indicating no statistical significance in the placebo test.

kernel density of the estimated coefficients for the randomly generated treatment groups, while the X-axis shows the corresponding t-values. The results of the placebo test indicate that the t-values of BE coefficients follow a normal distribution, with most values falling between  $-2.0$  and  $2.0$ , suggesting that the estimated BE coefficients lack statistical significance in the placebo test. Consequently, we can infer that omitted variables have a minimal impact on the estimation results, confirming the robustness of the baseline regression findings.

	(1)	(1)	(1)
	BE	BE	BE
did1	0.006** (2.270)	0.005* (1.857)	0.006* (1.950)
Constant	0.028 (0.371)	0.080 (1.035)	0.053 (0.698)
Control variables	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	1291	1312	1308
R <sup>2</sup>	0.461	0.549	0.518

**Table 7.** PSM-DID test. The regression results using the PSM-DID method with three matching techniques: radius matching, nearest-neighbor matching, and kernel density matching (Columns 1–3).

	(1)	(2)	(3)	(4)
	BE	did	BE	BE
did	0.005* (1.754)		0.237*** (3.757)	0.005** (2.315)
kdDID	0.001 (0.432)			
City topographic variation		0.076*** (0.018)		
Constant	0.078 (1.021)		0.031 (0.235)	-0.014 (-0.365)
Control variables	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	No	No
Year fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	No	Yes	Yes	No
N	1312	1312	1312	1179
R <sup>2</sup>	0.549	0.358		0.400

**Table 8.** Others robust test. The first column includes the “Broadband China” policy as a control variable. The second and third columns show the first and second stages of the instrumental variable method, respectively. The fourth column presents the regression results after winsorizing continuous variables.

#### PSM-DID test

Our study distinguishes between the treatment and control groups based on whether a city was selected as a smart cit. However, the selection of SCP is influenced by factors such as geographic location, infrastructure development, and financial advancement, which may lead to non-random sample selection. To address this issue, we employ the PSM-DID method to re-match the samples before conducting the regression analysis. The results are presented in Table 6. We apply three different matching methods: radius matching, nearest-neighbor matching, and kernel density matching, corresponding to Columns (1) to (3) in Table 7. The regression results indicate that across all three matching methods, the estimated coefficients remain significantly positive at the 10% level. This suggests that smart city program contribute to improving the business environment. Moreover, the PSM-DID estimates are consistent with those derived from the standard DID method, reinforcing the robustness of our conclusions.

#### Other robustness tests

Firstly, this study considers the potential interference of the Broadband China pilot policy, which was implemented concurrently with SCP initiative during the sample period. The Ministry of Industry and Information Technology and the National Development and Reform Commission launched the Broadband China strategy in three phases in 2014, 2015, and 2016, covering 120 cities. This policy aimed to enhance local network infrastructure to support economic and social development. According to Philipp Schade<sup>38</sup>, government-led digital infrastructure development can expand market and resource access, reduce entrepreneurs’ fear of failure, and enhance the role of opportunity recognition in entrepreneurial activities. Given that industrial upgrading, green development, and digital infrastructure construction both are key channels for improving the urban business environment. The Broadband China policy may influence the estimation of BE coefficients, potentially leading to an overestimation or underestimation of the impact of SCP. Therefore, it is crucial to account for this policy’s effect in our analysis. As shown in Column (1) of Table 8, after including a dummy variable for the

Broadband China policy (kdDID) in the model, the BE coefficient remains significantly positive at the 10% level. This reinforces the robustness of our findings, confirming that the estimated effect of SCP is not biased by the concurrent Broadband China initiative.

Secondly, to address sample selection bias and endogeneity issues arising from omitted variables, we follow the approach of Gong et al.<sup>39</sup> and employ a two-stage regression model to partially mitigate endogeneity concerns. For the selection of instrumental variables, we draw from the methodologies of Lin and Tan et al.<sup>24,40</sup>, using city topographic variation as the instrumental variable. On one hand, network infrastructure is a critical component of smart city development, and topographic variation, as an essential natural condition, influences both population distribution and the cost, signal quality, and operational efficiency of network infrastructure. Therefore, city topographic variation satisfies the relevance requirement of an instrumental variable. On the other hand, topographic variation does not directly affect the business environment, fulfilling the exogeneity criterion. As shown in Column (2) of Table 8, the first-stage regression results indicate that cities with greater topographic variation are more likely to be selected as smart city pilot sites. Column (3) presents the second-stage regression results, showing that when topographic variation is used as an instrumental variable, the BE coefficient remains significantly positive, further confirming the robustness of the baseline regression results.

Finally, we apply a 1% winsorization to the control variables to mitigate the influence of outliers on the estimation results and re-estimate the baseline model. The results are presented in Column (4) of Table 8. It can be observed that the BE coefficient remains significantly positive at the 5% level, indicating that our regression results remain robust even after accounting for the impact of outliers.

## Heterogeneity

### *Urban size heterogeneity*

Given that the impact of SCP on the business environment may vary depending on city size, we conduct a heterogeneity analysis based on urban scale. In 2014, China's State Council issued a classification standard for city sizes based on permanent resident population, dividing cities into five tiers and seven categories. According to this standard, cities with a population below 1 million are classified as medium-sized cities, those with 1 to 5 million residents as large cities, those with 5 to 10 million residents as megacities, and those exceeding 10 million residents as super megacities. As of 2021, in western China, only a few cities—Wuhai (Inner Mongolia), Tongchuan (Shaanxi), Jiayuguan and Jinchang (Gansu), and Shizuishan (Ningxia)—had populations below 1 million. To ensure meaningful analysis, we set 5 million residents as the cutoff: cities with fewer than 5 million residents are classified as large cities, while those above 5 million are considered megacities. Since only three cities—Chongqing, Chengdu, and Xi'an—qualify as super megacities, we merge them into the megacity category for analysis. Table 9 presents the regression results: Column (1) reports estimate for megacities, while Column (2) shows results for large cities. The findings suggest that smart city program significantly enhance the business environment in megacities, but the effect is not evident in large cities. This is consistent with the findings of Jiang et al. and Yao et al.<sup>3,12</sup> regarding smart cities. A possible explanation is that larger cities benefit more from economies of scale and agglomeration effects, as they already possess well-developed information resources and network infrastructure. Since advanced infrastructure is a fundamental determinant of business environment improvement, megacities are better positioned to ensure the effective implementation of SCP, leading to greater optimization of the business environment.

### *Urban characteristic heterogeneity*

Appio<sup>36</sup> find that the development of smart cities requires not only the support of digital infrastructure, but also the coordinated collaboration of social capital and human capital. However, each city has distinct regional characteristics, such as human capital levels, financial support, and digital infrastructure development, which may lead to varying effects of SCP on the business environment. Human capital levels help determine whether a city has sufficient reserves to support future production and innovation activities. Financial support levels reflect the government's commitment to optimizing the business environment. The level of digital infrastructure development indicates whether a city has the necessary foundation to support smart city construction.

	(1)	(2)	(3)	(4)
	BE	BE	BE	BE
did	0.053*** (3.469)	0.003 (1.160)	0.000 (0.139)	0.013** (2.576)
Constant	-2.029*** (-3.121)	0.118** (2.145)	0.093 (1.204)	-0.051 (-0.381)
Control variables	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N	196	1098	632	678
R <sup>2</sup>	0.790	0.296	0.181	0.656

**Table 9.** Heterogeneity analysis about urban size and urban characteristic. Column (1) reports estimate for megacities; Column (2) shows results for large cities; Column (3) represents low human capital levels; Column (4) represents high human capital levels.

Therefore, this study selects three regional characteristic indicators—human capital level, financial investment intensity, and digital infrastructure development—for heterogeneity analysis. Human capital level is measured as the proportion of undergraduate and associate degree students in the city's total year-end population, with the median value used as the cutoff to distinguish between high and low human capital levels. Financial investment intensity is measured as the ratio of fixed asset investment to local public budget expenditure, with the median value also serving as the threshold for distinguishing different levels of financial support. Digital infrastructure development is measured by the number of broadband internet access users in the city, with the median value similarly used to differentiate between high and low levels of digital infrastructure.

Columns (3) and (4) of Table 9 represent city samples with low and high levels of human capital, respectively. The results indicate that in cities with high human capital, smart city pilot policies exert a significantly positive impact on the business environment. In contrast, such policies show no effect in cities with low human capital. Human capital is a key driver of urban productivity and innovation, enabling firms to more effectively absorb and utilize new knowledge<sup>41</sup>. According to Romer's endogenous growth model<sup>42</sup>, technological progress depends not only on R&D investment, but also on the ability to disseminate and absorb knowledge. Firms must possess sufficient absorptive capacity to benefit from the widespread application of internet-based technologies<sup>41,43</sup>. The theory of human capital externalities further suggests that cities with high levels of human capital, characterized by a greater concentration of highly educated labor, are more likely to form learning organizations and innovation clusters. These cities therefore possess stronger capabilities for knowledge absorption and transformation<sup>44</sup>. As a result, cities with higher levels of human capital are better positioned to leverage SCP to optimize their business environments.

Column (1) and Column (2) of Table 10 represent city samples with low and high levels of financial support, respectively. The results suggest that smart city construction has a significantly positive effect in cities with lower financial support levels. In these regions, infrastructure and government services are relatively underdeveloped, meaning that when smart city program is introduced, technological advancements help address existing shortcomings, leading to notable improvements in the business environment. In contrast, cities with higher financial support levels already possess well-established infrastructure, making the marginal benefits of smart city construction less pronounced. The “low baseline” effect suggests that regions with weaker initial conditions experience higher marginal gains from SCP. This aligns with the findings of Monica Escaleras<sup>45</sup>, who demonstrated that the impact of fiscal decentralization on business environments is more significant in low-income countries than in high-income countries.

The last two columns of Table 10 represent city samples with low and high levels of digital infrastructure, respectively. The results indicate that in cities with a higher number of broadband internet users, SCP has a significantly positive effect, whereas in cities with lower material support levels, the same effect is not observed. Cities with better digital infrastructure are equipped with high-quality IoT infrastructure, cloud computing facilities, and geospatial infrastructure, which enhance internet penetration rates. The internet not only enhances firms' innovation capabilities by providing access to external knowledge, but also improves internal communication, thereby strengthening their ability to absorb and apply that knowledge effectively<sup>41,46</sup>. These factors provide the necessary material foundation and accelerators for technological innovation. Both spatially and temporally, cities with stronger material support are better positioned to transition from traditional urban models to smart city frameworks, ultimately fostering a more efficient and intelligent business environment.

To further investigate the synergistic effect between fiscal support and digital infrastructure, the sample was divided into four groups based on the levels of fiscal support and digital infrastructure, and separate regressions were conducted. The results are presented in Table 11. Specifically, when both fiscal support and digital infrastructure are low (Column 1), or when fiscal support is high but digital infrastructure remains low (Column 2), the effects of smart city policies on the business environment are statistically insignificant. In contrast, when fiscal support is low but digital infrastructure is high (Column 3), the policy effect is positive and statistically significant at the 1% level. Similarly, when both fiscal support and digital infrastructure are high (Column 4), the effect is positive and significant at the 5% level. These findings suggest that high levels of digital infrastructure play a crucial role in enhancing the effectiveness of smart city policies, regardless of fiscal

	(1)	(2)	(3)	(4)
	BE	BE	BE	BE
did	0.006** (1.994)	0.009 (1.509)	0.002 (0.982)	0.025*** (3.779)
Constant	0.149* (1.814)	-0.031 (-0.214)	0.062 (1.258)	-0.447** (-2.380)
Control variables	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N	654	656	656	654
R <sup>2</sup>	0.253	0.615	0.284	0.680

**Table 10.** Other heterogeneity analysis about urban characteristic. Column (1) represents low levels of financial support; Column (2) represents high levels of financial support; Column (3) represents low levels of digital infrastructure; Column (4) represents high levels of digital infrastructure.

	(1)	(2)	(3)	(4)
	BE	BE	BE	BE
did	0.002 (0.761)	0.002 (0.664)	0.020*** (2.634)	0.028** (2.206)
Constant	0.001 (0.016)	0.211** (2.567)	0.214 (1.079)	-1.295*** (-3.962)
Control variables	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N	318	338	336	318
R <sup>2</sup>	0.386	0.293	0.480	0.748

**Table 11.** The synergistic effect between fiscal support and digital infrastructure. Column 1 represents that both fiscal support and digital infrastructure are low. Column 2 represents that fiscal support are high and digital infrastructure are low. Column 3 represents that fiscal support are low and digital infrastructure are high. Column 4 represents that fiscal support are high and digital infrastructure are high.

	(1)	(2)	(3)	(3)
	Marketization	BE	Internationalization	BE
did	0.034* (1.655)		0.241*** (2.749)	
Lag_marketization		0.008** (1.996)		
Lag_internationalization				0.006* (1.786)
Constant	11.173*** (20.241)	0.025 (0.277)	-1.10e+06 (-0.023)	-0.335*** (-6.982)
Control variables	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N	1312	1230	1312	1230
R <sup>2</sup>	0.942	0.568	0.645	0.803

**Table 12.** Mechanism test. Columns 1 present the regression results for marketization mechanisms. Column 2 shows the results for endogeneity tests. Columns 3 present the regression results for internationalization mechanisms. Column 4 shows the results for endogeneity tests.

support levels. In regions with limited fiscal resources, improved digital infrastructure can substantially amplify the positive impact of policy interventions, thereby compensating for resource constraints.

### Mechanism test

After conducting a preliminary analysis of the impact of SCP on the business environment, we further explore the transmission mechanisms between the two. In 2024, China proposed the goal of establishing a market-oriented, internationalized, and law-governed business environment. Based on this, we analyze the factors influencing the relationship between SCP and the business environment from three perspectives: marketization, internationalization, and legal institutionalization. Based on prior studies, we use the year-end balance of loans from financial institutions as a proxy for marketization<sup>47,48</sup>, the ratio of total imports and exports to regional GDP as a proxy for internationalization<sup>49,50</sup>, and the frequency of digital economy policy terms as a proxy for legal institutionalization<sup>51</sup>. We then apply Eq. (2) to conduct a mechanism test. In addition, we use the one-period lagged values of the mechanism variables as instrumental variables to address potential endogeneity between the mechanism variables and the business environment. Table 12 and Table 13 present the results of the mechanism regressions and the corresponding endogeneity tests. The results show that all mechanism regressions are significantly positive at the 1% level and successfully pass the endogeneity tests. The results indicate that smart city development optimizes the business environment by enhancing market-oriented, internationalized, and law-based institutional frameworks. These findings provide empirical support for Hypothesis 2 proposed in our theoretical analysis.

The underlying reasons for these findings can be summarized as follows: First, in cities with a higher level of financial development, the financial market is more mature, offering a greater variety of financial institutions and services. This increases the diversity and accessibility of corporate loans, thereby easing financing constraints and reducing borrowing costs for enterprises. With more available funds, businesses can invest more in innovation

	(1)	(2)	(3)
	Legal institutionalization	BE	BE
did	0.002*** (7.636)		-0.014** (-2.494)
Lag_legal institutionalization		0.993** (2.468)	
Fintech*did			0.006*** (3.921)
Constant	-0.011** (-2.092)	0.108 (1.409)	0.088 (1.146)
Control variables	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	1312	1230	1312
R <sup>2</sup>	0.616	0.565	0.555

**Table 13.** Legal institutionalization mechanism test and moderate test. Columns 1 present the regression results for Legal institutionalization mechanisms. Column 2 shows the results for endogeneity tests. Column 4 shows the moderating effect of Fintech.

and research & development (R&D), which are considered key factors in improving the business environment<sup>1</sup>. Second, Digital platforms reduce transaction costs in international commerce through multiple channels while simultaneously lowering entry barriers for cross-border trade in various products. Intermediaries specializing in goods and services facilitate global connections, establish networks, and enable seamless interactions between suppliers and customers across international markets<sup>52</sup>. Third, SCP enable governments to tailor policy solutions based on local challenges, policy needs, and political conditions, leading to more effective governance<sup>53</sup>. Governments that successfully implement reforms can reduce administrative burdens and create a more favorable regulatory environment for businesses. Improvements in administrative management and tax incentives have been shown to significantly enhance the business environment<sup>54</sup>.

Additionally, this study conducts an extended test to determine whether Fintech plays a positive moderating role in the relationship between SCP and the business environment. The development of smart cities enhances Fintech by improving infrastructure, ICT technologies, and technological collaboration. At the same time, advancements in Fintech contribute to the business environment by expanding financing channels for enterprises, reducing transaction costs, increasing transparency, minimizing information asymmetry, fostering innovation and competition, and enhancing regulatory efficiency. These mechanisms help create a fairer, more transparent, and more efficient business environment, providing crucial support for the sustainable growth of enterprises.

We empirically test the moderating effect of Fintech using Eq. (3), with the results presented in Column (3) of Table 13. The findings show that the interaction term between Fintech and smart city development has a coefficient of 0.006, which is significantly positive at the 5% level. This confirms our hypothesis that Fintech indeed plays a positive moderating role in the relationship between SCP and the business environment, further supporting the validity of our analysis.

### Spatial spillover effects

The previous analysis confirmed the impact of smart city development on the business environment. However, failing to account for spatial correlations between cities may introduce estimation biases. To address this issue, this study incorporates a spatial Durbin model (SDM) and constructs a geographical distance matrix to examine the effects of SCP on other cities while considering spatial proximity. This study adopts a geographic distance matrix as the spatial weight matrix. Existing research shows that technology diffusion, information transmission, and policy spillovers typically weaken with increasing distance<sup>55,56</sup>. Geographic proximity promotes resource flows, knowledge spillovers, and policy diffusion, which help improve the business environment in neighboring areas. Based on the assumption that spatial externalities diminish with distance, the geographic distance matrix is better suited to capture the spillover effects of smart city policies. To ensure robustness, this study also uses an economic distance matrix for comparison. A sensitivity analysis under different distance thresholds is provided in the supplementary materials. Based on Eqs. (7)–(9), the spatial effects for the period 2006–2021 are calculated and presented in Table 14. The analysis reveals that during this period, the Moran's I index for the business environment, calculated using a geographical distance weight matrix, is consistently greater than zero. Additionally, the test results show that except for 2009, the p-values for all other years are below 0.1, indicating that the prerequisites for selecting and applying spatial econometric models are met.

To assess whether the spatial Durbin model (SDM) can be simplified into a spatial lag model (SLM) or a spatial error model (SEM), we conduct LM-lag, R-LM-lag, R-LM-err, LR-lag, and LR-err tests. The results represent in Table 15. This table indicates that except for the LM-lag test, which is significant at the 10% level, all other tests are significant at the 1% level. It reaffirms the presence of positive spatial autocorrelation and spatial lag effects in the business environment. Based on the results of the Hausman test, we select the spatial Durbin model (SDM) to estimate the spillover effects of smart city development.

Year	Moran's I	Z	P
2006	0.025	1.662	0.097
2007	0.027	1.742	0.082
2008	0.029	1.804	0.071
2009	0.025	1.64	0.101
2010	0.025	1.682	0.093
2011	0.028	1.785	0.074
2012	0.025	1.688	0.091
2013	0.031	1.935	0.053
2014	0.031	1.932	0.053
2015	0.034	2.066	0.039
2016	0.043	2.38	0.017
2017	0.046	2.552	0.011
2018	0.043	2.443	0.015
2019	0.033	2.042	0.041
2020	0.032	1.991	0.046
2021	0.030	1.918	0.055

**Table 14.** Moran's I index. The Moran's index from 2006 to 2021, with p-values being statistically significant at the 10% level.

Test	Statistic	P value
LM-lag	3.016	0.082
R-LM-lag	32.100	0.000
R-LM-err	29.755	0.000
LR-lag	19.780	0.000
LR-err	1550.000	0.000
Hausman	105.780	0.000

**Table 15.** Spatial correlation test. Except for the LM-lag test, which is significant at the 10% level, all other tests are statistically significant at the 1% level.

	(1)	(2)	(3)	(4)
	Main effect	Direct effect	Indirect effect	Total effect
SCP	0.006** (2.020)	0.008*** (2.701)	0.141** (2.310)	0.006** (2.340)
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N	1200	1200	1200	1200

**Table 16.** Spatial spillover effects using the distance matrix. The first column represents the main spatial effect, the second column shows the direct spatial effect, the third column presents the indirect spatial effect, and the fourth column reports the total spatial effect.

Table 16 presents the estimated spatial spillover effects of smart city development on the business environment. Specifically, Column (1) reports the estimation results using a geographical distance matrix within the SDM framework, where the coefficient is 0.006 and statistically significant at the 5% level, indicating that smart city development generates a notable positive spillover effect. To further analyze these spatial spillover effects, we apply partial differentiation to the spatial Durbin model (SDM) and decompose the effects into total effects, direct effects, and indirect effects. The regression results, shown in Columns (2) to (4) of Table 16, indicate that the direct effect coefficient is 0.008, while the indirect effect coefficient is 0.141, both of which are significantly positive at the 1% level. Moreover, the indirect effect is greater than the direct effect, suggesting that the implementation of SCP not only improves the business environment of the target city but also enhances the business environment of geographically proximate cities. The development of digital infrastructure enhances local intelligent transportation and logistics systems while simultaneously facilitating the cross-regional flow of resources, capital, and technology. This, in turn, drives the digital transformation of surrounding areas, improves urban governance capacity, and optimizes the overall business environment.

	(1)	(2)	(3)	(4)
	Main effect	Direct effect	Indirect effect	Total effect
Policy	0.010** (2.812)	0.011*** (2.840)	0.019** (2.459)	0.0290*** (3.635)
Control variables	Yes	Yes	Yes	Yes
Area fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
N	1200	1200	1200	1200

**Table 17.** Spatial spillover effects using the economic distance matrix. The first column represents the main spatial effect, the second column shows the direct spatial effect, the third column presents the indirect spatial effect, and the fourth column reports the total spatial effect.

To ensure the robustness of the results, we have conducted and included a sensitivity analysis using 900km distance thresholds in the supplementary materials. These additional analyses demonstrate the stability of our findings across different geographic thresholds, further supporting the appropriateness of using the geographic distance-based spatial weight matrix. In addition, we also conducted robustness checks using the economic distance matrix. The results remained consistent, indicating that our findings are robust to different specifications of the spatial weight matrix. The regression results based on the economic distance matrix are presented in Table 17.

## Conclusion and policy recommendations

This study uses panel data from 82 cities in western China covering the period from 2006 to 2021. It treats SCP as a quasi-natural experiment and employs a multi-period difference-in-differences model to investigate the relationship between smart city development and the regional business environment. The empirical results show that SCP significantly improves the business environment in western China. To ensure the robustness of the baseline results, we conducted a series of tests, including parallel trend tests, placebo tests, and propensity score matching DID. All results consistently support the main findings. From a mechanism perspective, SCP improves the business environment by applying next-generation information technologies to promote a market-oriented, internationalized, and law-based economic environment. The heterogeneity analysis reveals that the impact of SCP varies across cities, depending on factors such as population size and regional characteristics. The policy has a stronger effect in larger cities. Meanwhile, the SCP more effectively enhances the business environment in those with higher levels of human capital, lower levels of financial support, and stronger material infrastructure. In particular, improved digital infrastructure can substantially amplify the positive impact of policy interventions in regions with limited fiscal resources, thereby compensating for resource constraints. In addition, Fintech strengthens the positive effect of SCP on business environment. The study also finds evidence of spatial spillover effects, indicating that the benefits of SCP extend beyond pilot cities to neighboring areas. These findings offer important policy implications and theoretical insights for cities and regions seeking to improve their business environment, achieve high-quality and sustainable regional economic development.

Based on the above findings, this paper offers the following policy recommendations from both short-term and long-term perspectives. In the short term, governments can draw lessons from the “City Brain” model in Hangzhou and establish intelligent government platforms in capital cities. By integrating big data analytics and artificial intelligence technologies, these platforms can improve digital governance systems, enhance data security, and optimize public service delivery. More efficient urban governance, in turn, can help create a stable and predictable business environment for enterprises. In long-term, the 2023 business environment reform plan of the State Council of China incorporated digital governance in the performance evaluation indicators of local governments. This policy provides clear guidance for promoting digital transformation at the regional level. Local governments should steadily enhance their digital capabilities and improve service delivery. It also ensures that reforms lead to meaningful outcomes. Furthermore, advancing regional cooperation is essential for improving the business environment. The European Union, for example, has established dedicated funds—such as the Smart Cities Infrastructure Fund and the Smart Development Fund—to support resource integration and cross-sector collaboration. Following this model, western China could consider setting up a Smart City Development Fund to promote interprovincial technology transfer and reduce the digital divide across regions.

While smart city enhanced efficiency and economic benefits, they may also inadvertently widen regional digital divides, exacerbating existing inequalities. As suggested by van Dijk’s (2020) theory of digital social stratification, unequal access to digital resources and competencies can marginalize certain social groups. Therefore, inclusive digital-skills training programs should accompany smart city development policies to mitigate these risks and ensure equitable benefits.

## Limitations and future research

Although this study provides a new perspective on the impact of SCP on the business environment it has certain limitations that require further refinement and expansion. The first limitation is data limitations. This study relies on a dataset covering 82 cities in western China from 2006 to 2021. As such, the external validity of the findings in the context of economically developed countries has yet to be fully established. Future research could expand the scope of data coverage to examine the applicability and heterogeneous effects of smart city

policies in other regions or countries. Second, the limitation of business environment indicators. The indicators used to measure the business environment in this study are primarily derived from official statistical data. This approach may underestimate the role of the informal sector, which plays a significant part in the economies of many cities<sup>57</sup>. Lastly, the study primarily examines short-term effects, without fully exploring long-term impacts. Future research could extend the time span and apply dynamic models or causal inference methods for a more comprehensive assessment of policy sustainability.

## Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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### Additional information

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