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SPATIAL ECONOMETRIC ANALYSIS OF INFORMATION AND COMMUNICATION TECHNOLOGY INNOVATION DIFFUSION AND ITS INFLUENCE FACTORS

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Abstract: This paper uses the statistical data of 288 cities above the prefecture level in the country from 2001 to 2018 to study the diffusion of information and communication technology (ICT) innovation and its influencing factors. Firstly, the improved Bass model is used to measure the diffusion speed of ICT innovation, and then a panel data fixed-effect dynamic SAR model of ICT innovation diffusion and its influencing factors is constructed, and the parameters of the dynamic SAR model are estimated by the pseudo-maximum likelihood estimation method. The research shows that the time and space effect of ICT innovation diffusion is significant, and innovation diffusion is not only affected by local influences but also by neighboring cities; factors such as population density, population flow, average household ICT consumption expenditure, and ICT supply capacity have a significant impact on its innovation diffusion, and These factors have significant short-term spatial spillover effects and long-term return feedback effects.
Keywords: Information and communication technology (ICT); Bass model; Dynamic SAR model; Spatial effect; Quasi-maximum likelihood estimation method

1 LITERATURE REVIEW

With the rapid development of China's mobile services, broadband services and radio and television services, and the continuous deepening of " 3 -network integration", the information and communication technology (ICT) industry plays a role as a catalyst and booster for the development of the national economy, especially when entering the After 2010, China has gradually stepped into the "fast lane" of the integrated development of mobile, broadband and radio and television, and entered the era of information and communication technology (referred to as "ICT era") marked by "Internet +". The rapid update and deep integration of communication technology, information technology and terminal hardware technology have injected new momentum into the development of the entire industry. At the same time, the penetration, drive and multiplier of the information and communication technology industry to the national economy have become more and more significant, becoming a driving force for economic development. It will further promote and accelerate the transformation and upgrading of the national economy. For this reason, this paper studies the diffusion of ICT innovation and its influencing factors from the perspective of industrial integration. The results provide reference and reference for 5G operation and Internet integration development.

The process of dissemination and adoption among potential users through a certain channel, and pointed out that the diffusion of technological innovation includes three aspects, namely, the diffusion among enterprises, the diffusion within the enterprise and the joint process between the two. The overall spread of effects. Li Baohong [2] summarized the connotation and essence of ICT innovation. ICT innovation is mainly based on the generation of new ideas, through the commercialization of ICT innovation and its diffusion to potential markets, deep integration and even the whole process of technology substitution. Wu Chunyou et al. [3] believe that the diffusion of technological innovation is realized by two aspects: "expansion" and "scattering". The process of transfer and dissemination outside the enterprise.

Scholars at home and abroad often use the "S-shaped" curve of innovation diffusion in the research of technological innovation, among which Mansfield model[4] and Bass model[5] are classic models for studying innovation diffusion[6]; Liu Jingjing[7] uses multiple regression model to analyze Shanghai and Chongqing's second -generation mobile phone (2G) users in China to study the diffusion law and its influencing factors; Li Zaiyang et al. [8] conducted an empirical study on the diffusion of mobile communication technology based on statistical data from 1990 to 2012; The Mansfield model studies the regional differences and diffusion mechanisms of the development paths of China's mobile communication industry, and evaluates the differences in the development paths of mobile communications in different regions of China and the influencing factors of diffusion; Model, an empirical study on the diffusion trend of ICT and mobile Internet innovations.

Fang Yuanping [12] used the information technology indicators and service innovation indicators of 21 prefecture-level cities in Guangdong Province from 2001 to 2011 to study the impact of information technology on service industry innovation with a static spatial model. The results show that there is a relationship between service industry innovation and information technology. Significant spatial correlation exists. Ye Qianqian [13] used the monthly panel data of 29 provinces from 2013 to 2015 to construct a static spatial model to study the influencing factors and spatial spillover effects of Internet financial technology innovation diffusion. Silva et al. [14] applied the spatial dynamic model of panel data to study the influencing factors and spatial spillover effects of urban and rural population growth in Brazil. Yesilyurt and Elhorst [15] used the annual data of 144 countries (1993-2007) to study the influencing factors and spatial effects of national defense expenditures by using panel data spatial static and dynamic models. It can be seen that the application of spatial econometric analysis methods in various fields is becoming more and more popular and in-depth.

of all, most of them focus on the research on the diffusion or influence mechanism of mobile service innovation, and there are few researches on the field of information and communication technology integration ; Modern intelligent iterative algorithms do not estimate many parameters; moreover, provincial-level panel data are mostly used for analysis and research, and the spatial weight matrix is only set to 31 provinces. The research granularity is relatively large, and the stability of parameter estimation results is poor; There are few econometric analysis methods to study the influencing factors of ICT innovation diffusion. In order to further enrich the research results in this field, this paper first improves and optimizes the innovation diffusion model, uses the improved Bass model to estimate the parameters by using the simulated annealing method, and calculates the innovation diffusion speed according to the parameter estimation results; secondly, uses the panel data space The dynamic econometric model conducts spatial econometric analysis on the speed of innovation diffusion and its influencing factors, and the analysis on the mechanism of innovation diffusion is more comprehensive and the research is more in-depth.

2 RELATED THEORIES AND METHODS

2.1 Innovation Diffusion Speed Model and Estimation Method

Scholars at home and abroad often use the Bass model to study and analyze innovation diffusion. Bass uses probability theory and calculus theory to set up and derive the resistance [5].

Use electronic product innovation diffusion model, namely Bass model. The differential expression of the classic Bass model is

$$n(t) = \frac{dN(t)}{dt} = p\,[m - N(t)] + \frac{q}{m} N(t)\,[m - N(t)] \tag{1}$$

Among them: n (t) is the number of non-cumulative adopters; N (t) is the number of cumulative adopters; m is the maximum value of cumulative adopters in the whole life cycle; p is the innovation coefficient, and p > 0; q is the imitation coefficient, And q > 0. The new adopter or non-cumulative adopter model (hereinafter referred to as "non-cumulative Bass model") at time t is

$$n(t) = m\,(p + q)2\,\frac{e^{-(p+q)t}}{\qquad 2}$$

p ⌈ê q e-(p + q)t + 1ùú (2)

Bass model parameter estimation mostly uses least 2 multiplication (OLS) [5], nonlinear least 2 multiplication (NLS) [16], least 2 multiplication and nonlinear least 2 multiplication "hybrid" method [17] for parameter estimation. With the development of computer technology, modern intelligent algorithms are increasingly used in the estimation of Bass model parameters, such as quasi-Newton method[18], ant colony algorithm[18-19], particle swarm algorithm[20] and genetic algorithm[18, twenty one].

2.2 Spatial Dynamic Panel Model and Estimation Method

With the in-depth application of computer technology in econometric analysis, quantitative modeling has gradually evolved from section models and panel models to dynamic space panel models. Dynamic space panel models have stronger explanatory power to reality and better fitting effects. The panel data spatial econometric model is divided into two types: fixed effect and random effect. Lee and Yu[22] believed that the fixed effect model of the space panel is more suitable than the random effect model, and the estimation results are more robust. And the calculation is simpler. In recent years, many scholars at home and abroad have adopted panel data fixed-effect dynamic spatial autoregressive model (referred to as "dynamic SAR model") for spatial econometric analysis. The latest research results build a panel data fixed-effect dynamic SAR model, and the general expression of the model 1 is

$$Y_t = \mu + \tau Y_{t-1} + \delta W Y_t + \eta W Y_{t-1} + X_t \beta + \xi_t + \varepsilon_t \tag{3}$$

Among them: Y_t is the dependent variable; W is the spatial weight matrix, which is used to describe the spatial dependence; WY_t is the endogenous interaction effect between the explained variables; τ is the time lag item Y_{t-1} coefficient of the dependent variable, which reflects the explained The influence of the variable time lag item on the current explained variable; δ is the spatial autoregressive item or lag item (WY_t) coefficient, reflecting the influence of the interpreted variable space lag item on the current explained variable; η is the dependent variable space-time lag item (WY_{t-1}) coefficient, which reflects the influence of the time-space lag item of the explained variable on the current explained variable; β is the $K \times 1$ unknown parameter vector to be estimated; W is the $N \times N$ order non-negative matrix; $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \cdots, \varepsilon_{Nt})^T$ are independent and identically distributed random disturbance term vectors with a mean of 0 and a finite variance of σ^2.

Formula (3), the individual effect item μ does not change with time, and at the same time satisfies the correlation between the individual effect μ and the variable matrix X, which is called the space fixed effect type; the time effect item ξ_t remains consistent in the time dimension, does not change with individuals, and satisfies The individual effect ξ_t is related to the variable matrix X, which is called the time fixed effect type; if both the individual effect and the time effect are satisfied, the model is called the time-space fixed effect type.

LeSage and Pace[23] used the partial differential of the spatial econometric model to explain the impact of variable changes in the model, using the main diagonal elements in the partial derivative matrix to represent direct effects, and using off-diagonal elements to represent indirect effects. LeSage[24] proposed a general econometric model of panel data space dynamics. At a specific time point, from the partial derivative matrix of the expected value of Y corresponding to the kth explanatory variable in X of spatial units 1 to N, short-term effects and long-term effects are expressed Formula is:

ê ··· ú = (IN - δ W) - 1 [β 1k IN + β2k W] (4)

Elhorst[25] used the maximum likelihood method (ML) to estimate the spatial and temporal static fixed-effect spatial model, and Yu et al. and Elhorst[15] used the annual data of 144 countries to study the influencing factors and spatial spillover effects of national defense military expenditures using panel data spatial static and dynamic models. These research results provide a valuable reference for this study.

This paper combines the latest research results in the field of ICT innovation diffusion and spatial measurement at home and abroad, from the perspective of information and communication technology integration, and uses the panel data of 288 cities above the prefecture level to construct a dynamic spatial measurement model to study the influencing factors of ICT innovation diffusion. Therefore, the granularity and dynamic spatial econometric model selection and estimation methods of ICT innovation diffusion research objects are innovative to a certain extent. From the perspective of empirical research, the influence mechanism of ICT innovation diffusion has been expanded from the analysis based on traditional influencing factors to the analysis based on spatio-temporal endowment and influencing factors; from the perspective of theoretical research, the practical research of dynamic spatial econometric analysis method has been further expanded , verifying that applied spatial econometric analysis has a stronger explanatory power to reality.

3 INNOVATION DIFFUSION MODEL IMPROVEMENT AND DIFFUSION SPEED CALCULATION

3.1 Data Description and Source

4th revision of the "National Economic Industry Classification" standard in 2017, information and communication technology is defined as telecommunications, radio and television, and satellite transmission services. Therefore, this paper defines ICT adopters as fixed telephone users, mobile phone users, and broadband Internet users. and broadcast television users. ICT users are the sum of fixed users, mobile users, Internet broadband access users (referred to as broadband) and broadcast TV users, so the calculation caliber of n (t)i at the end of year t in city i is

n (t)i = FPi, t + MPi, t + BBi, t + RTi, t (5)

Where: n (t)i is the total number of ICT users in city i at the end of year t; FPi, t, MPi, t, BBi, t, RTi, t are fixed-line, mobile, broadband and broadcast TV users in city i at the end of year t, respectively number.

The data is selected from the year-end arrivals of fixed-line, mobile, Internet broadband, and radio and television users in 288 cities above the prefecture level in the country from 2001 to 2018. The data of the communication industry comes from the "China City Statistical Yearbook" from 2002 to 2019. Radio and television users The provincial annual data comes from the "China Statistical Yearbook" from 2002 to 2019. Since there are no statistics in the data yearbook of 284 cities above the prefecture level, this paper uses the city's permanent resident population as the weight, and calculates the corresponding city's annual data based on provincial data. See Table 1 for data description.

3.2 Model Improvement and Diffusion Velocity Calculation

Table 1 ICT and Statistical description of user data by business

description type	ICT	fixed line	move	internet broadband	Broadcasting
Number of years	18	18	18	18	18
number of cities	288	288	288	288	288
number of observations	5184	5184	5184	5184	5184
average	492.6	88.9	295.3	52.3	56.1
standard deviation	609.9	107.4	397.7	82.0	62.2
minimum value	9 5	2 0	0 5	0 0	0 5
maximum value	6050.7	1112.3	4076.4	1070.1	745.5
period	2001-2018	2001-2018	2001-2018	2001-2018	2001-2018

Among them: n (t)i represents the arrival number of ICT adopters in the i-th city at the end of the year, and k is the intercept term. It is necessary to focus on estimating the parameters k, m, p, and q in formula (9). Model parameter estimation method In this paper, the simulated annealing method is used to estimate the parameters of the Bass model of ICT innovation diffusion in 288 cities above the prefecture level in the country. The output results of some cities are shown in Table 2.

From the test results of the model parameters in Table 2, the adjusted R2 and F statistics test results are significant, and the overall fitting effect of the model is better. The maximum value (S*) and the time to reach the maximum value (T *) of ICT non-cumulative adopters in 288 cities across the country are respectively calculated by formula (3) and formula (4). The process of ICT innovation diffusion is essentially a process in which potential users are continuously transformed into actual users, and the diffusion speed (or adoption rate) is an important indicator to describe the speed of innovation diffusion [27].

Table 2 Estimation and testing of Bass model parameters for ICT innovation diffusion by city

serial number	City	k	m	p	q	S*	T*	Adj. R2	F-statistic
1	Beijing	1251.0	74181.4	0.005	0.239	5861.2	16.0	0.970	174.5
2	Tianjin	0.0	69210.9	0.009	0. 133	2619.2	19.0	0.988	431.9
3	Shijiazhuang	0.0	57698. 1	0.007	0. 125	2010.4	21.8	0.978	232.7
4	Tangshan	0.0	33408.0	0.008	0. 147	1370.9	18.4	0.982	280. 1
...	...	...	...	...	...	...	...	...	...
287	Urumqi	0.0	18221. 1	0.009	0. 153	783.5	17.3	0.965	144.5
288	Karamay	0.0	6464.3	0.004	0. 114	197. 1	28.6	0.944	88.7

Ratioit represents the diffusion speed of ICT innovation in city i at the end of year t; n (t)it represents the number of users (ICT) in city i at the end of year t; S represents the maximum number of non-cumulative adopters in city i*i. Using formula (10), we can get the diffusion speed of ICT innovation in 288 cities across the country from 2001 to 2018.

4 SPATIAL ECONOMETRIC ANALYSIS OF FACTORS AFFECTING INNOVATION DIFFUSION SPEED

4.1 Influencing Factors and Data Sources of Innovation Diffusion Speed

This paper divides the influencing factors of ICT innovation diffusion speed into regional resource endowment, regional economic endowment, and regional resource supply. Combining the characteristics of the ICT industry, the variables of regional resource endowment are population density and per capita passenger flow; regional economic endowment is the proportion of the third industry and Per capita ICT consumption expenditure per household; regional resource supply is per capita fixed switching capacity, per capita mobile switching capacity, per capita communication optical cable length, per capita radio and television optical cable length, per capita broadband access port number, and take logarithm of these factors as explanatory variables. ICT innovation Diffusion rate (Ratioit) was used as an explained variable. The data comes from the "China City Statistical Yearbook" and "China Statistical Yearbook" from 2002 to 2019. The provincial annual data of radio and television income and the length of radio and television optical cables come from the "China Statistical Yearbook" from 2002 to 2019. Since there are no statistics in the data yearbook of 284 cities above the prefecture level, this paper takes the permanent resident population of the city as the weight, according to the provincial data. Calculate the annual data for the corresponding city. See Table 3 for indicator descriptions.

Table 3 ICT Innovation Diffusion and Influencing Factor Model Index Setting and Explanation

variable type	index	model variable	variable attribute	Indicator Interpretation
Diffusion speed	ICT Diffusion Speed	Ratio	dependent variable	See formula (10)
Regional resources endowment	Population density	lnpop	independent variable	Population density = total resident population at the end of the year / total area of the city in that year
	Passenger traffic per capita	lnvolume	independent variable	Per capita passenger traffic = total passenger traffic at the end of the year/total resident population at the end of the year
Regional economy endowment	the third industry	lnterindustry	independent variable	the tertiary industry = the total amount of the tertiary industry at the end of the year / the GDP at the end of the year
	Per Household ICT Consumption Expenditure	lnexpenditure	independent variable	Per household (per user) consumption expenditure = total ICT income at the end of the year/number of ICT users at the end of the year, ICT income = communication income + radio and television income
Regional resources supply	Fixed-line switching capacity per capita	lnfixexch	independent variable	Per capita fixed exchange capacity = total fixed exchange at the end of the year / total resident population at the end of the year
	Mobile switching capacity per capita	lnmobexch	independent variable	Per capita mobile exchange capacity = total mobile exchange at the end of the year/total resident population at the end of the year
	Communication cable length per capita	lncomcable	independent variable	Per capita communication optical cable length = total length of communication optical cables at the end of the year/total resident population at the end of the year
	The length of radio and television optical fiber cable per capita	lncomcable	independent variable	Per capita length of radio and television optical cables = total length of radio and television optical cables at the end of the year/total resident population at the end of the year
	Number of broadband access ports per capita	lnaccess	independent variable	The number of access ports per capita = the total number of access ports at the end of the year/the total resident population at the end of the year, and access ports refer to broadband

	Internet access ports

4.2 Space Effect Test and Weight Matrix Setting

The ICT diffusion rate (Ratiot) of 288 cities in the country from 2001 to 2018 is calculated by formula (10). Using the spatial adjacency weight matrix of 288 cities, Moran's index (Moran'I) is used to test its spatial correlation. It can be seen from Table 4 that Moran's indices all pass the 1% significance level Z-value test, and Moran's indices are all less than zero. There is a significant negative correlation between ICT innovation diffusion and geographical space, reflecting the dependence of ICT innovation diffusion on geographical space.
Spatial weight matrix selection In this paper, spatial adjacency matrix and spatial distance matrix are used, and the spatial adjacency matrix includes 1st -order adjacency matrix, 2nd -order adjacency matrix and 3rd -order adjacency matrix. The selection of spatial weight matrix generally meets the general requirement of "spatial correlation decreases with the increase of distance", and follows the principle of "limitation and non-negativity".

Table 4 Moran index and Z value

years	Moran index	Z	years	Moran index	Z
2001	-0.279	-7.015***	2010	-0.274	-6.873***
2002	-0.286	-7.179***	2011	-0.260	-6.539***
2003	-0.261	-6.556***	2012	-0.257	-6.452***
2004	-0.268	-6.725***	2013	-0.257	-6.447***
2005	-0.249	-6.240***	2014	-0.252	-6.336***
2006	-0 263	-6 595***	2015	-0 287	-7 209***
2007	-0.273	-6.866***	2016	-0.297	-7.465***
2008	-0.275	-6.912***	2017	-0.248	-6.231***
2009	-0.265	-6.648***	2018	-0.214	-5.345***

Note: *, **, *** indicate passing the 10%, 5% and 1% significance test respectively.

Distance spatial weight matrix: first obtain the latitude and longitude information of 288 cities across the country, and the source of the information is "National Basic Geographic Information Center". The distance between cities is calculated by latitude and longitude. In this paper, the square of the reciprocal distance is used to construct the spatial weight matrix. The feature that reflects the rapid attenuation of spatial dependence with the increase of distance is denoted as W4.

4.3 Model Setting and Estimation of Innovation Diffusion Influencing Factors

Taking the ICT diffusion speed Ratiot calculated above as the explained variable, population density, per capita passenger flow, proportion of the tertiary industry, per household ICT consumption expenditure, per capita fixed switching capacity, per capita mobile switching capacity.
Among them: Ratiot - 1 means time lag; WRatiot means space lag; WRatiot - 1 means space-time lag. The parameters of the fixed-effect dynamic SAR model were estimated using the MATLAB software package developed by Yesily-urt[15] and the fixed-effect dynamic space SAR model estimation program, and the quasi-maximum likelihood method proposed by Yu et al.[25] was used to estimate the model. It can be seen from Table 5 that whether it is a time fixed effect, a space fixed effect or a space-time fixed effect SAR model, the distance weight matrix (W4) model fits better than the first-order, second-order, and third-order spatial adjacency matrices, reflecting that ICT innovation diffusion has Features that decay rapidly as distance increases (decays by the square of the inverse of the distance between cities).

Table 5 Selection and comparative analysis of weight matrix of SAR model based on dynamic space panel

spatial weight matrix		1st order adjacency matrix 1	2nd order adjacency matrix 2	3rd order adjacency matrix W	Moment matrix W4
time fixed effect	Nobs	4896	4896	4896	4896
	R^2	0.9729	0.9734	0.9730	0.9731
	σ^2	0.0020	0.0020	0.0020	0.0020
	log L	8211.1	7908.0	7780.0	8251.1
space fixed effect	Nobs	4896	4896	4896	4896
	R^2	0 97710	0 97770	0 97750	0 97770
	σ^2	0.0022	0.0018	0.0018	0.0018
	log L	8621.3	8680.0	8670.9	8690.0
time	Nobs	4896	4896	4896	4896

and space fixed effect	R^2	0.9796	0.9795	0.9793	0.9797
	σ^2	0.0022	0.0018	0.0018	0.0018
	log L	8930.0	8909.0	8866.8	8937.5

4.4 Estimation and Interpretation of the Model of Influencing Factors of Innovation Diffusion

Using the spatial distance weight matrix (W4), the quasi-maximum likelihood method is used to estimate the fixed-effect dynamic SAR model of innovation diffusion. It can be seen from Table 6 that the three effects of time, space and space-time of ICT innovation diffusion are generally significant. The likelihood ratio of the joint significance test of the spatial fixed effect of the dynamic SAR model is 1372.88, and the null hypothesis is rejected at a significant level of 1%, indicating that the spatial fixed effect of ICT innovation diffusion is significant. The likelihood ratio of the joint significance test of the time fixed effect of the dynamic SAR model is 535.09, and the null hypothesis is rejected at a significant level of 1%, indicating that the time fixed effect of ICT innovation diffusion is significant. Comparing the R2, σ 2 and logL results of the three fixed-effect dynamic SAR models, the spatio-temporal fixed-effect dynamic SAR model is better than the spatial-fixed-effect SAR model and the time-fixed-effect SAR model. From the perspective of ICT development, the space-time fixed effect dynamic SAR model has a stronger explanatory power to reality. Time lag (Ratiot - 1), space lag (WRatiot), and space-time lag (WRatiot - 1) have a significant impact on the diffusion speed of ICT innovation. The coefficients are 0.7282, 0.4268 and -0.3003 respectively, and the sum is 0.7282+0.4268 - 0.3003= 0.8548<1, which satisfies the necessary and sufficient conditions for the stationarity of the panel data fixed-effect dynamic spatial econometric model.

4.4.1 Analysis of the time and space endowment of innovation diffusion

The driving coefficient of the time-lag item (Ratiot - 1) of the time-spatial fixed-effect dynamic SAR model on ICT innovation diffusion is 0.7282 (T significant), indicating that the previous period of ICT innovation diffusion has a significant effect on the current inertia. The driving coefficient of space-time fixed effect dynamic SAR model space lag term (WRatiot) on ICT innovation diffusion is 0.4268 (T significant), indicating that there is a typical positive spatial spillover effect in innovation diffusion between cities, indicating that ICT innovation diffusion exists between cities in a short distance. cluster effect. Judging from the estimated effect of the space-time lag term (WRatiot - 1) of the three models, the correlation relationship after adding the spatio-temporal lag term

Both R2 and log-likelihood ratios (logL) have increased, indicating that innovation diffusion between cities is dynamic, continuous and systematic. The driving coefficient of the space-time lag term (WRatiot - 1) of the space-time fixed effect dynamic SAR model on ICT innovation diffusion is -0.3003, indicating that the innovation diffusion speed of neighboring cities in the previous period has a significant inhibitory effect on the current innovation diffusion speed of the city.

Table 6 Comparison and Analysis of Parameter Estimation Results of Dynamic Fixed Effect SAR Model of Influencing Factors of Innovation Diffusion

variable type	variable/statistic	time fixed effect		space fixed effects		space-time fixed effects	
		coefficient	T	coefficient	T	coefficient	T
time and space endowment	$Ratio_{t-1}$	0.9040	141. 17***	0.7282	62.41***	0.7282	62.41***
	$WRatio_t$	0.2470	9.70***	0.4268	19.02***	0.4268	19.02***
	$WRatio_{t-1}$	-0.2059	-7.60***	-0.3003	-9.89***	-0.3003	-9.89***
Regional resource endowment	lnpop	0.0002	0.25	0.0407	7.04***	0.0407	7.04***
	lnvolume	-0.0024	-2. 18**	0.0018	1.29	0.0018	1.29
regional economic endowment	lnterindustry	0.0003	0.10	0.0056	1.44	0.0056	1.44
	Inexpenditure	-0.0165	-3. 15***	-0.0121	-2.09**	-0.0121	-2.09**
Regional resource supply	lnfixexchange	-0.0043	-2.74***	-0.0060	-4.48***	-0.0060	-4.48***
	lnmobexchange	0.0249	13.53***	0.0386	19.42***	0.0386	19.42***
	lncomcable	0.0039	2.86***	-0.0027	-0.60	-0.0027	-0.60
	lntvcable	-0.0026	-2.91***	-0.0051	-6.01***	-0.0051	-6.01***
	lnaccess	-0.0021	- 1.54	0.0041	3.22***	0.0041	3.22***
Overall Model Test	Nobs	5184		5184		5184	
	R^2	0.973		0.978		0.980	
	σ^2	0.0020		0.0018		0.0018	
	log L	8251.07		8669.96		8937.51	
	Space effect test: Joint significance test of space fixed effects Likelihood ratio, degree of freedom, significance and p value are: 1372.88, 287, 0.000						
	Time effect test: time fixed effect joint significance test likelihood ratio, degree of freedom, significance and p value are: 535.09, 16, 0.000						

Note: *, **, *** indicate passing the 10%, 5% and 1% significance test respectively.

4.4.2 Regional endowment analysis of innovation diffusion

Whether it is time fixed effect, space fixed effect or space-time fixed effect, hereinafter referred to as " three kinds of fixed effects", population density (lnpop) has a positive impact on ICT innovation diffusion, and the significance of adding space and space-time fixed effect models is enhanced. The driving coefficient of population density on the diffusion of ICT innovation in the space-time fixed effect dynamic SAR model is 0.0407, and has a significant impact (T significant), which is consistent with the research conclusion of Luo Yuze et al. [9]. It shows that the greater the urban population density, the more significant the driving force to the diffusion of ICT innovation, and the faster the diffusion speed, indicating that the diffusion of ICT innovation has the characteristics of scale and clustering. The impact of the " three fixed effects" per capita passenger flow (lnvolume) on the diffusion of ICT innovation is not significant, but the influence coefficient of the time fixed effect is -0.0024. After adding the space and space-time fixed effects, the influence coefficient changes from negative to positive. The diffusion of ICT innovation has a positive driving effect and is more in line with reality. The driving coefficient of per capita passenger flow to ICT innovation diffusion in the space-time fixed effect dynamic SAR model is 0.0018, indicating that the greater the city's per capita passenger flow, the greater the promotion of ICT innovation diffusion, but T is not significant.

4.4.3 Analysis of innovation diffusion economic endowment

third industry (lnterindustry) of " three kinds of fixed effects" on the diffusion of ICT innovation shows that the influence coefficient increases after adding space and space-time fixed effects, but it has no significant impact on the diffusion of ICT innovation. The driving coefficient of the proportion of the tertiary industry to the diffusion of ICT innovation in the space-time fixed effect dynamic SAR model is 0.0056, indicating that the more developed the tertiary industry in the city, the easier it is to use new technologies and new products, and the more conducive to the diffusion of ICT innovation.

4.4.4 Analysis of regional consumption endowment of innovation diffusion

" Three kinds of fixed effects" per household ICT consumption expenditure (lnexpenditure) has a significant negative impact on the diffusion speed of ICT innovation, and T is relatively significant, which is inhibitory to the diffusion of ICT innovation. The influence coefficient of ICT consumption expenditure per household on ICT innovation diffusion in the space-time fixed effect dynamic SAR model is -0.0121, indicating that the more ICT consumption expenditure per household, the slower the innovation diffusion speed. The importance and necessity of " also fully demonstrates the important role of "speed increase and fee reduction" in promoting the diffusion of information and communication technology innovation, and is an important factor in further promoting the "Internet +" strategy and promoting the rapid development of the digital economy.

4.4.5 Analysis of innovation diffusion resource endowment

The resource endowment of ICT innovation diffusion mainly includes per capita fixed switching capacity, per capita mobile switching capacity, per capita length of communication optical cables, per capita length of radio and television optical cables, and per capita number of broadband Internet access ports. From the T-value test results of the five indicators, except for the length of communication optical cables per capita, the other four indicators have a significant impact on the diffusion of ICT innovation, and the regression coefficients of these five indicators have good explanatory power for reality. The influence coefficient of fixed exchange capacity per capita is -0.0060, which shows that with the continuous reduction of fixed telephone users in China, the more fixed exchanges per capita, the slower the diffusion of ICT innovation, which is also in line with reality; the influence coefficient of mobile exchange capacity per capita is 0.0386, It shows that the more mobile exchanges per capita, the more it can promote the diffusion of ICT innovation; the length of communication optical cables per capita and the length of radio and television optical cables have a negative impact on the diffusion of ICT innovation, and their influence coefficients are -0.0027 and -0.0051, respectively, indicating that the longer the length of optical cables per capita is. The longer the per capita possession of communication resources, the more dispersed the resources, the slower the diffusion of ICT innovation; and the number of broadband access ports per capita has a positive and significant impact on the diffusion of ICT innovation, and its coefficient of influence is 0.0041, indicating that the per capita has more The number of broadband access ports is more conducive to the diffusion of ICT innovation and plays a positive role in promoting. Therefore, the impact of fixed-line switching capacity, communication and broadcasting cable length on the diffusion of ICT innovation has reached the threshold, and the drive for innovation diffusion has weakened. However, the mobile switching capacity and the number of broadband access ports have not reached the threshold, and still have a relatively large impact on the diffusion of ICT innovation. Strong driving force.

4.4.6 Analysis of the spatial effect of the influencing factors of innovation diffusion

It can be seen from table (7) that the spatial effects of passenger flow per capita, the proportion of the tertiary industry and the length of communication optical cables per capita are not significant, while the population density, ICT consumption expenditure per household, fixed and mobile switching capacity per capita, the length of radio and television optical cables per capita and the per capita The short-term effect and long-term effect of the number of broadband access ports are relatively significant, and the direct effect is greater than the indirect effect, indicating that the factors affecting the diffusion of ICT innovation have a short-term spatial spillover effect and a long-term spatial backflow (or feedback) effect. Regardless of the short-term effect or the long-term effect, the direct and indirect effects of population density, per capita mobile switching capacity and per capita broadband access port number are significantly positive. It shows that in the short term, these three factors play a positive role in promoting the diffusion of ICT innovation in the city, and at the same time, there is a significant spatial spillover effect on neighboring cities, which has an indirect role in promoting. In the long run, these factors of neighboring cities have a significant spatial return effect on the city, which has a feedback effect. However, per household consumption expenditure, per capita fixed switching capacity, and per capita length of radio and television optical fiber cables are all significantly negative in both the short-term and long-term effects, indicating that these three factors not only inhibit the diffusion of ICT innovation in the region, but also inhibit the adjacent regions.

Table 7 Short-term effect and long-term effect analysis of factors affecting ICT innovation diffusion

Explanatory variables	short term effect			long term effect		
	direct effect	indirect effect	total effect	direct effect	indirect effect	total effect
lnpop	0.042***	0.029***	0.071***	0. 154***	0. 127***	0.281***
	(6.06)	(5.46)	(5.99)	(6.09)	(5.12)	(6.45)
lnvolume	0.002	0.001	0.003	0.006	0.005	0.012
	(1.27)	(1.26)	(1.27)	(1.27)	(1.23)	(1.27)
lnterindustry	0.006	0.004	0.010	0.021	0.018	0.039
	(1.57)	(1.55)	(1.57)	(1.57)	(1.50)	(1.56)
Inexpenditure	-0.013**	-0.009**	-0.022**	-0.047**	-0.039**	-0.086**
	(-2.30)	(-2.23)	(-2.29)	(-2.29)	(-2.07)	(-2.24)
lnfixexchange	-0.006***	-0.004***	-0.010***	-0.023***	-0.019***	-0.041***
	(-4.28)	(-3.97)	(-4.21)	(-4.23)	(-3.54)	(-4.13)
lnmobexchange	0.040***	0.028***	0.067***	0. 147***	0. 122***	0.268***
	(18. 13)	(11.05)	(17.49)	(16.58)	(5.86)	(11.79)
lncomcable	-0.003	-0.002	-0.005	-0.011	-0.010	-0.020
	(-1.13)	(-1.12)	(-1.13)	(-1.13)	(-1.07)	(-1.11)
lntvcable	-0.005***	-0.004***	-0.009***	-0.019***	-0.016***	-0.035***
	(-5.70)	(-5.15)	(-5.62)	(-5.56)	(-3.76)	(-4.89)
lnaccess	0.004**	0.003**	0.007**	0.016**	0.013**	0.028**
	(2.68)	(2.62)	(2.67)	(2.68)	(2.88)	(2.86)

Note: *, **, *** indicate passing the 10%, 5% and 1% significance test respectively.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Main Conclusion

5.1.1 Spatial econometric models of ICT innovation diffusion are more explanatory and more practical

This paper uses the dynamic SAR model to study the diffusion of ICT innovation in my country and its impact. It shows that the time lag, space lag and space-time lag of ICT innovation diffusion in my country are significant, and its impact is significantly higher than that of the nine core factors. Compared with non-spatial econometric models, dynamic spatial econometric models are more explanatory and closer to reality. In addition, in the short term, the spatial spillover effect of ICT innovation diffusion is significant; in the long run, the feedback effect of innovation diffusion is significant. These spatial impact information cannot be captured by traditional econometric models.

5.1.2 ICT innovation diffusion time, space and spatio-temporal endogenous interaction effects are significant

four types of spatial weight matrices, the spatial distance weight matrix is the best choice, which is more accurate than the traditional adjacency matrix in measuring spatial effects. As the distance between cities increases, the influence of ICT innovation diffusion between cities decays geometrically and rapidly. From the perspective of time dimension, the diffusion rate of the current period is significantly affected by the diffusion rate of the previous period.

5.1.3 The diffusion of ICT innovation is significantly affected by factors such as population density and per household ICT consumption expenditure

The higher the population density, the faster the diffusion of ICT innovation; the higher the per household ICT consumption expenditure, the slower the diffusion of ICT innovation. These two elements not only have a significant impact on the diffusion of innovation in the region, but also have significant short-term spillover effects and long-term return feedback effects.

5.1.4 The diffusion of ICT innovation is significantly affected by the supply of regional resources such as switching capacity, optical cable length and the number of Internet broadband access ports

The greater the per capita mobile switching capacity and the number of Internet broadband access ports per capita, the faster the diffusion of ICT innovation. These factors not only promote the diffusion of innovation in the region, but also promote the diffusion of innovation in adjacent regions. The higher the fixed switching capacity per capita, the more the length of communication optical cables and radio and television optical cables per capita, the more unfavorable it is to the diffusion of ICT innovation.

5.2 Policy Suggestion

5.2.1 With the help of the Internet + strategy, continue to promote technological innovation and provide inexhaustible power for the diffusion of ICT innovation

Technological innovation is the prerequisite for driving the diffusion of ICT innovation. Through the integration of information technology, communication technology and Internet technology, the in-depth integration and iterative innovation between technologies will be accelerated, and larger bandwidth, larger capacity, higher Internet quality, and more broadband access ports will provide more powerful support for the diffusion of ICT innovation. support and security. At the same time, accelerate the promotion of "speed increase and fee reduction", the rapid popularization of 5G and the special project of gigabit home access, which will help the rapid development of new business forms such as mobile Internet, Internet of Things, cloud computing and big data, and provide inexhaustible power for the diffusion of ICT innovation.

5.2.2 With the help of the Internet + strategy, continue to improve the construction of information and communication infrastructure, and promote the coordinated development of regions through the diffusion of ICT innovation

The coordinated development of information and communication technology among regions is the external driving force for ICT innovation. Promote the coordinated development of the three corners of the Yangtze River, the three corners of the Pearl River Delta, the northern coast, and the three northeastern provinces through industrial policies such as industrial integration, business integration, and technological innovation ; through vigorously promoting regional policies such as the development of the western region and " One Belt , One Road" , to promote the flow of population and resources, thus forming the regional cluster effect of ICT innovation diffusion.

5.2.3 With the help of the Internet + strategy, deepen the integration of the three networks, and accelerate the pace of national economic transformation through the diffusion of ICT innovation

The deep integration of the information and communication technology industry is the internal driving force for the diffusion of ICT innovation. Hu Wenyu et al. [18] pointed out that from the perspective of the evolution path of ICT, the innovation ability in the information and communication technology (ICT) era has been significantly enhanced compared with the previous two stages, and the integration of the ICT industry, especially the integration of the 3 networks, has been accelerated to give full play to the industry. Convergence as a driver of innovation diffusion. Therefore, it is necessary to strengthen the deep integration and precise integration of the communication industry, information technology industry and radio and television industry, leverage the Internet + strategy, give full play to the leading role of information and communication technology in the development of the industry, and drive economic transformation through deep integration and innovation of ICT to help national economic growth.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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