

## Article

# Research on the Impact Mechanism of Smart City Construction on Economic Growth—An Analysis Based on the Schumpeterian Innovation Theory Framework

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**Abstract:** Smart city construction aims to promote the digital transformation of cities, support the modernization of urban governance, and stimulate urban innovation and development. In this paper, we analyze the role of smart city construction on economic growth and the impact mechanism driving this. In terms of theoretical analysis, we discuss the role of smart city construction in economic growth based on Schumpeterian innovation theory. In terms of empirical analysis, we evaluate the impact of smart city construction on economic growth with panel data of Chinese prefecture-level cities from 2011 to 2019, using time-varying difference-in-differences models and the event study method. The findings of the research indicate that the construction of smart cities has a positive effect on regional economic growth and the results can be confirmed through a series of robustness tests. Smart city construction generates mediating effects by enhancing urban innovation capability and entrepreneurship, thereby promoting urban economic growth. Furthermore, the impact of smart city construction on economic growth exhibits heterogeneous effects due to variations in the degree of marketization. In regions with a higher level of marketization, the promotional effect of smart city construction on economic growth is stronger. Consequently, it is imperative to intensify the implementation of smart city construction and persistently pursue market-oriented reforms.



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**Keywords:** smart city pilot scheme; economic growth; innovation capability; entrepreneurship level; difference-in-differences model

## 1. Introduction

China's "14th Five-Year Plan" places a strong emphasis on achieving socialist modernization by 2035 and raising per capita GDP to the level of moderately developed countries. However, the global pandemic has resulted in a notable decline in China's economic growth, with the GDP growth rate dropping from 6.1% in 2019 to 3% in 2022<sup>1</sup>. This trend is accompanied by a decline in the employment rate. In 2022, the employment rate of college graduates in China decreased by 15.8% compared to the previous year, reaching 23.6%<sup>2</sup>. Meanwhile, the demographic dividend accumulated over the past 40 years of China's reform and opening-up is gradually disappearing. With negative population growth in 2022<sup>3</sup>, it is unsustainable to rely on the demographic dividend to achieve high growth. These issues will contribute to social instability, which will be further compounded by unexpected factors. Therefore, the question of how to maintain growth and promote social stability has become a significant concern in the present era.

The Chinese government has proposed the "Overall Layout Plan for Building a Digital China" to achieve Chinese-style modernization, emphasizing the role of digitalization in driving economic growth in China. The plan emphasizes accelerating the construction of digital infrastructure, promoting the release of the value of digital elements, improving the quality of digital economic development, and perfecting the digital governance system. Of

these, accelerating the construction of digital infrastructure forms the foundation of the Digital China plan. The construction of smart cities primarily integrates new-generation information technologies, such as the Internet, the Internet of Things, cloud computing, 5G technology, and blockchain, with urban infrastructure construction. This integration accelerates the construction of digital infrastructure and promotes the transformation of traditional cities into new urbanization [1].

According to Schumpeter's innovation theory, the emergence of entrepreneurs and innovation is the fundamental driver of economic growth [2]. Schumpeter's innovation is a form of "creative destruction", wherein the emergence of new technologies displaces old ones [3]. This process is followed by the emergence of a new round of innovation representing advanced productive forces, which replaces the existing ones. Smart cities accelerate the development of internet services, optimize resource allocation in an intelligent manner, improve resource utilization efficiency, and promote urban development and governance [4]. First, smart cities can reduce "information asymmetry" within regions and bridge the "information gap" between supply and demand. This enables entrepreneurs to innovate continuously in response to ever-changing demands, thereby promoting technological iteration and progress. The formation of an innovation model which is "demand-driven" and "creative destruction" can be achieved. Second, the development of smart cities will give rise to a new wave of software innovations, revolutionizing information technology and driving urban innovation [5]. Meanwhile, entrepreneurs will further apply renovated information technology, accelerate technological improvement, and promote technological development. This will not only fuel the development of smart cities but also continuously enhance the level of innovation and entrepreneurship within cities [6]. Third, smart cities have a rigid demand for human capital with high-end digital skills and clustered them [7]. The aggregation of this human capital provides the necessary knowledge and intellectual support for entrepreneurs to carry out innovative research, thereby further enhancing urban innovation and entrepreneurship levels and contributing to economic growth. Therefore, this paper explores the effect of smart city construction on economic growth and the mechanisms driving this, and provides evidence and feasible suggestions for a broader understanding of the development results and development obstacles of smart city construction.

In this paper, we focus on four main questions: (1) Does smart city construction contribute to economic growth? (2) Through what mechanisms does smart city construction impact on economic growth? (3) What are the heterogeneous characteristics of smart city construction on economic growth? (4) As a new approach to urban construction and development, what improvements can be made to smart city construction? This paper analyses the role of smart city construction in economic growth based on Schumpeter's innovation theory and evaluates the impact of smart city construction on economic growth using panel data for Chinese prefecture-level cities, using a time-varying difference-in-differences model and the event study method. We find that smart city construction plays an active role in promoting economic growth. Smart city development can stimulate innovation and entrepreneurship and generate intermediary effects that in turn promote economic growth. Meanwhile, this paper finds that the impact of smart city construction on economic growth may vary depending on the degree of marketization in a region. As the degree of marketization increases, the stimulating effect of smart city construction on economic growth increases, suggesting that market reform helps smart city construction to play a positive role.

The remainder of this paper is organized as follows. Section 2 analyses the conclusions and shortcomings of existing studies. Section 3 provides a theoretical analysis of the relationship between smart city development and economic growth and presents the hypotheses of this paper. Section 4 presents the models and variables used in the empirical analyses. Section 5 discusses the results of benchmark regressions, parallel trend tests, counterfactual tests and robustness tests. Section 6 presents the analysis of mediation effects

and heterogeneity. Section 7 summarizes the conclusions and limitations of our study and directions for further research.

## 2. Literature Review

The majority of existing research on smart cities concentrates on the development of smart cities, the lives of their residents, environmental protection, and urban innovation [8–10]. Zhu et al. [11] show that the development of smart cities towards a more human-centered direction can help cities to prosper and improve the wellbeing of their residents. Wang and Zhou [12] explore the impact of core smart city investments with a logit model and find that investments in information and communications technology (ICT) have not demonstrated a positive impact on the quality of life of citizens. However, investments in human capital have the potential to improve quality of life. Salman and Hasar [13] point out that the expansion of cities into megacities has led to the emergence of several new environmental problems, particularly those related to water, waste, air, and traffic. These issues cannot be addressed through traditional methods, while smart city management offers a promising solution to these challenges. Linde et al. [14] argue that smart city construction can drive the formation of new kinds of ecosystem, enabling companies, municipalities, and citizens to collaborate in novel ways and facilitating sustainability benefits from ecosystem innovation. Bokhari et al. [15] collected many questionnaires from South Korea and Pakistan and find that smart city building promotes smart decision-making and social innovation by enabling all relevant stakeholders to share information.

In the study of smart cities and economic growth, Zhao and Zhang [16] suggest that big data provides the information basis for building smart cities in various ways, which can accelerate the transformation and upgrading of industrial structure and realize economic development, while taking into account social livelihood and environmental protection. Caragliu and Del [17] analyze a new dataset of European metropolitan areas using propensity score matching estimates and find that smart city policies stimulate innovation and create technological spillover effects, which increase a city's knowledge stock and become a major driver of economic growth. Duygan et al. [18] conducted a comparative analysis of smart cities in Switzerland. They find that the innovativeness of smart cities has spatial heterogeneity; a configuration with a high share of the service sector, the presence of universities, and densely populated urban areas is conducive to smart city development. Strielkowski et al. [19] show that there is a need for better management including strong networks of leaders to drive smart city policies and investments to make smart cities work for sustainable economic development. This is also related to the challenges that may be faced in building smart cities. Khan et al. [20] suggest that smart cities may cause problems in terms of privacy, legislation and policy, finance, infrastructure, and technology. Jonek et al. [21] say that building smart cities can lead to unsustainable urban development and socio-economic exclusion, with an unsatisfactory level of prosperity for residents and a difficult financial situation for cities.

From the above, it can be seen that the existing literature on smart cities contains many aspects, but it is mainly carried out in the form of case analyses and empirical tests, which lack innovation on the theoretical level of smart city construction. Meanwhile, there is no consistent conclusion on the mechanism by which smart cities promote economic growth.

The difference-in-differences model is usually used to estimate the net effect of a policy by comparing the changes in the treatment and control groups before and after the policy is implemented [22–24]. Using DID analysis, Chu et al. [25] find that China's smart city program has served to protect ecosystems and promote economic growth by promoting urban technological innovation, improving resource allocation, and reducing industrial and non-water droplet emissions. Jiang et al. [26] suggest that smart city pilots can drive technological advancement and increase green total factor productivity in cities with the DID method. There are times when the implementation of a policy occurs at different times, requiring the use of a time-varying DID [27,28]. Callaway and Sant'Anna [29] employ a difference-in-differences model with multiple time periods and discover that the minimum

wage policy can bring down the wage level of the youth labor force. Guo and Zhong [30] constructed a multiple period difference-in-differences (DID) model and assessed the improved influence of smart city development on urban innovation performance. In order to arrive at a more accurate empirical analysis of the smart city pilot scheme and economic growth, this paper chooses to use a time-varying DID model.

On the basis of the existing research, this paper makes three main contributions: First, from the perspective of Schumpeterian innovation theory, we verify that smart city pilot schemes serve as a new driving force for China's economic growth. Second, by incorporating smart city pilot schemes into the Schumpeterian model, we theoretically analyze the impact mechanism of smart city pilots on economic growth. Third, through empirical evidence, we confirm the validity of Schumpeter's innovation theory and show that smart city pilot schemes stimulate innovation, drive entrepreneurship, and consequently boost regional economic growth.

### 3. Theoretical Mechanisms and Research Hypotheses

This paper builds on Aghion and Howitt [31] by incorporating smart city pilot schemes into a Schumpeterian model, which assumes that there are  $N$  regions in the economy, each with final manufacturers, intermediate manufacturers, and consumers. Consumers only consume one type of good, referred to as the "final product". The final product is produced by perfectly competitive final firms using two inputs: intermediate products with the latest technology and labor. Here we examine the general product market, excluding some specific products such as the state-monopolized military market and the civil-military integration market. The level of technological progress in an economy is determined by the technological innovation of intermediate manufacturers, the success of which depends on their investment in R&D, their knowledge of end-market demand, and the talent pool and infrastructure support in the region.

#### 3.1. The Behavior of Final Product Firms

On the basis of the production function of final product firms from Aghion and Howitt [31], we assume that the production of final product firms requires two production factors: labor and intermediate products, with a continuum of intermediate products equal to 1. The production technology of final products exhibits constant returns to scale, which satisfies concave characteristics and the Inada conditions. The production function constructed in this paper is as follows:

$$Y_{i,t} = L_{i,t}^{1-\alpha} \int_0^1 A_{i,t,m}^{1-\alpha} x_{i,t,m}^\alpha d(m) \quad (1)$$

where  $Y_{i,t}$  represents the quantity of final products produced by the final manufacturers in region  $i$  at time  $t$ ;  $L_{i,t}$  is the unit labor input in region  $i$  at time  $t$ ;  $x_{i,t,m}$  is the input of intermediate product  $m$  in region  $i$  at time  $t$ ;  $A_{i,t,m}$  measures the level of technology for the production of final products using intermediate products  $m$ , indicating the quality of intermediate products;  $1 - \alpha$  is the labor output elasticity in the production of final goods;  $\alpha$  is the output elasticity of intermediate goods; and  $0 < \alpha < 1$ .

The final product market is a perfectly competitive market, with the price of the final product standardized to 1. Therefore, the relative price of intermediate product  $m$  is  $p_{i,t,m}$ , and the relative wage of labor is  $w$ . The optimization behavior of the representative final firm can be represented as follows:

$$\max_{x_{i,t,m}, L_{i,t}} [L_{i,t}^{1-\alpha} \int_0^1 A_{i,t,m}^{1-\alpha} x_{i,t,m}^\alpha d(m) - \int_0^1 p_{i,t,m} x_{i,t,m} d(m) - wL_{i,t}] \quad (2)$$

Taking the first-order optimality condition of Equation (2), we obtain the intermediate goods price and labor wage as follows:

$$p_{i,t,m} = \alpha L_{i,t}^{1-\alpha} A_{i,t,m}^{1-\alpha} x_{i,t,m}^{\alpha-1}; w = (1-\alpha) L_{i,t}^{-\alpha} \int_0^1 A_{i,t,m}^{1-\alpha} x_{i,t,m}^{\alpha} d(m) \quad (3)$$

### 3.2. Firm Behavior in Intermediate Goods Sectors

It is assumed that the output of the intermediate goods sector can only be used as inputs for final products, and that the final product manufacturers will choose to produce the series of intermediate products with the latest technology. Thus, the intermediate product producers have a monopoly market in each period, the intermediate product producers use the final product as inputs and produce with a 1:1 technology ratio. In order to prevent other intermediate firms from earning monopoly profits in the next period, intermediate firms compete with each other by increasing their investment in research and development, thus continuously improving the quality of intermediate products.

The intermediate good  $m$  is produced by the manufacturer  $M$ . If in period  $t$ , the representative intermediate firm  $M$  possesses the highest quality intermediate product, then the firm maximizes its monopoly profit by selecting the optimal quantity of final product input. Combining Equation (3), the optimal behavior of the intermediate product firm is as follows:

$$\max_{x_{i,t,m}} [\alpha (A_{i,t,m} L_{i,t})^{1-\alpha} x_{i,t,m}^{\alpha} - x_{i,t,m}] \quad (4)$$

The optimal quantity of intermediate products for maximizing profit, as derived from the first-order condition of Equation (4), is:

$$x_{i,t,m}^* = \alpha^{\frac{2}{1-\alpha}} A_{i,t,m} L_{i,t} \quad (5)$$

The expression for  $x_{i,t,m}^*$  shows that the optimal output of the  $m$ -th type of intermediate goods sector is proportional to the unit labor input  $L$  and the technological level  $A_{i,t,m}$  of the intermediate good  $m$ . Substituting Equation (5) into Equation (4) gives the profit function of the  $m$ -th type of intermediate goods firm, that is:

$$\pi_{i,t,m}^* = (1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} A_{i,t,m} L_{i,t} \quad (6)$$

According to Schumpeterian growth theory, intermediate goods are monopolized in each period. If in the next period, intermediate goods with higher productivity are developed by other firms, the identity of the monopolist will shift to the firm with the latest technology [32,33]. Therefore, in each period, the “entrepreneurs” in the intermediate goods sector will continuously innovate to maintain the ability to earn monopolistic profits in the next period. If the innovation in new technology is successful, productivity will increase significantly compared to the previous period. Using  $A_{i,t,m}$  to denote the productivity of intermediate products after successful innovation by intermediate product manufacturer  $M$ , and  $\gamma$  as a parameter measuring the scale of innovation, we have

$$A_{i,t,m} = \gamma A_{i,(t-1),m}, \text{ with } \gamma \geq 1. \quad (7)$$

However, if the innovation fails, the productivity of intermediate inputs in this period will be the same as that in the previous period, then  $A_{i,t,m} = A_{i,(t-1),m}$ . The reason why there is no decline in the level of innovation after an innovation failure is that even if a firm does not acquire more productive technology, it can still produce with the original technology. The probability of successful innovation is related to the investment in research made by the intermediate goods sector. The more money invested, the more likely the

innovation will succeed. According to Aghion and Howitt [31], the probability function for successful innovation in the intermediate sector is given by:

$$\varphi\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right) = \theta_{i,t} \left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right)^\sigma \quad (8)$$

In Equation (8),  $R_{i,t,m}$  represents the research and development (R&D) expenditure of firm M in the intermediate product sector. Since the price of final products is standardized to 1 and final products are used as inputs, the quantity of final products serves as R&D expenditure.  $\theta_{i,t}$  reflects the innovation productivity of the intermediate product sector in region i in period t, and  $\sigma$  represents the elasticity of innovation probability with respect to R&D expenditure, which ranges from 0 to 1. It can be observed that the innovation probability function is inversely proportional to  $A_{i,t,m}^*$ , as innovation becomes more complex and difficult to achieve with technological progress. Therefore, it is not the absolute level of R&D expenditure that affects the probability of innovation success, but the R&D expenditure adjusted for productivity, namely  $\frac{R_{i,t,m}}{A_{i,t,m}^*}$ . Taking the first and second order derivatives of the innovation probability function yields:

$$\varphi'_{i,t,m}\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right) = \sigma\theta_{i,t}\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right)^{\sigma-1} > 0; \quad \varphi''_{i,t,m}\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right) = \sigma(\sigma-1)\theta_{i,t}\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right)^{\sigma-2} < 0 \quad (9)$$

From Equation (9), it can be seen that the innovation probability function obeys the law of diminishing marginal returns.

The development of intermediate products is always faced with uncertainty, which may either succeed or fail. However, regardless of the success of the innovation, firms must expend a quantity of final products, represented as  $R_{i,t,m}$ , as R&D costs. Therefore, when faced with uncertainty, the behavior of intermediate goods manufacturers is to choose the optimal input costs in order to maximize expected profits.

$$\max_{R_{i,t,m}} \varphi\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right) \pi_{i,t,m}^* - R_{i,t,m} \quad (10)$$

According to Equation (10), the marginal value of the monopolistic intermediate good producer per unit period is  $\pi_{i,t,m}^* - R_{i,t,m}$ .

Substituting Equation (6)  $\pi_{i,t,m}^*$  into Equation (10) and taking the first-order condition with respect to  $R_{i,t,m}$ , we obtain:

$$\varphi'_{i,t,m}\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right) \frac{\pi_{i,t,m}^*}{A_{i,t,m}^*} = 1 \quad (11)$$

The left-hand side of Equation (11) represents the marginal benefits of innovation, while the right-hand side represents the marginal costs of R&D. Due to the diminishing marginal returns of the innovation probability function in  $\frac{R_{i,t,m}}{A_{i,t,m}^*}$ , the marginal returns form a downward-sloping curve, while the marginal cost is a horizontal line with a value of 1. According to the R&D arbitrage equation in Equation (11), productivity-adjusted R&D expenditure will be constant in equilibrium, and the innovation probability function will also be constant in equilibrium. Then, we can obtain the result at equilibrium, as shown in Equation (12):

$$\frac{R_{i,t,m}}{A_{i,t,m}^*} = \left\{ \sigma\theta_{i,t}(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{1}{1-\sigma}}; \quad \varphi\left(\frac{R_{i,t,m}}{A_{i,t,m}^*}\right) = \theta_{i,t}^{\frac{1}{1-\sigma}} \left\{ \sigma(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{\sigma}{1-\sigma}} \quad (12)$$

From Equation (12), it can be seen that the research and development expenditure and innovation probability functions at equilibrium depend on the elasticity  $\sigma$ , the innovation productivity of intermediate goods sectors  $\theta_{i,t}$ , labor supply  $L$ , and the elasticity of intermediate goods output  $\alpha$ .

### 3.3. The Impact of Smart City Pilot Projects

The construction of smart cities utilizes new generation information technologies such as the Internet, Internet of Things (IoT), and artificial intelligence (AI) to collect, store, process, and deeply analyze data, generating information. This helps to reduce the “information asymmetry problem” among economic entities within the city, facilitating instant and effective communication between the supply and demand sides. Entrepreneurs within the region can innovate and conduct targeted research and development according to changes in terminal markets, thereby increasing the probability of successful innovation.

On the other hand, the construction of smart cities creates a rigid demand for high-end human capital and makes them clustered. This concentration of human capital provides necessary guarantees for entrepreneurs to innovate, thus enhancing the probability of innovation success. Furthermore, smart city construction promotes the development of digital technology and the digital economy within the region. The development of the digital economy has a significant impact on the total factor productivity of firms and regions and significantly improves innovation efficiency [34,35].

In summary, the construction of smart cities has a positive promoting effect on the probability of innovation success. Intermediate firms can utilize various favorable factors in smart cities to enhance the efficiency of their research and development, thereby increasing the probability of innovation success. Therefore, the innovation productivity  $\theta_{i,t}$  of intermediate product sectors can be regarded as an increasing function of the degree of smart city construction, as follows:

$$\theta_{i,t} = C_{i,t}^\lambda \quad (13)$$

where  $C_{it}$  represents the degree of smart city construction in region  $i$  at time  $t$ ,  $\lambda$  is the efficiency parameter of smart city research and development. Substituting Equation (13) into Equation (12), we have:

$$\frac{\overline{R_{i,t,m}}}{A_{i,t,m}^*} = \left\{ \sigma C_{i,t}^\lambda (1 - \alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{1}{1-\sigma}}; \varphi \left( \frac{\overline{R_{i,t,m}}}{A_{i,t,m}^*} \right) = \left( C_{i,t}^\lambda \right)^{\frac{1}{1-\sigma}} \left\{ \sigma (1 - \alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{\sigma}{1-\sigma}} \quad (14)$$

From Equation (14), we can know that smart cities affect the regional research and development intensity and the probability of innovation success by improving the innovation productivity in the region.

### 3.4. Economic Growth

Substituting the optimal output  $x_{i,t,m}^*$  of intermediate goods in class  $m$  into the final firm's production function, we obtain the optimal output  $Y_{i,t}^*$  of the final product manufacturer:

$$Y_{i,t}^* = \alpha^{\frac{2\alpha}{1-\alpha}} L_{i,t} \int_0^1 A_{i,t,m} d(m) = \alpha^{\frac{2\alpha}{1-\alpha}} A_{i,t} L_{i,t} \quad (15)$$

where  $A_{i,t} = \int_0^1 A_{i,t,m} d(m)$  represents the average technological progress level of all intermediate goods sectors. Equation (14) indicates that the optimal output is proportional to  $A_{i,t}$ . Since the current technological productivity is related to the probability of successful innovation, the current technological productivity is equal to the weighted average of technological productivity when innovation succeeds and when innovation fails, which is:

$$A_{i,t} = \varphi \left( \frac{\overline{R_{i,t,m}}}{A_{i,t,m}^*} \right) \gamma A_{i,(t-1)} + \left( 1 - \varphi \left( \frac{\overline{R_{i,t,m}}}{A_{i,t,m}^*} \right) \right) A_{i,(t-1)} \quad (16)$$

From Equation (15), it can be deduced that the economic growth rate of the region is:

$$g_{i,t} = \frac{A_{i,t} - A_{i,(t-1)}}{A_{i,(t-1)}} = \overline{\varphi \left( \frac{R_{i,t,m}}{A_{i,t,m}^*} \right)} (\gamma - 1) = \left( C_{i,t}^\lambda \right)^{\frac{1}{1-\sigma}} \left\{ \sigma(1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{\sigma}{1-\sigma}} (\gamma - 1) \quad (17)$$

It can be observed from Equation (17) that the economic growth of a region is influenced by the construction of smart cities.

In order to explore the impact of smart city construction on regional economic growth, we conduct a comparative static analysis of Equation (17), and it can be inferred:

$$\frac{dg_{i,t}}{dC_{i,t}} = \frac{1}{1-\sigma} \left( \lambda C_{i,t}^{\lambda-1} \right) \left( C_{i,t}^\lambda \right)^{\frac{\sigma}{1-\sigma}} \left\{ \sigma(1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{\sigma}{1-\sigma}} (\gamma - 1) > 0 \quad (18)$$

As can be seen from the above equation, the degree of smart city construction,  $C_{i,t}$ , promotes regional economic growth. Thus, we obtain the first hypothesis of this paper:

**Hypothesis 1.** *Smart city construction promotes economic growth.*

Next, we explore the impact mechanism of smart city construction on economic growth. Through comparative static analysis of Equation (14), it can be seen that:

$$\frac{d \overline{\frac{R_{i,t,m}}{A_{i,t,m}^*}}}{dC_{i,t}} = \frac{\sigma}{1-\sigma} (\varphi C_{i,t}^{\varphi-1}) \left\{ (1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\} \left\{ \sigma(C_{i,t}^\varphi) (1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{\sigma}{1-\sigma}} > 0 \quad (19)$$

$$\frac{d \overline{\varphi \left( \frac{R_{i,t,m}}{A_{i,t,m}^*} \right)}}{dC_{i,t}} = \frac{1}{1-\sigma} (\varphi C_{i,t}^{\varphi-1}) \left( C_{i,t}^\varphi \right)^{\frac{\sigma}{1-\sigma}} \left\{ \sigma(1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L_{i,t} \right\}^{\frac{\sigma}{1-\sigma}} > 0 \quad (20)$$

Therefore, it can be seen that smart city construction promotes increased innovation research and development expenditure for intermediate products, thereby stimulating economic growth. At the same time, smart cities enhance the probability of innovation success, which significantly increases innovative entrepreneurial activities and drives economic growth. Hence, the second hypothesis of this paper is derived:

**Hypothesis 2.** *The digital economy can promote economic growth by incentivizing innovation and entrepreneurship.*

## 4. Model and Variables

### 4.1. Empirical Strategy

Based on theoretical analysis, we treat the national smart city construction pilot released by the Chinese Ministry of Housing and Urban-Rural Development as an exogenous shock and constructs the following model using the time-varying difference-in-differences method:

$$\log gdp_{it} = \alpha + \beta city_{it} + \vartheta X_{it} + \sigma_t + \mu_i + \varepsilon_{it} \quad (21)$$

In Equation (21),  $\log gdp_{it}$  stands for economic growth,  $city_{it}$  represents smart city pilot projects,  $X_{it}$  is a set of control variables, including: level of industrialization (industry), level of industrial structure (thirdindustry), level of urbanization (urban), government scale (gov), fixed asset investment (far), and foreign direct investment (fdi). These control variables take into account the ecosystem of the focus city, the size of the investment, etc., and exclude the unfavorable impact of these omitted variables on the regression results [36].  $\mu_i$  is the city fixed effect that excludes the impact of ecosystem differences between target cities on economic growth,  $\sigma_t$  is the time fixed effect. Considering that there may be unobservable omitted variables at the provincial level that change over time and affect city-level economic growth, the joint fixed effects of province and year are used to

control for the influence of these potential factors.  $\varepsilon_{it}$  is the random disturbance term, with standard errors clustered at the city level.

#### 4.2. Variable Explanation and Data Source

**Dependent variable:** Economic growth is measured as the logarithm of real GDP. As nominal GDP is affected by inflation and other factors, real GDP is measured at constant 2010 prices, with data taken from the “China City Statistical Yearbook”. This study focuses on a sample of 276 prefecture-level cities from the *Urban Yearbooks* spanning from 2011 to 2019.

**Independent variables:** The core variable in this study is the “National Smart City” pilot dummy variable. The smart city pilot projects are divided into three batches. On 5 December 2012, the Ministry of Housing and Urban-Rural Development officially released the “Notice on Carrying out the National Smart City Pilot Work”, which established the first batch of 90 cities (districts, counties, towns). In 2013 and 2014, the second and third batches of pilot cities, respectively, were determined. If a region is a “smart city” pilot area and implements a “smart city” construction project, the variable  $city_{it}$  is assigned a value of 1, otherwise it is assigned a value of 0.

**Control variables:** The level of industrialization is measured by the share of the output value of the secondary sector in the regional gross domestic product (GDP), while the industrial structure is represented by the share of the output value of the tertiary sector in the regional GDP. The level of urbanization is assessed by the proportion of the non-agricultural population to the total population. Government scale is calculated as the ratio of government fiscal expenditure to the regional GDP. The level of fixed-asset investment is determined by the ratio of fixed-asset investment in the current year to regional GDP. Foreign direct investment (FDI) is represented by the proportion of actual utilization of foreign direct investment to the regional GDP. All data above are from the *China City Statistical Yearbook* for 2011–2019.

**Mediating variables and heterogeneity variables:** The mediating variables are the level of innovation and the level of entrepreneurship. The level of innovation is measured by the number of patent applications (patent) and the number of invention patents (invent) in the current year, sourced from the “CIRDS Patent Innovation Database”. Entrepreneurship level is measured by the new firm index (newfirm) and the trademark authorization index (trademark) from the “Peking University Regional Innovation and Entrepreneurship Data”. The heterogeneity analysis primarily focuses on marketization, drawing upon Fan Gang’s Marketization Index [37]. It includes scores on the relationship between the government and the market (govmarket), the development of the non-state economy (private), the development of factor markets (factor), and the development of intermediary organizations and legal aspects (law). The descriptive statistical results of the relevant variables are presented in Table 1.

**Table 1.** Descriptive Statistics.

| Variable             | (1)<br>Mean | (2)<br>SD   | (3)<br>Min | (4)<br>Max |
|----------------------|-------------|-------------|------------|------------|
| $\log gdp_{it}$      | 7.3237      | 0.9276      | 4.7757     | 10.3585    |
| $industry_{it}$      | 47.2969     | 10.7372     | 11.7       | 89.3400    |
| $thirdindustry_{it}$ | 40.6948     | 10.0926     | 10.1500    | 83.5200    |
| $gov_{it}$           | 0.1996      | 0.1017      | 0.0439     | 0.9155     |
| $far_{it}$           | 0.7872      | 0.2829      | 0.0872     | 2.1969     |
| $fdi_{it}$           | 0.0273      | 0.0276      | 0.0000     | 0.2990     |
| $urban_{it}$         | 0.1315      | 0.1275      | 0.0245     | 1.4729     |
| $patent_{it}$        | 6268.4665   | 14,225.9850 | 20         | 202,178    |
| $invent_{it}$        | 2303.1713   | 5699.8378   | 4          | 65,251     |
| $trademark_{it}$     | 5232.0992   | 2857.7833   | 34.2       | 10,000     |
| $newfirm_{it}$       | 5219.4953   | 2828.5827   | 204.8      | 10,000     |
| $private_{it}$       | 8.2100      | 2.0728      | 1.4700     | 11.8000    |
| $factor_{it}$        | 5.9764      | 2.0134      | 0.5900     | 15.8700    |
| $law_{it}$           | 6.8845      | 4.4261      | −0.4100    | 24.3300    |
| $govmarket_{it}$     | 6.1388      | 1.3240      | 1.4800     | 9.2200     |

## 5. Empirical Analysis

### 5.1. Benchmark Regression Results

In this paper, we estimate the theoretical model with the difference-in-differences method, and the regression results of smart city construction on economic growth are shown in Table 2. According to model (1), the impact of the digital economy on economic growth was examined after controlling for time fixed effects and individual fixed effects, but without any control variables. The coefficient of the city pilot dummy variable is positive and at the 1% significance level, suggesting that the smart city construction significantly promotes economic growth. In order to better identify the effect of smart city construction on economic growth, model (2) adds a series of control variables, including industrialization level, industrial structure, government scale, fixed-asset investment, foreign direct investment, and urbanization level, and from the positive coefficient of the city pilot dummy variable we can see that the construction of smart cities has an active effect on real GDP at the 5% significance level. Model (3) further controls for the joint fixed effects of provinces and years based on model (2), which eliminates the potential impact on the results of factors within provinces that may change over time. The coefficient of the city pilot dummy variable is positive and at the 10% significance level. Therefore, Hypothesis 1 is validated, indicating that smart city construction promotes economic growth.

**Table 2.** Empirical Analysis Results of Smart City Construction on Economic Growth.

| Variable                        | (1)                    | (2)                     | (3)                     |
|---------------------------------|------------------------|-------------------------|-------------------------|
| $city_{it}$                     | 0.0274 ***<br>(0.0058) | 0.0097 **<br>(0.0040)   | 0.0069 *<br>(0.0036)    |
| $industry_{it}$                 |                        | 0.0144 ***<br>(0.0011)  | 0.0134 ***<br>(0.0011)  |
| $thirdindustry_{it}$            |                        | 0.0041 ***<br>(0.0014)  | 0.0059 ***<br>(0.0014)  |
| $gov_{it}$                      |                        | −0.4846 ***<br>(0.0478) | −0.3241 ***<br>(0.0455) |
| $far_{it}$                      |                        | 0.0568 ***<br>(0.0101)  | 0.0432 ***<br>(0.0116)  |
| $fdi_{it}$                      |                        | 0.1089<br>(0.0879)      | −0.1387<br>(0.0918)     |
| $urban_{it}$                    |                        | 0.0125<br>(0.0247)      | −0.0383 *<br>(0.0224)   |
| Constant                        | 6.9879 ***<br>(0.0039) | 6.2051 ***<br>(0.1035)  | 6.2189 ***<br>(0.1142)  |
| Year Fixed Effect               | yes                    | yes                     | Yes                     |
| City Fixed Effect               | yes                    | yes                     | Yes                     |
| Year × Province<br>Fixed Effect | no                     | no                      | Yes                     |
| Observation                     | 2474                   | 1565                    | 1565                    |
| $within R^2$                    | 0.9115                 | 0.9449                  | 0.9671                  |

Note: This table shows the results obtained with difference-in-differences model. For all regressions, the independent variable is the “National Smart City” pilot dummy variable, and the dependent variable is the economic growth measured by the logarithm of real GDP. \*\*\*, \*\*, and \* indicate that the coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses represent the robust standard errors clustered at the city level.

### 5.2. Parallel Trends and Counterfactual Tests

An important assumption in using the difference-in-differences method is that if there is no impact of the smart city pilot policy, the experimental and control groups should show consistent time trends, i.e., there are no systematic differences before the intervention. To test this assumption, we employ an event study methodology:

$$\log gdp_{it} = \alpha + \sum_{t=-3}^{t=3} \beta_t citydummy_{it} + \theta X_{it} + \sigma_t + \mu_i + \varepsilon_{it} \quad (22)$$

The variable  $citydummy_{it}$  is a dummy variable, and the model controls the event window of the smart city pilot promotion with seven dummy variables. For the observations three years before the smart city pilot promotion and before,  $Citydummy_{i,-3}$  is assigned a value of 1, and the rest of them are assigned a value of 0. For the observations three years after the smart city pilot promotion and beyond,  $Citydummy_{i,+3}$  is assigned a value of 1, and the rest are assigned a value of 0. The remaining dummy variable  $citydummy_{it}$  takes the value of 1 if the observation is in the  $t$ -th year of the smart city construction promotion, and 0 otherwise.

The regression results are shown in Table 3. The first column is the result of the basic regression, the second column is the result of the regression with control variables and the third column is the result of the regression with both control variables and the joint fixed effects of provinces and years. In column (1)–(3), the coefficients of the city dummies before the smart city pilot promotion are not statistically significant. We can infer from these coefficients that before the implementation of the national smart city pilot scheme, there was no systematic difference in economic growth between pilot and non-pilot areas. However, the coefficients of the city dummies after the implementation of the smart city pilot scheme are positive and statistically significant, especially three years after the implementation of the pilot scheme. These results reveal that pilot areas show a significant growth trend in economic growth, compared to the non-pilot areas, which is consistent with the general trend assumption. Meanwhile, to provide a counterfactual test, we fabricate the smart city pilot schemes by bringing forward the smart city pilot shock by two or three years. In column (4) and (5), the coefficients of the city dummies are not statistically significant, meaning that smart city pilot schemes drive economic growth, while fictional smart city pilot schemes are ineffective. This indicates the robustness of the impact of smart city pilot schemes on economic growth.

**Table 3.** Parallel trends and counterfactual tests.

| Variable                        | (1)                    | (2)                    | (3)                  | (4)                 | (5)                 |
|---------------------------------|------------------------|------------------------|----------------------|---------------------|---------------------|
| $Citydummy_{i,-3}$              | −0.0155<br>(0.0125)    | −0.0072<br>(0.0081)    | −0.0092<br>(0.0071)  | −0.0059<br>(0.0061) |                     |
| $Citydummy_{i,-2}$              | −0.0060<br>(0.0085)    | −0.0046<br>(0.0053)    | −0.0054<br>(0.0047)  |                     | −0.0050<br>(0.0037) |
| $Citydummy_{i,0}$               | 0.0053<br>(0.0084)     | 0.0022<br>(0.0053)     | 0.0022<br>(0.0046)   |                     |                     |
| $Citydummy_{i,+1}$              | 0.0121<br>(0.0091)     | 0.0043<br>(0.0058)     | 0.0031<br>(0.0051)   |                     |                     |
| $Citydummy_{i,+2}$              | 0.0214 **<br>(0.0092)  | 0.0094<br>(0.0059)     | 0.0049<br>(0.0053)   |                     |                     |
| $Citydummy_{i,+3}$              | 0.0337 ***<br>(0.0077) | 0.0196 ***<br>(0.0071) | 0.0104 *<br>(0.0063) |                     |                     |
| Controls                        | no                     | yes                    | yes                  | yes                 | yes                 |
| Year Fixed Effect               | yes                    | yes                    | yes                  | yes                 | yes                 |
| City Fixed Effect               | yes                    | yes                    | yes                  | yes                 | yes                 |
| Year × Province<br>Fixed Effect | no                     | no                     | yes                  | yes                 | yes                 |
| Observation                     | 2474                   | 1565                   | 1565                 | 1565                | 1565                |
| within $R^2$                    | 0.9121                 | 0.9451                 | 0.9672               | 0.9670              | 0.9670              |

Note: This table shows the results of parallel trends and counterfactual tests. For all regressions, the independent variable is the dummy variable representing the promotion process of smart city pilot projects, and the dependent variable is the economic growth measured by the logarithm of real GDP. \*\*\*, \*\*, and \* indicate that the coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses represent the robust standard errors clustered at the city level.

### 5.3. Robustness Test

In this study, we conduct robustness tests in three ways, and the regression results are shown in Table 4. First, considering the possibility that other similar policies during the policy period may also affect economic growth, we incorporate the Broadband China

policy ( $BDChina_{it}$ ) as a measure of other impacts on digital infrastructure construction into the model, as suggested by relevant studies [38]<sup>4</sup>. It is found that after incorporating the impact of Broadband China, the coefficient of the independent variable is positive and at the 10% significance level. Smart city construction still has a significant positive effect on economic growth, indicating the robustness of the conclusion. Second, considering the possibility of other preferential policies for economic growth in the four municipalities directly under the central government, Beijing, Shanghai, Chongqing, and Tianjin, the second column removes samples from these four cities. In column (2), after removing these samples, the coefficient of the independent variable is positive and at the 5% significance level, which means that smart city construction still has a significant positive effect on economic growth, confirming the robustness of the conclusion. Finally, given that the selection of smart city pilot sites may be influenced by factors such as terrain, we control for the interaction between regional slope, which does not change over time, and time fixed effects. The result in column (3) shows that the coefficient of the independent variable is positive and at the 1% significance level and the conclusion remains robust, suggesting that smart city construction promotes economic growth. In Column (4), we take all the above three scenarios into account at the same time and the coefficient of the independent variable is still significant positive. Therefore, it can be inferred that our conclusion is robust, and that smart city construction can promote economic growth.

**Table 4.** Robustness Test.

| Variable                                    | (1)                    | (2)                    | (3)                    | (4)                    |
|---------------------------------------------|------------------------|------------------------|------------------------|------------------------|
| $city_{it}$                                 | 0.0074 *<br>(0.0040)   | 0.0093 **<br>(0.0040)  | 0.0103 ***<br>(0.0040) | 0.0078 *<br>(0.0040)   |
| $BDChina_{it}$                              | 0.0244 ***<br>(0.0042) |                        |                        | 0.0245 ***<br>(0.0042) |
| Constant                                    | 6.1691 ***<br>(0.1024) | 6.1749 ***<br>(0.1036) | 6.1925 ***<br>(0.1027) | 6.1268 ***<br>(0.1016) |
| Controls                                    | yes                    | yes                    | yes                    | yes                    |
| Year Fixed Effect                           | yes                    | yes                    | yes                    | yes                    |
| City Fixed Effect                           | yes                    | yes                    | yes                    | yes                    |
| Year $\times$ Terrain slope<br>Fixed Effect | no                     | no                     | yes                    | yes                    |
| Observation                                 | 1565                   | 1541                   | 1565                   | 1541                   |
| within $R^2$                                | 0.9463                 | 0.9447                 | 0.9461                 | 0.9473                 |

Note: This table shows the results of robust tests. For all regressions, the independent variable is the “National Smart City” pilot dummy variable, and the dependent variable is the economic growth measured by the logarithm of real GDP. In Column (1), we incorporate the Broadband China policy. In Column (2), we remove samples from Beijing, Shanghai, Chongqing, and Tianjin. In Column (3), the regression is with an interaction between the regional slope and time fixed effect. In Column (4), the regression is a synthesis of three situations. \*\*\*, \*\*, and \* indicate that the coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses represent the robust standard errors clustered at the city level.

## 6. Further Research

### 6.1. Mediation Analysis

We use stepwise regression to examine the mediating effect of smart city construction on economic growth. The specific models are as follows:

$$med_{it} = \alpha + \beta city_{it} + \sigma_t + \mu_i + \varepsilon_{it} \quad (23)$$

$$loggdp_{it} = \alpha + \beta city_{it} + med_{it} + \sigma_t + \mu_i + \varepsilon_{it} \quad (24)$$

where  $med_{it}$  is the mediating variable. Equation (23) examines the impact of smart city construction on the mediator variable, while Equation (24) examines the impact of the mediator variable on economic growth. In Equation (24),  $city_{it}$  is used to distinguish between the direct and mediating effects of smart city construction on economic growth. According to the theoretical analysis, the mediating variables are divided into two categories: innovation variables and entrepreneurship variables. Innovation variables are measured by

the number of patent applications ( $patent_{it}$ ) and the number of invention patents ( $invent_{it}$ ) in the region in a given year. Entrepreneurship variables are measured by the number of newly established enterprises ( $newfirm_{it}$ ) and the number of trademark authorizations in the region ( $trademark_{it}$ ). The corresponding empirical results are shown in Tables 5 and 6.

**Table 5.** Mediation Analysis: Innovation-Driven Mechanism.

| Variable          | (1)<br>$loggdp_{it}$   | (2)<br>$patent_{it}$   | (3)<br>$loggdp_{it}$   | (4)<br>$invent_{it}$   | (5)<br>$loggdp_{it}$   |
|-------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| $city_{it}$       | 0.0275 ***<br>(0.0058) | 2.0510 ***<br>(0.5358) | 0.0256 ***<br>(0.0058) | 1.5258 ***<br>(0.2233) | 0.0239 ***<br>(0.0059) |
| $patent_{it}$     |                        |                        | 0.0010 ***<br>(0.0002) |                        |                        |
| $invent_{it}$     |                        |                        |                        |                        | 0.0024 ***<br>(0.0006) |
| Constant          | 5.4174 ***<br>(0.0219) | −2.1473<br>(2.0249)    | 6.9483 ***<br>(0.0040) | −0.8576<br>(0.8442)    | 6.9493 ***<br>(0.0039) |
| Year Fixed Effect | yes                    | yes                    | yes                    | yes                    | yes                    |
| City Fixed Effect | yes                    | yes                    | yes                    | yes                    | yes                    |
| Observation       | 2438                   | 2438                   | 2438                   | 2438                   | 2438                   |
| $adj R^2$         | 0.9946                 | 0.8252                 | 0.9112                 | 0.8108                 | 0.9947                 |

Note: This table shows the results of mediation analysis with the innovation-driven mechanism. In Column (1), (3) and (5), the independent variable is the “National Smart City” pilot dummy variable, and the dependent variable is the economic growth measured by the logarithm of real GDP. In Column (2) and Column (4), the independent variable is the “National Smart City” pilot dummy variable, and the dependent variables are the number of patent applications and the number of invention patents, respectively. \*\*\* indicates that the coefficients are statistically significant at the 1% level, respectively. The values in parentheses represent the robust standard errors clustered at the city level. The test of intermediary effect yields a Z-statistic value.

**Table 6.** Mediation Analysis: Entrepreneurial Mechanism.

| Variable          | (1)<br>$loggdp_{it}$   | (2)<br>$newfirm_{it}$  | (3)<br>$loggdp_{it}$   | (4)<br>$trademark_{it}$ | (5)<br>$loggdp_{it}$   |
|-------------------|------------------------|------------------------|------------------------|-------------------------|------------------------|
| $city_{it}$       | 0.0278 ***<br>(0.0058) | 1.6764 ***<br>(0.5537) | 0.0257 ***<br>(0.0058) | 0.8368 *<br>(0.4912)    | 0.0264 ***<br>(0.0057) |
| $newfirm_{it}$    |                        |                        | 0.0013 ***<br>(0.0002) |                         |                        |
| $trademark_{it}$  |                        |                        |                        |                         | 0.0017 ***<br>(0.0002) |
| Constant          | 6.9879 ***<br>(0.0039) | 4.2805 **<br>(2.0989)  | 5.4120 ***<br>(0.0218) | 2.9388<br>(1.9377)      | 5.4125 ***<br>(0.0217) |
| Year Fixed Effect | yes                    | yes                    | yes                    | Yes                     | yes                    |
| City Fixed Effect | yes                    | yes                    | yes                    | Yes                     | yes                    |
| Observation       | 2462                   | 2462                   | 2462                   | 2462                    | 2462                   |
| $adj R^2$         | 0.9951                 | 0.9523                 | 0.9952                 | 0.9602                  | 0.9952                 |

Note: This table shows the results of mediation analysis with the entrepreneurial mechanism. In Columns (1), (3) and (5), the independent variable is the “National Smart City” pilot dummy variable, and the dependent variable is the economic growth measured by the logarithm of real GDP. In Column (2) and Column (4), the independent variable is the “National Smart City” pilot dummy variable, and the dependent variables are the number of newly established enterprises and the number of trademark authorizations in the region, respectively. \*\*\*, \*\*, and \* indicate that the coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses represent the robust standard errors clustered at the city level. The test of intermediary effect yields a Z-statistic value.

In the first column of Table 5, as demonstrated in the previous sections, the coefficient of the city pilot dummy variable is positive and at the 1% significance level, which suggests that smart cities promote economic growth. Columns (2) and (4) examine the relationship between smart city construction and innovation. The coefficients of the city pilot dummy variable are positive indicate that smart city construction can drive innovation, and the results are both significant at the 1% level. Columns (3) and (5) examine the relationship between innovation and economic growth. The coefficients of the innovation variables are

both positive show that the intermediary variable, innovation, is positively correlated with economic growth, indicating that smart city construction can influence economic growth through the intermediary variable. Additionally, the coefficients of the city pilot dummy variable of columns (3) and (5) are both positive, revealing that the direct effect remains existent and positive.

As shown in Table 6, in Column (1), the coefficient of the city pilot dummy variable is positive and at the 1% significance level, which suggests that smart cities promote economic growth. Columns (2) and (4) examine the relationship between smart city construction and entrepreneurship. The coefficients of the smart city pilot dummy variable are both significantly positive, indicating that smart city construction can stimulate entrepreneurship, promote the establishment of new firms, and contribute to an increase in trademark authorizations. Columns (3) and (5) test the relationship between entrepreneurship and economic growth. The coefficients of the entrepreneurship variables are both positive, which demonstrates a positive correlation between entrepreneurship as a mediator variable and economic growth. Therefore, smart city construction can influence economic growth through this mediator variable. Additionally, the coefficients of the city pilot dummy variable of Columns (3) and (5) are both positive, indicating that the direct effect also holds true. In conclusion, Hypothesis 2 is validated, the digital economy can promote economic growth by incentivizing innovation and entrepreneurship.

## 6.2. Heterogeneity Analysis

The impact of smart city construction on economic growth may vary depending on the degree of regional marketization. To examine this heterogeneity, we adopt Fan Gang's marketization index to quantify the degree of marketization, and conduct a heterogeneity analysis from several perspectives, including the relationship between government and market, the development of the non-state-owned economy, the development of factor markets, the development of intermediary organizations, and the legal perfection. Among these, the score for the relationship between government and market increases as the allocation of resources becomes more market-oriented. Similarly, the score for the development of the non-state-owned economy increases as its development becomes more extensive. The development score for factor markets increases as they become more reliant on market allocation. Moreover, as intermediary organizations become more developed and laws become sounder, the scores for intermediary organization development and legal perfection also increase.

The regression results are shown in Table 7. In the first column, we add an interaction term of the smart city pilot dummy and the relationship between government and market in the model. It can be observed that the coefficient of the interaction term is significantly positive, which means that as the government plays a more service-oriented role and the market plays a more fundamental role in resource allocation, the incentive effect of smart city construction on real GDP growth becomes more evident. In the second column, we add an interaction term of the smart city pilot dummy and the development of the non-state economy. It can be seen that the coefficient of the interaction term is significantly positive, which implies that the more developed a region's non-state economy is, the stronger the incentive effect of smart city construction on real GDP growth. In Column (3), we include an interaction term of the smart city pilot dummy and factor market development. The positive coefficient of the interaction term shows that the higher the degree of regional factor marketization, the more smart city construction contributes to real GDP growth. In the fourth column, we include an interaction term of the smart city pilot dummy and the score for intermediary organizations and legal aspects. It is evident that the coefficient of the interaction term is significantly positive so that the more sound the legal framework in a region and the more developed the intermediary organizations, the more pronounced the incentive effect of smart city construction on real GDP growth. The above results suggest that the incentive effect of smart city construction on economic growth increases as the degree of marketization increases.

**Table 7.** Heterogeneity Analysis of Marketization Degree.

| Variable                          | (1)                          | (2)                          | (3)                          | (4)                          |
|-----------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| $city_{it}$                       | 351.4388 ***<br>(42.3847)    | 390.3169 ***<br>(42.4369)    | 379.3784 ***<br>(40.1369)    | 416.3693 ***<br>(40.8972)    |
| $city_{it} \times govmarket_{it}$ | 212.9930 ***<br>(23.4104)    |                              |                              |                              |
| $govmarket_{it}$                  | −15.5806<br>(30.5001)        |                              |                              |                              |
| $city_{it} \times private_{it}$   |                              | 146.7559 ***<br>(17.5421)    |                              |                              |
| $private_{it}$                    |                              | −23.2581<br>(40.6657)        |                              |                              |
| $city_{it} \times factor_{it}$    |                              |                              | 268.7115 ***<br>(18.4518)    |                              |
| $factor_{it}$                     |                              |                              | −50.0065 ***<br>(16.5050)    |                              |
| $city_{it} \times law_{it}$       |                              |                              |                              | 99.3357 ***<br>(7.6929)      |
| $law_{it}$                        |                              |                              |                              | 20.4515<br>(12.5230)         |
| Constant                          | 4345.5511 ***<br>(1110.7531) | 4501.9291 ***<br>(1155.3452) | 3915.2873 ***<br>(1051.1220) | 3645.0774 ***<br>(1066.0965) |
| Controls                          | yes                          | Yes                          | yes                          | yes                          |
| Year Fixed Effect                 | yes                          | Yes                          | yes                          | yes                          |
| City Fixed Effect                 | yes                          | Yes                          | yes                          | yes                          |
| Observation                       | 1565                         | 1565                         | 1565                         | 1565                         |
| within $R^2$                      | 0.4952                       | 0.4904                       | 0.5439                       | 0.5293                       |

Note: This table shows the results of the heterogeneity analysis of marketization degree. For all regressions, the independent variable is the “National Smart City” pilot dummy variable, and the dependent variable is the economic growth measured by the logarithm of real GDP. \*\*\* indicates that the coefficients are statistically significant at the 1% level, respectively. The values in parentheses represent the robust standard errors clustered at the city level.

## 7. Conclusions and Recommendations

This paper analyzes the impact of smart city pilot projects on economic growth and proposes the mechanism of innovation and entrepreneurship based on Schumpeter’s innovation theory. Using data from prefecture-level cities from 2011 to 2019 and employing a difference-in-differences approach, we evaluate the relationship between smart city construction and economic growth. The main conclusions drawn from our analysis are as follows: First, with the Schumpeterian theoretical model, we demonstrate that the construction of smart cities leads to an increase in research and development (R&D) expenditure within the region, thereby enhancing the probability of innovation success and fostering economic growth. Second, we use a multi-period difference-in-differences model to verify that smart city construction promotes economic growth. A series of robustness tests, such as the event study method, support the conclusions of this paper. Third, smart city construction can have a mediating effect, i.e., smart city construction can enhance innovation and entrepreneurship within the city, which in turn promotes economic growth. Fourth, areas with higher degrees of marketization exhibit a more pronounced positive impact of smart city construction on economic growth.

In this paper, we provide theoretical and empirical evidence for the impact of smart city construction on economic growth. Based on the conclusions drawn from this study, several relevant suggestions can be proposed. First, there should be further promotion of smart city construction, fostering the development of next-generation information technologies, and continuous improvement in technologies such as big data processing and computing. These efforts should be integrated with urbanization to drive economic growth. Second, during the process of smart city construction, efforts should be made to facilitate communication among various stakeholders within the city. This will enable enterprises, governments, and consumers to continuously integrate information and provide timely feedback, promoting targeted research and development by enterprises, improving consumer welfare, and making government governance more rational and effective. Finally, alongside smart city construction, attention should also be paid to local market-oriented reforms. Regions

with higher levels of marketization benefit more from smart city construction in driving economic development. Therefore, it is necessary to follow the path of marketization and to continue market-oriented reforms in China.

This paper still has certain limitations in the study of smart cities and economic growth. We choose real GDP to measure economic growth but lacked a discussion of the sustainability of economic growth. What we are pursuing in raising the level of the economy is not simply economic growth, which may lead to overproduction and overconsumption. Overproduction may lead to an inefficient allocation of resources and problems such as business difficulties, rising unemployment and an increase in non-performing bank loans. Overconsumption, however, may lead to overconsumption of resources, a surge in personal indebtedness, a reduction in savings and a decline in the quality of consumption. Neither is conducive to sustainable economic development.

The core objective of smart city development is to use advanced information and communication technology (ICT) to integrate information and improve the efficiency of city management, thereby enhancing the residents' quality of life and achieving sustainable development. The goal of sustainable development should not be contradictory to the goal of economic growth. Our study indicates that smart city development stimulates economic growth by fostering innovation and entrepreneurship. However, we do not address the heterogeneity of innovation and entrepreneurship due to the availability of data. On the one hand, innovation and entrepreneurship that favors environmental protection and efficient use of resources may have a different effect on smart city construction and economic growth relative to other types of innovation and entrepreneurship. On the other hand, improving the industrial structure and introducing high-quality innovations can also alleviate the problem of overproduction or overconsumption.

Furthermore, some studies have indicated that the construction of smart cities requires cities to have a high financial capacity, and may also give rise to social problems such as the income distribution within society. The issues of whether economic growth can effectively alleviate the financial pressure of cities in the context of smart city construction, and whether the economic growth brought about by smart cities has a positive or negative impact on the distribution of income in society, require further discussion.

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## Notes

- <sup>1</sup> The data are sourced from the annual economic growth rate published by the National Bureau of Statistics of China.
- <sup>2</sup> The data are sourced from the Michael Page *China Graduate Employment Report*.
- <sup>3</sup> The data are sourced from the natural population growth rate data of permanent residents published by the National Bureau of Statistics of China.
- <sup>4</sup> The Broadband China initiative was initiated by the State Council in 2013 with the release of the “Broadband China” strategy and implementation plan. The first batch of pilot cities for the “Broadband China” strategy was approved by the Ministry of Industry and Information Technology and the National Development and Reform Commission in 2014. The second batch of pilot cities was proposed in 2015, followed by the third batch of demonstration cities in 2016.

## References

- Śledzik, K. *Schumpeter's View on Innovation and Entrepreneurship. Management Trends in Theory and Practice*; Hittmar, S., Ed.; Faculty of Management Science and Informatics, University of Zilina & Institute of Management by University of Zilina: Zilina, Slovakia, 2013. [\[CrossRef\]](#)
- Silva, B.N.; Khan, M.; Han, K. Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. *Sustain. Cities Soc.* **2018**, *38*, 697–713. [\[CrossRef\]](#)
- Liu, S.; Gao, Y.; Ding, X. Finding new theoretical thinking of innovation-driven development—Thinking based on new Schumpeterian growth theory. *Manag. World* **2017**, *12*, 8–19. (In Chinese)
- Yuan, H.; Zhu, C. Do smart cities accelerate urban innovation? *China Soft Sci.* **2020**, *12*, 75–83. (In Chinese)
- Chen, P. Urban planning policy and clean energy development Harmony-evidence from smart city pilot policy in China. *Renew. Energy* **2023**, *210*, 251–257. [\[CrossRef\]](#)
- Ku, S.; Yang, J.; Liu, J. Problems and Countermeasures in the Construction of Smart Cities in China. *China Soft Sci.* **2013**, *1*, 6–12. (In Chinese)
- Lima, M. Smarter organizations: Insights from a smart city hybrid framework. *Int. Entrep. Manag. J.* **2020**, *16*, 1281–1300. [\[CrossRef\]](#)
- Mao, Y.; Xie, Y. Research on the impact of smart city construction on the climb of China's global value chain. *Urban Issues* **2022**, *11*, 4–13. (In Chinese)
- Kummitha, R.K.R.; Crutzen, N. How do we understand smart cities? An evolutionary perspective. *Cities* **2017**, *67*, 43–52. [\[CrossRef\]](#)
- Hudson, L.; Wolff, A.; Gooch, D.; van der Linden, J.; Kortuem, G.; Petre, M.; ten Veen, R.; O'Connor-Gotra, S. Supporting urban change: Using a MOOC to facilitate attitudinal learning and participation in smart cities. *Comput. Educ.* **2019**, *129*, 37–47. [\[CrossRef\]](#)
- Zhu, H.; Shen, L.; Ren, Y. How can smart city shape a happier life? The mechanism for developing a Happiness Driven Smart City. *Sustain. Cities Soc.* **2022**, *80*, 103791. [\[CrossRef\]](#)
- Wang, M.; Zhou, T. Does smart city implementation improve the subjective quality of life? Evidence from China. *Technol. Soc.* **2023**, *72*, 102161. [\[CrossRef\]](#)
- Salman, M.Y.; Hasar, H. Review on environmental aspects in smart city concept: Water, waste, air pollution and transportation smart applications using IoT techniques. *Sustain. Cities Soc.* **2023**, 104567. [\[CrossRef\]](#)
- Linde, L.; Sjödin, D.; Parida, V. Dynamic capabilities for ecosystem orchestration A capability-based framework for smart city innovation initiatives. *Technol. Forecast. Soc. Chang.* **2021**, *166*, 120614. [\[CrossRef\]](#)
- Bokhari, S.A.A.; Myeong, S. Use of artificial intelligence in smart cities for smart decision-making: A social innovation perspective. *Sustainability* **2022**, *14*, 620. [\[CrossRef\]](#)
- Zhao, Z.; Zhang, Y. Impact of smart city planning and construction on economic and social benefits based on big data analysis. *Complexity* **2020**, *1*, 8879132. [\[CrossRef\]](#)
- Caragliu, A.; Del, B.C.F. Smart innovative cities: The impact of Smart City policies on urban innovation. *Technol. Forecast. Soc. Chang.* **2019**, *142*, 373–383. [\[CrossRef\]](#)
- Duygan, M.; Fischer, M.; Pärli, R. Where do Smart Cities grow? The spatial and socio-economic configurations of smart city development. *Sustain. Cities Soc.* **2022**, *77*, 103578. [\[CrossRef\]](#)
- Strielkowski, W.; Veinbender, T.; Tvaronavičienė, M.; Lace, N. Economic efficiency and energy security of smart cities. *Econ. Res.-Ekon. Istraživanja* **2020**, *33*, 788–803. [\[CrossRef\]](#)
- Khan, H.H.; Malik, M.N.; Zafar, R. Challenges for sustainable smart city development: A conceptual framework. *Sustain. Dev.* **2020**, *28*, 1507–1518. [\[CrossRef\]](#)
- Jonek, K.I.; Wolniak, R. Economic opportunities for creating smart cities in Poland. Does Wealth Matter? *Cities* **2021**, *114*, 103222. [\[CrossRef\]](#)
- Brewer, M.; Crossley, T.F.; Joyce, R. Inference with difference-in-differences revisited. *J. Econom. Methods* **2018**, *7*, 20170005. [\[CrossRef\]](#)
- Wang, H.; Chen, Z.; Wu, X. Can a carbon trading system promote the transformation of a low-carbon economy under the framework of the porter hypothesis?—Empirical analysis based on the PSM-DID method. *Energy Policy* **2019**, *129*, 930–938. [\[CrossRef\]](#)
- Arkhangelsky, D.; Athey, S.; Hirshberg, D.A.; Imbens, G.W.; Wager, S. Synthetic difference-in-differences. *Am. Econ. Rev.* **2021**, *111*, 4088–4118. [\[CrossRef\]](#)
- Chu, Z.; Cheng, M.; Yu, N.N. A smart city is a less polluted city. *Technol. Forecast. Soc. Chang.* **2021**, *172*, 121037. [\[CrossRef\]](#)
- Jiang, H.; Jiang, P.; Wang, D. Can smart city construction facilitate green total factor productivity? A quasi-natural experiment based on China's pilot smart city. *Sustain. Cities Soc.* **2021**, *69*, 102809. [\[CrossRef\]](#)
- Goodman-Bacon, A. Difference-in-differences with variation in treatment timing. *J. Econom.* **2021**, *225*, 254–277. [\[CrossRef\]](#)
- Callaway, B.; Goodman-Bacon, A.; Sant'Anna, P.H.C. *Difference-in-Differences with a Continuous Treatment*; National Bureau of Economic Research: Cambridge, MA, USA, 2024. [\[CrossRef\]](#)
- Callaway, B.; Sant'Anna, P.H.C. Difference-in-differences with multiple time periods. *J. Econom.* **2021**, *225*, 200–230. [\[CrossRef\]](#)

30. Guo, Q.; Zhong, J. The effect of urban innovation performance of smart city construction policies: Evaluate by using a multiple period difference-in-differences model. *Technol. Forecast. Soc. Chang.* **2022**, *184*, 122003. [[CrossRef](#)]
31. Aghion, P.; Howitt, P.W. *The Economics of Growth*; The MIT Press: Cambridge, MA, USA, 2009.
32. Mankiw, N.G.; Whinston, M.D. Free entry and social inefficiency. *RAND J. Econ.* **1986**, *17*, 48–58. [[CrossRef](#)]
33. Acemoglu, D. *Introduction to Modern Economic Growth*; Princeton University Press: Princeton, NJ, USA, 2008.
34. Huang, Q.; Yu, Y.; Zhang, S. Internet development and manufacturing productivity enhancement: Internal mechanism and Chinese experience. *China Ind. Econ.* **2019**, *8*, 5–23. (In Chinese)
35. Zhang, L.; Ma, L. Digital economy, industrial structure upgrading and total factor productivity. *Stat. Decis. Mak.* **2022**, *38*, 5–10. (In Chinese)
36. Liu, R.; Zhao, R. Does National High-Tech Zone Promote Regional Economic Development?—Validation based on double difference method. *Manag. World* **2015**, *8*, 30–38. (In Chinese)
37. Fan, G.; Wang, X.; Zhang, L.; Zhu, H. Report on the relative process of marketisation in different regions of China. *Econ. Res.* **2003**, *3*, 9–18. (In Chinese)
38. Tian, G.; Zhang, X. Digital economy, non-farm employment and social division of labour. *Manag. World* **2022**, *38*, 72–84. (In Chinese)

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