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RESEARCH ARTICLE

Can Smart City Construction Promote the Level of Public Services? Quantitative Evidence From China

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ABSTRACT Effectively improving the level of public services (PSL) has long been a key topic of concern in theoretical and practical circles. A smart city is a real product of the high integration of digital technology and urban governance, which has a close theoretical correlation with PSL, but there is no academic research to quantitatively verify the relationship between the two. To bridge this research gap, this study empirically analyzes the relationship between smart city construction and PSL by constructing panel data of 212 prefecture-level cities in China from 2006 to 2018 using the difference-in-difference (DID) model. The baseline regression finds that smart city construction significantly improves PSL during the sample period. Among them, smart city construction improved the quality of education and medical services (EAM) by approximately 5.18% and the level of social life security (SLS) by approximately 4.04%. This result holds after performing the robustness test. The mechanism analysis revealed that smart city construction has a significant positive impact on PSL through informational, technological, and economic effects. The above study examines the policy effects of smart city construction and provides a course of action to optimize PSL. The study suggests that the public service effects of smart city construction can be further improved by transforming the urban governance model and establishing a systematic technological innovation mechanism.

INDEX TERMS Smart city, public service level, informatization, technological innovation, economic growth.

I. INTRODUCTION

Public service is both the main responsibility of modern government and the foundation of the modernization of national governance through the rights of the people [1]. It directly reflects the satisfaction of citizens' rights and the improvement of the effectiveness of the national government through the government's responsibility for public services. Public services, as public goods provided by the government to guarantee the right to life and development of all citizens, are the prerequisites for people's survival and development and are the basis for the existence and development of human society. Since the 1960s, public services have gradually become the key to understanding the government's ability to perform

its duties in Western theoretical discourse, and the level of development and quality of public services has become an important measure of the government's ability to govern. However, with the rapid progress of urbanization, industrialization, and citizenship, the "urban diseases" such as traffic congestion, environmental degradation, lack of resources, and deterioration of quality of life caused by rapid population growth and urban expansion have posed increasingly serious problems, which pose increasingly serious problems and challenges to the management of today's governments. In this context, the modern development model that combines and integrates with new information and communication technologies—Smart cities are born. The rapid development of new-generation information and communication technologies such as blockchain, cloud computing, artificial intelligence, and big data has injected powerful momentum into

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the construction of urban informatization, digitalization, and wisdom, and provided an opportunity for transformation and change in urban management. It also drives cities to carry out a new round of transformation by creating a city form that is connected, interconnected, and intelligent in one, using big data and ICT (artificial intelligence, RF sensing technology, cloud computing, 5G, etc.) to make city management more efficient and intelligent, improve resource utilization efficiency, improve service delivery and quality of life, and reduce environmental pollution, to realize the intelligence of city economy, life, management, and improve public services.

Under the call of *2030 Agenda for Sustainable Development* for sustainable development in social, environmental, economic, and other aspects, the improvement of public service quality has gradually become the key issue of government governance. But the improvement of public service level (PSL) is still one of its theoretical assumptions. The following questions may arise in this context. Is smart city a new direction for urban development, which is conducive to liveability and sustainability? How does it affect China’s PSL? However, until recently, such questions had not been broadly discussed in the literature of urban studies; there exists a controversy and lack in the quantitative analysis of the effects of smart city on PSL. Hence, to fill this gap in existing literature, this paper conceptually and empirically examines the extent to which smart city construction has changed PSL. To overcome the core difficulties in the evaluation of the construction effect of smart cities [2] and to achieve the scientific evaluation of the construction effect of smart cities on PSL, this study first analyzed and demonstrated the mechanism of the role of smart city construction on the improvement of PSL from the theoretical point of view. Then, we present hypotheses and models. Furthermore, we test these conjectures using a panel data set of 212 prefecture-level cities in China for the period 2006 to 2018. We estimate difference-in-differences (DID) regressions to control for unobserved heterogeneity that affects smart city selection and PSL. We also discuss selection concerns, validating the identifying assumption that the trends are parallel for the smart city pilots’ group and the control group which consist of cities absent the smart city initiative. At the same time, the robustness test was conducted through placebo test, PSM-DID test and winsorize. Consistent with the theoretical analyses, the empirical results show, enhanced by smart city initiatives, that the dramatic changes in informational, technological, and economic level efficiency exert a positive effect on PSL in the city. In summary, we find that smart city initiatives improve PSL in Chinese cities.

This study makes several important contributions. First, advancing the literature on the importance of smart city for different goals of sustainable urban development, we explore an equally vital outcome, namely urban public service. In doing so, we focus our attention on the multi-dimensionality of influential mechanisms instead of treating it as separate. Second, we complement recent findings on public service of smart city initiatives from the perspective

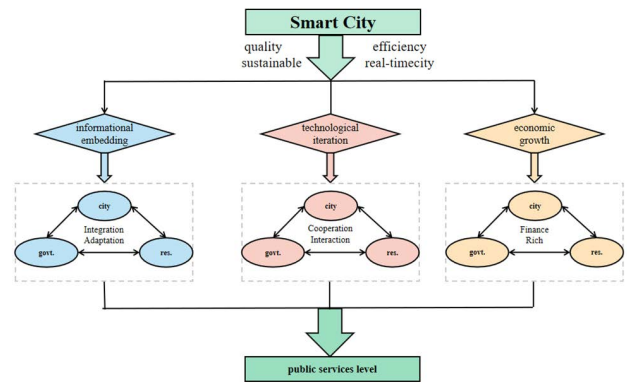


FIGURE 1. Theoretical framework.

of informational, technological, and economic. Within the smart city paradigm, PSL are expected to be improved, mainly through the comprehensive allocation of information, technology, economy and other resources. Finally, from an empirical standpoint, we pay special attention to a less-researched context (i.e. China) that provides a promising ground for examining the public service improvement effects of smart city initiatives at work in less-developed and emerging economies.

The remainder of this article is organized as follows: First, we present a literature review of the relationships between the Smart city and public service level and formulate our research hypotheses. Second, we describe our research methodology and explain the sample, data, and variables. Third, we report the empirical analysis results. Finally, we discuss our findings and outline recommendations for future research and implications for theory and practice. Through the above research, provide academic suggestions for smart cities construction and PSL.

II. LITERATURE REVIEW AND THEORETICAL HYPOTHESIS

In the era of the digital economy, with the rapid development of computers, communication, Internet platforms, and sensing technologies, the urban digital space is expanding and causing profound morphological transformation of the original physical space, economic space, and social space operation mode, and the smart city is a new model of urban governance based on the above transformation with the application of new technologies and oriented to the integration of multiple information. Among them, intelligent management for the transformation and improvement of public services for urban residents is an important part of smart city construction [3]. So far, scholars’ research on smart cities and public services can be summarized into four aspects (Figure 1).

First, the quality and efficiency dimensions of smart cities and public service levels. Smart city research originates from improving the quality of life of urban residents, building sustainable cities, improving the quality of life of citizens, and socially responsible living environments [4]. This challenge involves new ways and initiatives to improve the public

management of cities and the provision of public services [5]. On the one hand, smart cities increase the intelligence of urban systems through new technological developments that form innovative solutions to support traffic control, energy production, crime surveillance, etc [6]. The data collected through sensors provide raw materials for city government governance, forming “real-time city”, where the whole process of city operation is visualized and presented in real-time to city managers, better describing, modeling and predicting urban processes, simulating possible outcomes of future urban development, in a more fine-granular, dynamic, and interconnected way to make cities clear, knowable, and controllable, thereby enhancing the efficiency and effectiveness of government decision-making and improving the performance of public service supply model [7], [8]. Smart cities bring convenience and precision to government management and public service supply by mobilizing all parties and applying interdisciplinary knowledge as urban subjects seek innovative and sustainable governance solutions to solve many problems of urbanization and reshape government public service delivery models [9]. On the other hand, “sustainability” has been considered a fundamental goal and positive outcome of smart cities by important organizations such as the United Nations and the European Union, as well as by many (European) cities. Smart cities rely on smart technologies to generate data about how cities work, especially in terms of energy (production, distribution, and consumption) and transport, and to use them to reduce the costs and waste generated by urban life, such as reducing greenhouse gas emissions and improving urban energy efficiency, and in this way to provide better and sustainable public services to their inhabitants [10]. As mentioned above, we propose the following hypothesis.

H1: Smart city construction can effectively improve PSL in cities.

The second is the information embedding dimension of smart cities and public service levels. The application and integration of public service data in smart cities is the basis for improving the effectiveness of public services for residents. Smart cities are concerned with integrating modern urban production factors into a common framework, with special emphasis on the importance of information and communication technology (ICT) in enhancing urban competitiveness in the last 20 years [11]. In the face of growing urban problems, local governments, businesses, non-profit organizations, and citizens have embraced the concept of smart cities, adopting new Internet-based technologies to create better-living conditions and maintain ecological environments. Among them, urban public service data is multifaceted, heterogeneous, integrated, and large-scale data formed in the process of urban public product supply and centered on urban user behavior and demand data, which is embedded in urban digital space and is a mapping of urban physical space data, economic space data, and social space data. These data will accurately describe the quantity, quality, structure, and spatial distribution of urban public service supply with the integration

of information technology such as smart city Internet of everything and artificial intelligence, which can also measure the consumption and reasonable boundary of public services by residents and provide them with more personalized public services that match their social contributions, thus maximizing the utility of urban public services [12]. It can be said that smart city construction promotes information symmetry between urban public service supply and demand through the mining, extraction, and integration of urban public service data, thus solving the problem of lack of efficiency in urban public resource allocation and realizing the improvement of PSL. Based on the above analysis, we propose the following hypothesis.

H2: Smart cities enhance PSL through the effect of Informatization.

The third is the technology iteration dimension of smart city and public service level. Smart city governance is a new form of urban governance that integrates technological innovation, algorithm supremacy, and data-driven and efficiency orientation, it changes from separate governance to connected governance, from sub-domain governance to integrated governance, from electronic governance to data governance, and from fuzzy governance to precise governance, to realize the improvement of PSL. The impact of smart city construction practice on urban public service governance should be regarded as a dynamic process in which society and technology are intertwined [13]. On the one hand, the use of digital technology can effectively expand the scope of supply of high-quality public services and thus radiate to all people; at the same time, it can break the barriers to public service access between regions and urban and rural areas due to differences in economic development levels and governance resources, and promote full-coverage, cross-regional and cross-urban-rural public service cooperation and sharing [14]. At the same time, the diffusion effect of information technology innovation, the spillover effect of information and knowledge, and the universal effect released by digital technology are also the basis for achieving high-quality development of public services [15]. On the other hand, digital technology can be used to tap the needs of residents and build a “demand-response” type of government system [16], thus promoting the collaboration and cooperation between grassroots government and higher-level departments, building a more inclusive and convenient social communication channel, and achieving smarter and more democratic decision-making [17]. For example, research on urban public information service systems, medical service systems, public transportation systems, security service systems, and emergency response systems can help to achieve convenience, eliminate urban-rural disparity, improve government efficiency, and promote economic development as well as security and safety. Smart technologies support and facilitate citizen participation in important democratic activities and local decision-making, and in turn, positive social relationships help to promote smart cities, creating a self-reinforcing mechanism [18]. In San Francisco and Seoul,

open data and participatory service design stimulated civic engagement and generated active citizenship [19]. Smart city construction provides good governance to eliminate “big city disease”, urban-rural public service imbalance, and higher quality personalized public services. Based on this, we propose the following hypotheses.

H3: Smart cities improve PSL through technological effects.

The fourth is the economic growth dimension of smart cities and public service levels. For the study of the relationship between the level of regional economic development and public services, it is generally agreed in the academic community that there is a high correlation between the public services supplied by local governments and the level of their financial expenditures on public services, economically developed cities can provide higher quality public services [20]. Theoretically, public finance theory has earlier explored the relationship between economic development and public services. The theory argues that urban economic development increases government revenue, which provides a guarantee for increased fiscal spending on public services. The increase in fiscal spending helps accelerate the construction of urban infrastructure and enrich the supply of public services. At the same time, the positive external benefits of public services such as infrastructure, public education, culture, and science and culture technology, in turn, promote urban economic development. Institutionally, the demand for public services is the basic basis for fiscal expenditure, while fiscal expenditure is an important guarantee to ensure that the demand for public services is met [21]. In practical terms, China has been benefiting from the growth of the national economy, and its economic development and public services are in a dynamic adaptive relationship, with economic development driving PSL, which in turn feeds economic development [22]. In contrast, the economic crisis of 2008 brought less than desirable consequences to the Portugal local government, and the national economic depression led to a serious deterioration in the scope and PSL [23]. At the same time, smart city construction as a new driving force to lead the transformation of traditional industries and the development of new information technology industries, boost urban growth, expand urban development dividends, and optimize urban industrial structure have been widely recognized in academic and practical circles [24], [25]. “Smart” adds significant value and capital to cities [26], promotes the rapid growth of on-demand jobs and creative industries through digital platforms, provides a broad space for entrepreneurship and business opportunities [27], and enhances urban economies. For example, southern European countries see smart cities as an important solution to the economic crisis in search of urban transformation in the aftermath of economic downturns as well as to alleviate the crisis of political legitimacy [28]. In summary, smart city construction promotes regional economic development through industrial optimization, transformation, and agglomeration, which increases the human, material, and financial resources invested by the government in public services and achieves

an improved PLS. Accordingly, we propose the following hypotheses.

H4: Smart cities enhance PSL through economic effects.

III. STUDY DESIGN

A. MODEL SPECIFICATION

To explore the relationship between smart city construction and PSL, and its policy effects are analyzed by using the DID method, with the first pilot cities as the treatment group and the unpiloted cities as the control group. Considering the availability of data, this paper uses prefecture-level data, and the finalized sample range is 212 prefecture-level cities in China from 2006-2018 (Figure 2). The data were obtained from the China City Statistical Yearbook and the website of the National Bureau of Statistics, as well as the Statistical Yearbooks and government work reports of each city. A small number of missing data were complemented by linear interpolation. Based on the above discussion, the following test model is set:

$$PSL_{it} = \alpha_0 + (Treat_i \times Post_t) + \gamma X_{it} + \delta_t + \mu_i + \epsilon_{it} \quad (1)$$

where i and t represent the city and year, respectively. PSL_{it} represents PSL of each city. $Treat_i$ is a city grouping variable, where the treatment group is the pilot smart city, defined as 1, and the control group is the non-pilot city, defined as 0. $Post_t$ is a time grouping variable, where the first pilot in 2012 is used as the threshold, and the year 2012 and later is assigned the value 1, and the year before 2012 is assigned the value 0. X is the set of control variables, δ_t is the time fixed effect, μ_i is the city fixed effect, and ϵ_{it} is the random disturbance term.

B. DESCRIPTION OF VARIABLES

Key explanatory variable: smart city ($Treat_i \times Post_t$, $Smart_{it}$). In this paper, the cross-product of grouping and time dummy variables ($Treat_i \times Post_t$) in the model is used as the key explanatory variable to measure the policy effect of smart city construction to improve PSL.

Explained variable: public service level (PSL_{it}). PSL is a comprehensive consideration of the adequacy of the government’s provision of public services and the quantity of public goods, the balance of distribution, and the universality of residents’ enjoyment, and involves various aspects such as education, employment, medical care, insurance, health, housing, and culture, etc. There may be multiple correlations among its influencing factors, resulting in information redundancy. Therefore, in this paper, we choose to use principal component analysis (PCA) to extract the “principal components” that contain most of the information of the original data through dimensionality reduction, which can not only obtain the quantitative results of each dimension of PSL, but also fully reflect the contribution of the basic indicators of each dimension of PSL to the total index. Drawing on existing research, this paper selects six basic indicators, including the number of teachers in compulsory education, the number of beds in hospitals and health centers, the number of physicians, the total number of books in public libraries, the

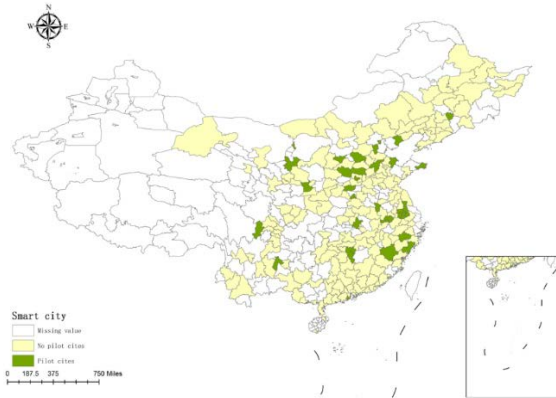


FIGURE 2. Study area.

proportion of urban workers participating in basic pension insurance, and the proportion of participants in unemployment insurance, representing education, medical care, culture, and insurance respectively, and obtains two measures of PSL through principal component analysis, which are named the quality of education and medical services(EAM) and the level of social life security(SLS).

Control variables: Considering that some city characteristic variables may interfere with PSL, this paper introduces some control variables: (1)Urban Economy: the logarithm of regional economic gross product is used to measure the level of urban economic development, Wagner's law suggests that with economic development, the scale of government expenditure will expand, and by measuring the scale and structure of a country's fiscal expenditure, it can reflect changes in government functions;(2) Population Size: expressed by population density, the quantity and quality of public service supply are influenced by urban population density, and people will tend to choose to live in the territory that best meets their public product preferences [29]; (3) Financial Development: measured by the year-end balance of loans from financial institutions as a proportion of regional economic GDP; (4) Fixed Assets: measured by regional fixed assets investment measured by the proportion of regional economic GDP; (5) Research Environment: expressed by the logarithm of science and technology expenditure, which covers the construction and investment in science and technology in urban smart cities and is closely related to PSL.

Mediating variables: Following the analysis of the theoretical hypotheses, we introduced three mediating variables: (1) Information Effect: measured by the sum of the number of cell phone subscribers and the number of Internet broadband access subscribers as a proportion of the total regional population; (2)Technology Effect: the city innovation per capita score from the Longrun Longxin China Regional Innovation and Entrepreneurship Index 2019 is used to measure the local technology innovation effect. The data is based on patent data from the China Intellectual Property Office and

TABLE 1. Descriptive statistics.

Variable Name	Variable Code	Mean	St. Dev.	Min	Max
The quality of education and medical services	EAM	5.94e-11	1	-1.439	7.275
The level of social life security	SLS	-4.03e-09	1	-0.930	11.114
Smart City	Smart	0.0813	0.2733	0	1
Urban Economy	GDP	16.2257	0.9838	13.160	19.305
Population Size	Pop	441.1563	325.4853	4.7000	2648.1
Financial Development	Fin	0.8579	0.5441	0.1122	7.4502
Fixed Assets	FA	0.7230	0.3081	0.0365	2.4014
Research Environment	Res	9.7308	1.5482	3.5264	15.529
Information Effect	Info	1.0703	1.0451	0.0471	11.496
Technology Effect	Tec	51.5596	29.0154	0.3425	100
Economic effects	Eco	2.5784	2.9770	0.0576	45.938

enterprise registered capital data from the China Industry and Commerce Bureau, and integrates the three dimensions of entrepreneurs, investment and technology, while considering the value of patents and the number of patents, which can accurately measure the degree of local innovation technology;(3) Economic effects: expressed by the proportion of local government fiscal expenditure to the regional economic GDP, a part of the local government's fiscal expenditure must be spent on public services, and the amount of investment is directly related to PSL. The results of descriptive statistics for each variable are shown in TABLE 1.

IV. EMPIRICAL RESULTS AND ANALYSIS

A. POLICY EFFECT ANALYSIS

To verify the authenticity of the H1, this paper applies the DID method to assess the impact of smart city construction on PSL. Before that, we need to test whether the model fits the fixed effects model. The Hausman test results¹ showed significant rejection of the original hypothesis, so this paper chose to use a fixed effects model combined with robust standard errors to increase the accuracy of the model. The corresponding baseline regression results are shown in Table 2. In Table 2, model (1) and model (2) are models without adding control variables, model (3) and model (4) add control variables for regression, and the above four models are the effects of smart city construction on PSL in two areas: EAM, and SLS. All estimation results show that regardless of whether control variables are added or not, smart city

¹Due to space limitations, the results of the Hausman test are available from the authors.

TABLE 2. Baseline regression results.

Variable code	Model (1)	Model (2)	Model (3)	Model (4)
Smart	0.0625** (0.0269)	0.0576*** (0.0205)	0.0519* (0.0272)	0.0404* (0.0229)
GDP			0.2883*** (0.0461)	0.2803*** (0.0536)
Fin			0.0312* (0.0179)	0.0025 (0.0166)
Pop			0.0005*** (0.0001)	0.0010*** (0.0002)
FA			-0.1961*** (0.0282)	-0.2031*** (0.0268)
Res			0.0282*** (0.0113)	0.0820*** (0.0178)
Intercept term			-3.4615*** (0.7624)	2.8394*** (0.8155)
Observations	2756	2756	2756	2756
Fit	0.9427	0.9255	0.9465	0.9318
Model selection	FE	FE	FE	FE

Note: Robust t-statistics in parentheses. ***, **, and * denote the reject of null hypotheses at 1%, 5%, and 10% significance level respectively. Each model used clustered standard errors to mitigate the heteroskedasticity problem.

construction has a statistically significant positive effect on PSL at the 1% level, indicating that smart city construction improves PSL. Among them, smart city construction significantly improved EAM by about 5.18% and SLS by about 4.04%. This also provides preliminary empirical evidence for the H1. In terms of control variables: *GDP*, *Fin*, *Pop*, and *Res* all have a significant positive impact on EAM, and *FA* has a significant negative impact on EAM. *GDP*, *Pop*, and *Res* all have a significant positive impact on SLS, and *FA* has a significant negative impact on SLS, and *Fin* is not significant. No matter EAM or SLS, in general, all of them are positively influenced by *GDP*, *Pop* and *Res*. It can be seen that economic development, as the foundation of people’s livelihood, is the basis for the government to provide public services, and at the same time, this is consistent with the characteristics of smart city construction using information technology as a means.

B. PARALLEL TREND TEST

Parallel trends are the assumed premise of the DID model, the treatment and control groups should have similar trends in PSL prior to the occurrence of the smart city pilot policy shock. The parallel trend tests are shown in Figures 3 and 4, which report the magnitude of the estimated parameter β and the corresponding 95% confidence interval for the explanatory variables. The parallel trend plots show that the coefficients of the effect variables fluctuated around 0 before the implementation of the smart city pilot policy and changed significantly after the policy implementation, indicating that the assumption of parallel trend was satisfied between the cities in the treatment and control groups. There was a homogeneous trend in PSL between the experimental and control groups before the implementation of the smart city policy, and there was no systematic difference related to the time trend.

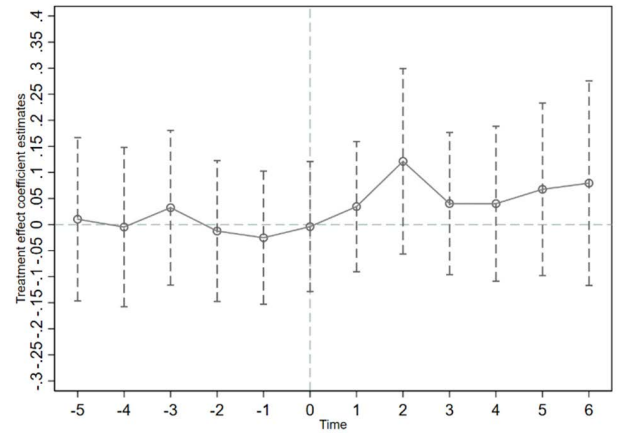


FIGURE 3. The parallel trend tests of EAM.

C. ROBUSTNESS TEST

1) PLACEBO TEST

Another possible estimation error of the DID method to identify policy effects is the effect of other unobservable individual characteristics that change over time on the estimation results. In this regard this paper first selects a series of observable control variables for urban characteristics, including *GDP*, *Fin*, *Pop*, *FA*, *Res*, etc. Second, drawing on the treatment of Chetty [30] and La Ferrara [31], the indirect placebo test is conducted by randomly generating a list of smart cities according to equation (2) and deriving expressions for the coefficients $\hat{\beta}$.

$$\hat{\beta} = \beta + \omega \times \frac{Cov(Smart_{it}, \varepsilon_{it} | R)}{(Smart_{it} | R)} \tag{2}$$

where *R* includes all other control variables and fixed effects, and ω is the effect of other unobservables on the explanatory variables; if $\omega = 0$, then unobservables do not affect the estimation results, $\hat{\beta}$ is proven to be unbiased, but this cannot be directly verified. For this reason, this paper applies an indirect placebo test, the logic of which is to find an error variable that theoretically will not have an effect on the outcome variable instead of *Smart_{it}*, due to random generation, $\beta = 0$; however, if $\hat{\beta}$ is not zero, it means that the estimating equation of this paper is wrong and this error estimating variable will have an effect on the outcome, that is, there are other characteristic factors that will affect the estimation result. In the case of this paper, a list of smart city cities is randomly generated by computer simulation, which generates an incorrect estimate: $\hat{\beta}$ random. To improve the identifiability of the placebo test, this process is then repeated 1000 times, thus generating 1000 $\hat{\beta}$ random accordingly. Figure 5 and Figure 6 depicts the distribution of $\hat{\beta}$ random, the probability density distribution of the estimated coefficients. Figure 3 and Figure 4 intuitively shows that the $\hat{\beta}$ random distribution is in the vicinity of zero and obeys a normal distribution, demonstrating that there is no policy effect of the randomly generated smart city pilot list, and it can be inferred that the boosting effect of the smart

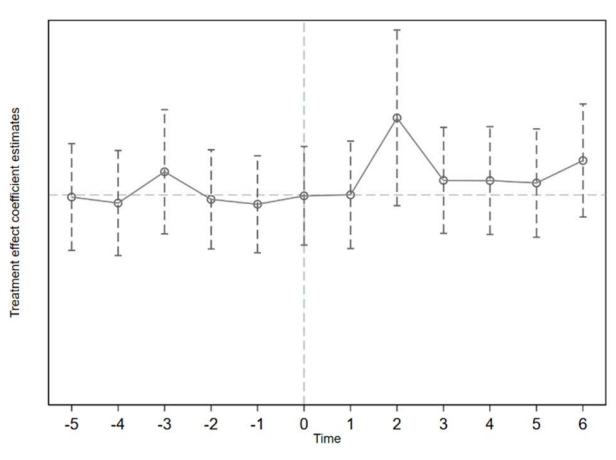


FIGURE 4. The parallel trend tests of SLS.

city pilot on the improvement of PSL of the treatment group is real.

2) PSM-DID TEST

In this paper, we overcome the endogeneity problem caused by sample self-selection bias by using PSM. The basic idea of PSM method is to find a city A among the unpiloted cities, so that the observable variables of A and the pilot city B match as much as possible, $X_A = X_B$, thus screening out the samples that are less affected by endogeneity, eliminating the grouping effect as much as possible, and ensuring the reliability and robustness of the DID method. It is divided into the following three steps. In the first step, the propensity score is estimated by logit model, and the k-nearest neighbor caliper matching method is used to match the experimental group with the control group. In the second step, a balanced hypothesis test was conducted to ensure that there was no significant difference in individual trait variables between the matched samples of the experimental and control groups. The results of the balance test in Table 3 show that the differences between the experimental and control groups after matching were significantly lower, and the absolute value of the standard deviation after matching was less than 20% [32], and the p-value of each variable after matching was significantly greater than 0.1, meaning that the original hypothesis of no systematic difference between the experimental and control groups could not be rejected, and the sample model met the requirements of the balance test. In the third step, based on re-screening and re-grouping the sample by PSM, the secondary test of smart city pilot policy effect was conducted. Model (5) and model (6) in Table 4 report the estimation results of the PSM-DID model without the inclusion of control variables for EAM and SLS, respectively, while model (7) and model (8) add control variables for regression, and it can be found that the coefficients of the pilot policy are still significantly positive, and the results estimated after matching are consistent with those estimated by the DID method. In other words, after considering the sample selection bias

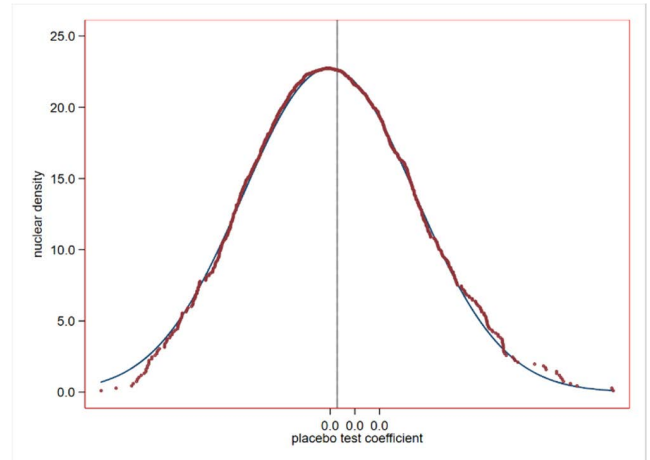


FIGURE 5. Placebo test coefficients-EAM.

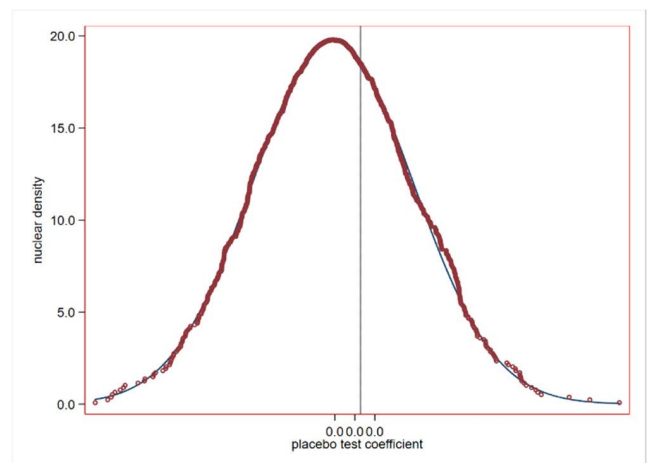


FIGURE 6. Placebo test coefficients-SLS.

problem, H1 of this paper still holds, which further indicates that the empirical results of this paper are robust and reliable.

3) WINSORIZE

Since the existence of extreme values of variables would affect the accuracy of model estimation, to more truly describe the relationship between smart city and PSL, in this paper, all continuous variables are treated with bilateral winsorize at the 1%, 2% and 3% levels and re-regression. The results show that the regression coefficient of $Smart_{it}$ is still significantly positive in Table 5. In summary, after passing the above robustness tests, H1 is fully verified, indicating that the smart city pilot policy can indeed promote the improvement of PSL.

D. FURTHER MECHANISM TESTING

From the empirical results, smart city construction can significantly improve PSL, but what is the conduction mechanism? As explained in the previous theoretical analysis

TABLE 3. Balance test.

Variable code	Match	Experimental group mean	Control group mean	Deviation rate	Deviation reduction ratio (%)	t	p> t
GDP	Before	16.825	16.173	70.8	92.7	9.67	0.000
	After	16.825	16.873	-5.1		-0.54	0.589
Fin	Before	1.0446	0.8414	37.4	95.8	5.38	0.000
	After	1.0446	1.0532	-1.6		-0.17	0.867
Pop	Before	578.18	429.03	48.1	99.1	6.62	0.000
	After	578.18	579.55	-0.4		-0.04	0.965
FA	Before	0.86027	0.7108	49.9	90.8	7.02	0.000
	After	0.86027	0.8464	4.6		0.43	0.665
Res	Before	10.918	9.6258	92.5	96.4	12.30	0.000
	After	10.918	10.964	-3.3		-0.37	0.713

TABLE 4. PSM-DID model estimation results.

Variable code	Model (5)	Model (6)	Model (7)	Model (8)
Smart	0.0649** (0.0269)	0.0634*** (0.0204)	0.0544** (0.0271)	0.0482** (0.0221)
Control variables	NO	NO	YES	YES
Intercept term	2.0412*** (0.1209)	-0.6260*** (0.0750)	-3.3005*** (0.7616)	3.2546*** (0.7929)
Observations	2753	2753	2753	2753
Fit	0.9435	0.9218	0.9467	0.9266
Model selection	FE	FE	FE	FE

Note: Robust t-statistics in parentheses. ***, **, and * denote the reject of null hypotheses at 1%, 5%, and 10% significance level respectively. Each model used clustered standard errors to mitigate the heteroskedasticity problem.

TABLE 5. Winsorize.

Variable code	Model (9)	Model (10)	Model (11)	Model (12)	Model (13)	Model (14)
Smart	0.0508** (0.0218)	0.0887*** (0.0188)	0.0176* (0.0194)	0.0869*** (0.0192)	0.0097* (0.0200)	0.0756*** (0.0197)
Control variables	YES	YES	YES	YES	YES	YES
Intercept term	-2.181*** (0.7534)	2.1017*** (0.5364)	-1.2000*** (0.7029)	2.3331*** (0.5918)	-1.7644*** (0.7606)	1.9653*** (0.6417)
Observations	2501	2490	2254	2229	2050	2020
Fit	0.9557	0.9124	0.9571	0.8726	0.9556	0.8625
Model selection	FE	FE	FE	FE	FE	FE

Note: Robust t-statistics in parentheses. ***, **, and * denote the reject of null hypotheses at 1%, 5%, and 10% significance level respectively. Each model used clustered standard errors to mitigate the heteroskedasticity problem.

in Part II, whether the promotion effect of smart cities on PSL is transmitted through the information effect, technology effect, and economic effect needs to be tested one by one using the mechanism test model. Here, we set the equations of the mediating effect model as follows [33]:

$$PSL_{it} = \alpha_0 + \alpha_1 Smart_{it} + \gamma X_{it} + \delta_t + \mu_i + \varepsilon_{it} \quad (3)$$

$$MOD_{it} = \eta_0 + \eta_1 Smart_{it} + \gamma X_{it} + \delta_t + \mu_i + \varepsilon_{it} \quad (4)$$

$$PSL_{it} = \theta_0 + \theta_1 MOD_{it} + \theta_2 Smart_{it} + \gamma X_{it} + \delta_t + \mu_i + \varepsilon_{it} \quad (5)$$

MOD_{it} in (4) denotes the mediating variables, including informatization effect, technology effect, and economic effect. If there is a conduction mechanism of these three

aspects, it is required that $Smart_{it}$ significantly affect PSL_{it} , $Smart_{it}$ significantly affect MOD_{it} , and MOD_{it} significantly affect PSL_{it} , in other words, in (3)-(5), α_1 , η_1 and θ_1 must meet the significance in statistical sense. If the regression coefficient θ_2 of $Smart_{it}$ in (5) is smaller than α_1 , it means that the effect of $Smart_{it}$ on PSL_{it} is partially absorbed by MOD_{it} and there is a partial mediation effect; if θ_2 is not significant, it means that the effect of $Smart_{it}$ on PSL_{it} is completely absorbed by MOD_{it} and there is a full mediation effect.

1) INFORMATION EFFECT TEST

From model (15) in Table 6, it can be seen that the impact coefficient of smart city on urban informatization is 0.0672,

TABLE 6. Mechanism test-information effect.

Variable code	Model (15)	Model (16)	Model (17)
Smart	0.0672*** (0.0240)	0.0460* (0.8398)	0.0393*** (0.0248)
Intermediate variables		0.0876*** (0.0322)	0.2560*** (0.0700)
Control variables	YES	YES	YES
Intercept term	0.6681 (0.7161)	-3.520*** (0.7629)	-1.2551 (0.8235)
Observations	2756	2756	2756
Fit	0.9579	0.9469	0.9285
Model selection	FE	FE	FE

Note: Robust t-statistics in parentheses. ***, **, and * denote the reject of null hypotheses at 1%, 5%, and 10% significance level respectively. Each model used clustered standard errors to mitigate the heteroskedasticity problem.

which is significant at the 1% level; model (16) indicates that the role of smart city on EAM decreases from 5.18% to 4.6%, which is significant at the 10% level, indicating that the role of smart city on EAM is partially transmitted through Internet information service; model (17) indicates that the role of smart city on SLS decreases from 4.04% to 3.93%, which is significant at 1% level, indicating that the role of smart city on SLS is partially transmitted through Internet information services. The above two points confirm the view that smart cities promote PSL through the information effect and verify the H2. The policy implementation, while promoting the construction of information infrastructure, also breaks the information barrier between the government and the public because of the information technology has the characteristic of zero cost of information dissemination, which clears the information barrier for transforming government functions and improving the efficiency of using public service funds.

2) TECHNOLOGY EFFECT TEST

In Table 7 of the mechanism test model estimation results, model (18) shows that the coefficient of the effect of smart cities on urban technological innovation is significantly positive. Model (19) indicates that by adding smart city, EAM variables and technology effect variables, the effect of smart city on EAM decreases from 5.18% to 4.97%, indicating that the promotion effect of smart city on EAM is partially transmitted through technology effect; Model (20) indicates that the effect of smart cities on SLS decreases from 4.04% to 3.81% with the inclusion of smart cities, SLS and technology effect variables, indicating that the effect of smart cities on SLS is partially transmitted through technology effect. Overall, smart cities can promote PSL through the technology effect, verifying the H3. This finding has some similarity with the findings of Caragliu [34], which shows that in the process

TABLE 7. Mechanism test-technology effect.

Variable code	Model (18)	Model (19)	Model (20)
Smart	1.6702** (0.8398)	0.0497* (0.0272)	0.0381* (0.0230)
Intermediate variables		0.0012** (0.0005)	0.0013*** (0.0005)
Control variables	YES	YES	YES
Intercept term	-188.24*** (25.259)	-3.221*** (0.7700)	3.0912*** (0.8320)
Observations	2756	2756	2756
Fit	0.9422	0.9466	0.9319
Model selection	FE	FE	FE

Note: Robust t-statistics in parentheses. ***, **, and * denote the reject of null hypotheses at 1%, 5%, and 10% significance level respectively. Each model used clustered standard errors to mitigate the heteroskedasticity problem.

TABLE 8. Mechanism test-economic effect.

Variable code	Model (21)	Model (22)	Model (23)
Smart	0.2797** (0.1425)	0.0444*** (0.0196)	0.0347*** (0.0225)
Intermediate variables		0.1087*** (0.0128)	0.0799*** (0.0094)
Control variables	YES	YES	YES
Intercept term	-42.72*** (2.6516)	-0.5615 (0.6397)	-0.2902 (0.5880)
Observations	2756	2756	2756
Fit	0.8139	0.9628	0.9356
Model selection	FE	FE	FE

Note: Robust t-statistics in parentheses. ***, **, and * denote the reject of null hypotheses at 1%, 5%, and 10% significance level respectively. Each model used clustered standard errors to mitigate the heteroskedasticity problem.

of smart city development, multiple subjects form multiple spiral feedbacks through the extensive and deep application of information and communication technologies to accelerate the iterative development of improved and updated technologies and further realize the modernization and development of public services.

3) ECONOMIC EFFECT TEST

Model (21) column in Table 8 shows that smart cities can significantly promote urban economic development; model (22) is with EAM as the core variable, and model (23) is with SLS as the core variable, while the economic effect variable is included in the regression equation with $Smart_{it}$, and the results show that the economic effect significantly improves EAM and SLS, and the coefficient of the smart city variable is reduced, indicating that the economic effect plays a partly

mediating role in the process of smart city's influence on PSL. In summary, the economic effect is a mediating variable for smart cities to promote the development of PSL, which verifies the H4.

V. DISCUSSION AND POLICY IMPLICATIONS

A. DISCUSSION

The smart city pilot policy launched in 2012 is a policy initiative in China to achieve the goals of innovation in urban management and convenience in public services, but whether it is effective needs to be further tested. This study examines whether the smart city pilot policy has affected PSL of the Chinese government from both theoretical and empirical perspectives. We considered the policy impact of smart city as a quasi-natural experiment in the Chinese context and applied the DID method and the mediating effect model to the panel data of 212 cities from 2006 to 2018.

First, as a new type of urban development, smart city is a strategic choice to improve PSL. The construction of smart cities has significantly improved the level of two basic public services, EAM and SLS. After a series of robustness tests, this result still holds true. Since the 1970s, how to improve PSL has become the main governance pressure faced by governments around the world. With the rapid development of digital technologies represented by the Internet, IoT and artificial intelligence, the provision of convenient and efficient public services through digital infrastructure construction has gradually been effectively used in the public sector [35]. Among them, as a new solution to the global urbanization problem, smart city is closely related in theory to the provision of urban municipal services [36]. Scholars such as Clohessy T pointed out that the essence of a smart city is a service [37]. Similar to the research conclusions of this paper, Mo and Ren found that the construction of big data analysis and management system, tourism public service platform and intelligent transportation network of intelligent tourism tourists' behavior can effectively improve the quality of tourism public service supply and increase tourists' satisfaction [38]. Using Chinese survey data, Yu et al. found that the improvement of public services brought about by the development of smart cities significantly increased the emotional well-being of residents [39]. Currently, given the numerous challenges that urban public administrations are grappling with, more and more cities are turning to smart solutions using information and communication technologies. Smart city construction has become an important carrier for the public sector to provide intelligent public services and administration, enabling the public sector to manage resources and make public services more effective through digital technology, and at the same time, it can be perceived and accepted by most residents.

Second, the mediation effect test shows that the construction of smart cities significantly improves PSL by producing information effects, technical effects, and economic effects. At the level of information effect, the concept of smart city has so far been built based on information, and its main feature is the comprehensive application of IT and information

resources [40]. In smart city construction, the public sector can use digital infrastructure such as IoT, the Cloud, Block Chain, Big Data, etc. to build a decision management system. Accurate smart public service delivery through providing the entire interconnection, integration and virtualization of its Space, Services and Structure (3S) [41]. Taking medical services as an example, Wu et al. used three-year panel data analysis of China's CHARLS national baseline survey and found that the informatization effect created by smart city construction can reduce the use of residents' outpatient services and increase the use of inpatient services, which is conducive to improving the health status of residents [42]. At the level of technological effect, a typical smart city project means not only the involvement of large multinational corporations and local public authorities, but also the involvement of local companies, usually aiming to translate general technological solutions into actual local living needs [43]. Taking supply chain design as an example, the technical measures of smart city load (Big Data analysis, industrial IoT) better promote the distributed manufacturing of supply chain design, optimize the existing industrial production system, and democratize supply chain design, and transformed the manufacturing industry from "global production" to the future "city-oriented" social materiality, meeting citizens' adequate service needs for market-oriented industries [44]. When evaluating the positive effects of smart city construction policies, Jiang et al. found that smart city construction improves green total factor productivity and green technology progress by promoting urban technological innovation. The results of this study are highly consistent with the conclusions of this paper. In terms of economic effects, smart city construction is a way to realize the economy and an important factor affecting economic development and competitiveness. Xiao and Xie pointed out that the construction of smart cities can significantly promote regional economic growth, with a growth rate of 5.4% to 5.9% [45]. Socio-economic prosperity is not only conducive to helping citizens achieve the highest personal and social well-being to improve their lives. At the same time, it will also help the public sector to obtain more adequate tax revenue and continuously increase the investment in social public services, thereby expanding the coverage of public services and improving PSL. The economic growth effects of smart cities have been fully discussed in the existing literature, and this study extends the relationship between the two to PSL and proposes a transmission mechanism of "smart cities - economic growth - PSL". It has certain theoretical innovation.

B. POLICY IMPLICATIONS

In the established urban development strategy, to better play a positive role in improving PSL in the smart city, we should start from the following aspects. First, change the mode of urban governance, and continue to promote the construction of smart cities. Accelerate the intelligence of infrastructure, vigorously develop smart pipe networks and smart water, promote the application of smart light poles and smart manhole

covers, accelerate the establishment of an IoT sensing system for urban components, and improve the level of urban digitization. Promote 5G, NB-IoT and other next-generation network technologies continue to evolve and promote high-speed broadband wireless communications full coverage. It should import advanced management ideas with the help of wisdom technology, establish a wisdom application system for urban management that combines unification and division and collaborative operation, fully perceive, and control the operation of the city, provide timely feedback on external changes and citizens' needs, thus improving the efficiency of the government and urban governance.

Second, pay attention to urban science research and development, and gradually improve the level of technological innovation. Smart city construction mainly through technological innovation effect to improve PSL, at the same time, smart city is also the innovation and application of information technology, is the result of intelligent transformation of urban natural, economic, and social systems by a new generation of information technology with the IoT as the core, so the construction of smart city must rely on technological innovation, promote the city to become a knowledge center and innovation incubator. On the one hand, optimize the environment of technological innovation. To strengthen the construction of public service platforms for technology research and development, application testing, evaluation, and testing, focus on promoting the "industry-academia-research" cooperation between enterprises and universities, research institutes, promote cooperation between enterprises, optimize the software and hardware environment for technology innovation in smart cities. On the other hand, the key to strengthening technology research and development lies in the training of professional talents to provide strong intellectual support for the development of smart cities.

Finally, play the function of smart city construction and continue to promote the economic development of the city. Smart city construction mainly improves PSL through economic effects, while the development of wisdom technology will be conducive to the breeding of new pillar industries and pioneering industries based on knowledge and information, giving birth to strategic emerging industrial clusters, and promoting urban economic development. On the one hand, pay attention to the positive externality of smart city construction to enhance the level of regional economic development, continuously promote the transformation of the traditional city development model to the intelligent model, accelerate the deep integration of the city's internal subsystems with the smart city model, especially to increase the investment in information infrastructure such as data centers and information networks, and enhance the development level of the city's intelligent facilities construction, thus driving the transformation and upgrading of the manufacturing industry from low and mid-range to high-end. On the other hand, according to local conditions, combined with the development base and comparative advantages of each region, focused, and targeted to promote the construction of smart cities in each region.

VI. CONCLUSION AND FUTURE WORK

A. CONCLUSION

Building smart cities is a key goal of future urban development, which is of great practical significance for promoting high-quality urban development. At present, the construction of smart cities has been vigorously promoted in countries around the world. Among them, China has launched a smart city pilot project since 2012. At present, the positive effect of smart cities on urban development has become a highly concerned research topic among scholars. To further enrich the existing academic research, this study empirically analyzes the relationship between smart city construction and the level of public services by constructing panel data of 212 prefecture-level cities in China from 2006 to 2018 using the difference-in-difference (DID) model. This study makes some interesting research conclusion. First, smart city construction significantly improves PSL during the sample period. Among them, smart city construction improved the quality of EAM by approximately 5.18% and SLS by approximately 4.04%. Second, the mechanism analysis revealed that smart city construction has a significant positive impact on PSL through informational, technological, and economic effects. The conclusion of this paper demonstrates again the positive effect of smart city construction, which has important implications for the future development of the city.

B. LIMITATIONS AND FUTURE WORK

There are still some limitations in this study. First, due to the wide range of public services and the lack of consensus in the academic field, as well as the difficulty in data collection, this paper only adopts two elements to measure PSL, namely, EAM and SLS, and the conclusions can only explain part of the dependent variables. In the future, it is necessary to establish a scientific public service content system and improve the data mining ability to draw more comprehensive research conclusions. Second, the impact of smart city construction penetrates all aspects of residents' lives, and this paper only considers the information effect, technology effect and economic effect, while the rest of the mechanism of action still needs further in-depth study. Third, this paper only focuses on the positive effect of smart cities on the level of public services, and the contribution of the conclusions is limited. In future studies, scholars can more widely consider the promoting effect of smart cities on urban sustainable development, including the development of smart cities and digital economy, the construction of resilient society, and the improvement of emergency management capacity.

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