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Public–Private Partnership Infrastructure Investment and Sustainable Economic Development: An Empirical Study Based on Efficiency Evaluation and Spatial Spillover in China

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Abstract: Public–private partnership (PPP), an innovative mode of infrastructure investment, has been widely applied in China and has become an essential policy tool with which to promote sustainable economic development. In order to comprehensively evaluate the economic consequences, using 31 provinces in China from 2003 to 2018 as samples, first, stochastic frontier analysis was performed to measure the input–output efficiency of infrastructure investment to evaluate the economic sustainability and efficiency of PPP compared to single government-led investment mode. Next, the overall economic growth effect of PPP was verified. Further, from the perspective of sustainable development of regional economies, the double-fixed effect spatial Durbin model was adopted to empirically test the spatial spillover effect of PPP and clarify its industrial heterogeneity. The results show the following. (1) The average input–output efficiency of infrastructure is 0.449, revealing a distribution law of decreasing from east to west and remarkable regional variation. However, a good trend of improvement emerged, reflecting the economic sustainability of infrastructure investment, and PPP has played a positive role in promoting it. (2) PPP has significant and positive economic growth and spatial spillover effects, which can promote regional economic integration, embodying its economic sustainability function. (3) The economic impact of PPP has significant industrial heterogeneity. Transportation PPP can bring greater economic benefits, confirming the vital position of transportation infrastructure in the sustainable development of regional economies. Energy and water PPP have positive externalities. All of this provides powerful and reliable proof of the realization of sustainable economic development under the regional virtuous circle driven by infrastructure investment through PPP.

Keywords: public–private partnership; infrastructure investment; sustainable development; input–output efficiency; spatial spillover; heterogeneity; economic disparity

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1. Introduction

Interconnected infrastructure is an essential foundation for sustainable economic development. As China's economy enters the new normal, the contradiction between the continuously growing demand for public goods represented by infrastructure and the insufficient supply efficiency and quality of single government-led investment mode under downward economic pressure and fiscal constraints has profoundly changed the supply and investment mode of infrastructure. PPP has become the most important means of investing in infrastructure. By June 2021, China's total PPP investment in infrastructure reached 15.59 trillion yuan, the largest share of which is transportation, accounting for 33.42%, or 5.21 trillion yuan. Moreover, given China's unique national conditions, unbalanced and inadequate development among regions remains a crucial long-term problem that restricts high-quality economic development. In this context, the Chinese government anticipates that PPP will promote sustainable economic development and create a new mechanism for coordinated regional development.

Compared to single government-led investment mode, can PPP bring economic sustainability and efficiency? Does PPP have economic growth and spatial spillover effects? Are there differences in the impacts of different industries? Existing studies have made extensive evaluations on the economic consequences of PPP, but most of them are theoretical and case studies based on questionnaire surveys and other qualitative methods, while only a few take China's data as a sample for empirical analysis on a macro scale. Some studies have directly investigated the impact of PPP on GDP and the possible influencing factors between them. Their results show that PPP has a significant positive effect on promoting economic growth [1,2] by enhancing the effectiveness of the implementation of fiscal and monetary policies, improving the mismatch of resources, and increasing total factor productivity [3,4]. Some studies in other countries have also proven that PPP is effective for economic development [5,6]. In addition, some studies have evaluated the economic impact of PPP from the perspective of infrastructure efficiency, showing a significant positive correlation between PPP and infrastructure efficiency in countries along the Belt and Road [7,8], while PPP was not shown to significantly improve the output efficiency of infrastructure in China when 245 cities from 2002 to 2015 were taken as a sample with the use of the multiperiod DID method [9].

In terms of the spatial spillover effect, most related studies have focused more on evaluating the impact of single government, social capital, or sector-specific investment. It was found that government investment can generate economic growth and spatial spillover effects [10], and it is a chain relationship in which private parties can improve economic performance through technological innovation [11], which can generate a positive spatial spillover effect [12], but may also become an obstacle to economic development [13]. Only one cross-regional study creatively considered the spatial effect of PPP and showed that it has a direct promoting effect and an indirect spillover effect on economic growth [14], but the sample for that study was the Belt and Road countries.

Based on the above, there are three scientific gaps worth filling. (1) Few studies have used rigorous econometric techniques to evaluate the economic consequences of PPP, and the dimensions of existing empirical studies are relatively narrow, so a comprehensive study evaluating the economic impact of PPP from the perspective of sustainable development is lacking. (2) In most studies, PPP is regarded as a policy impact that is treated as a dummy variable, so the accuracy of results needs to be verified and improved. Moreover, there is no consensus on the economic consequences of PPP, which needs further research and analysis. (3) The spatial spillover effect of PPP on regional economic development and the industrial heterogeneity of PPP are not widely discussed. It is worth enriching and extending this topic. All of these provide scope for this paper based on sample data with Chinese characteristics.

Accordingly, this paper conducts a comprehensive empirical examination of the impact of PPP on China's sustainable economic development from the dual dimensions of efficiency evaluation and spatial spillover based on the perspective of sustainability, and further explores the industrial heterogeneity of PPP to get more detailed conclusions. The main contributions and added value are as follows: (1) the input–output efficiency of infrastructure is scientifically evaluated and the implementation effect of PPP in China is verified, which has important practical significance for further improvement and promotion of PPP; (2) the spatial effect mechanism and effect of PPP are clarified, which bridges the gaps in the existing research and represents a useful attempt to approach this issue from the spatial economic perspective; and (3) the industrial heterogeneity of PPP in economic development is explored, which provides a reference basis for the development of PPP in different fields.

The paper is organized as follows: the theoretical analysis and research hypothesis are presented in Section 2 in order to establish the theoretical basis and empirical logic framework. The data, variables, and model used in this paper are included in Section 3. Section 4 presents the empirical analysis, which is the key content of this paper, including the analyses of infrastructure input–output efficiency, economic growth and spatial

spillover effects, and industry heterogeneity of PPP. Section 5 discusses and explains the results from the perspective of previous studies and working hypotheses. The last section presents the conclusion and suggestions.

2. Theoretical Analysis and Research Hypothesis

2.1. Impact of PPP on Input–Output Efficiency of Infrastructure

In economics, efficiency is the ideal maximum possible output with the same input or the ideal minimum possible input with the same output. The input–output efficiency of infrastructure evaluates the configuration state between infrastructure input and economic output within the concept of sustainable economic development. In the past, infrastructure investment was carried out by local Chinese governments, which led to monopolies. It was not until 2014 that PPP was applied on a large scale and gradually replaced single government-led investment, and the marketization of infrastructure investment gradually emerged.

According to public goods theory, in the new political economy, public good related to the national economy cannot be completely provided by a profit-maximizing market, but needs government intervention. The theory of welfare economics further points out that the government's powerful macro control should be limited to taxes and subsidies, and the task of optimizing the allocation of market resources should be left to private parties through market competition. Against the background of the Chinese system, PPP, as a mixed semi-organizational and semi-market economic form, can improve the efficiency and optimize the structure of resource allocation in infrastructure investment and promote the input–output efficiency of infrastructure through a synergistic effect.

On the one hand, the core mechanism of PPP is to introduce market mechanisms to infrastructure provision, letting the market participate in the allocation and management of public resources, which can effectively avoid the drawback of the "grabbing hands" of local governments caused by long-term administrative monopolies [15]; this is conducive to eliminating the inefficiency of the pattern of government-only status [16]. On the other hand, under the organic combination of the dual efficiencies of government and market, the competitive mechanism will further guide local governments' financial resources to other areas and weak links of people's livelihoods, and build a mechanism for more favorable cooperation between governments and private parties. This can promote the structural adjustment of resource allocation in government financial expenditure and the participation of private parties, in order to form a long-term sustainable supply mode that pursues infrastructure quality and efficiency [17]. Furthermore, the synergy effect of PPP is due to the complementary advantages of governments and private parties [18]. Local governments have macroscopic control and risk resistance ability and can implement powerful policy guidance; the added value of private parties, such as knowledge, skills, management experience, and innovation, becomes more productive with cooperation. PPP can also encourage professional institutions to participate in infrastructure construction, operation, and management, thus forming a "1 + 1 + 1 > 3" performance improvement mechanism of governments, private parties, and professional institutions [19]. Therefore, compared to the government-led single investment mode, PPP more reflects the win–win of economic and social benefits based on the synergistic effect.

Accordingly, the first research hypothesis is proposed.

Hypothesis 1A. *PPP is positively correlated with the input–output efficiency of infrastructure.*

Hypothesis 1B. *Compared with the single government-led investment mode, PPP has a more significant promoting effect on the input–output efficiency of infrastructure.*

2.2. Overall Economic Growth Effect of PPP

This paper analyzes the economic growth effect of PPP from the perspective of institutional innovation. According to the theory of institutional economics, effective institutional design is the key to ensuring and improving economic growth. Institutional innovation refers to reforming the existing system by key players in order to obtain specific benefits [20], which includes two forms, induced and mandatory. Induced institutional innovation achieves Pareto optimality through gradual accumulation of changes under the premise of compatible interests of various stakeholders. The effectiveness of institutional innovation is reflected in the coordination of interest distribution relationships among stakeholders, enhancing the interests of some stakeholders without harming others, so as to reach a consensus on reform, which can bring the bonus effect of institutional innovation to promote economic growth [21].

The essence of PPP is that it is an institutional design and innovation that gives full play to the respective endowment advantages of governments and private parties to carry out mutual long-term cooperation for the efficient supply of infrastructure and services. The understanding of PPP should be promoted to the level of institutional mechanisms, with the improvement of institutional efficiency as the core. The reform process of PPP in China is consistent with the logical process of institutional economics. With the transition of China's economy, the institutional arrangement of administrative monopolies in which local governments are the sole agents carrying out infrastructure investment, construction, and operation is difficult to sustain. Various drawbacks can be found, such as shortages of fiscal funds, insufficient supply capacity, and inefficient resource distribution. At this point, PPP, as an induced institutional innovation of "gradualism" initiated by the government, not only enables better realization of the government's public service functions, but also provides opportunities for private parties to gain economic benefits and fulfill social responsibilities, and bring more quality and inexpensive products and services to the public by giving full play to the endowment advantages of all parties through PPP's specialized cooperation mechanism. Thus, the Pareto optimality of the "triple win" of governments, private parties, and people's livelihoods can be achieved [22]. Moreover, the cost of induced institutional innovation is relatively low, the social unrest is relatively small, and the intervention of local governments can make it progress more smoothly [23].

PPP gives adequate consideration to economic efficiency and social equity, which strongly conforms to the core connotation of institutional innovation. China's development experience has proven that PPP is key to deepening supply-side reform, introducing mixed ownership to SOEs, and innovating the mode of infrastructure investment. Therefore, it can be assumed that PPP, as an effective institutional innovation, has the overall economic benefit of promoting sustainable economic development. In addition to giving play to the "invisible hands" of the institution, PPP as an investment has a natural capital accumulation effect, thus can promote economic development. According to investment multiplier theory, PPP can drive the investment of the whole society, thus stimulating employment and consumption, and can improve the scale and quality of infrastructure provision to lay a solid foundation for industrial agglomeration.

Accordingly, the second research hypothesis is proposed.

Hypothesis 2. *PPP is positively correlated with GDP, manifested as an economic growth effect.*

2.3. Spatial Economic Spillover Effect and Industrial Heterogeneity of PPP

The mechanism of PPP that can exert a spatial spillover effect lies in the functional attributes of infrastructure and the spatial autocorrelation of economic development.

First, infrastructure is networked. As an important carrier of economic connections between regions, the connectivity of infrastructure can realize the spatial flow of production factors, break the market segmentation caused by the administrative division or spatial distance of regions, and connect different regions as a whole. In particular, transportation infrastructure creates an indispensable basis for guiding the distribution of

productivity and the spatial distribution of the population, and also lays a solid foundation for improving the efficiency and competitiveness of regional economies. China attaches great importance to the networked economic advantages of transportation infrastructure, and has put forward the Belt and Road initiative and the strategy of building a country with a strong transportation network, which has become the "Chinese experience" that is valued worldwide.

Second, infrastructure has externalities, arising from the function of public goods. This means the social benefits of infrastructure often exceed its economic benefits, which means that infrastructure is not intended to make a profit, but to provide the necessary external conditions for the microeconomy and the necessary complementary goods for private capital, and to ensure the normal functioning of social and economic activities in a country or region. Marshall, in his book Principles of Economics, theorized about the extensive impact of infrastructure on other production units and summarized that the externalities of public goods have a spillover effect on economic growth. Pigou further distinguished and developed the theory of externality and spillover effects. The external benefit that infrastructure brings to other production units is called external economy or positive spillover, while the external effect that brings losses is called external diseconomy or negative spillover. In addition, the externalities of different types of infrastructure are heterogeneous. Transportation infrastructure not only has a direct impact on economic growth, but also has stronger externality, which has positive synergistic and spatial spillover effects [24,25]. Energy infrastructure is better reflected as an external economy [26], while the new energy has a negative external economic impact in China's developing areas [27].

Third, the spatial dependence of economic development is one of the prerequisites for the spatial spillover effect [28]. Spatial dependence refers to the relationships among things or social phenomena, depending on and even restricting each other in the spatial dimension. The existence of spatial dependence indicates that the occurrence and development of things or social phenomena are always influenced by other units. Economic development obviously has such spatial dependence. The economic development of different regions is not only determined by their production capacity, but also affected by the development situation of other regions, which is related to the flow of production factors and the links of communication, distribution, and consumption. It is precisely because of the spatial dependence of economic development that improving the infrastructure in one region can promote the development of that region and also have an impact on the development of other regions [29].

Accordingly, the third research hypothesis is proposed.

Hypothesis 3A. *PPP has a positive spatial spillover effect that can promote local economic development and the economic development of neighboring areas.*

Hypothesis 3B. *The spatial spillover effect of PPP varies by industry, and transportation PPP has a stronger economic effect and spatial spillover.*

3. Data, Variables, and Model

3.1. Data Sources

In the evaluation of the infrastructure input–output efficiency, the GDP of 31 provinces was selected as output, total infrastructure investment from various industries (transportation, energy, water, etc.) and various entities (government, enterprise, private) as capital input, and number of people employed in the infrastructure sector as labor input.

In empirically examining the impact of PPP on sustainable economic development, we used data from 31 provinces in China from 2003 to 2018 as panel samples. Data of PPP infrastructure investment come from the World Bank Private Participation in Infrastructure Database and the China Public–Private Partnerships Center. In order to ensure the reliability and validity of the study, this paper kept the PPP data from the executed infrastructure investment projects and excluded the data from discontinued

or abolished projects. Except for the telecom industry, due to its highly monopolistic nature and smaller sample size, PPP data of the transportation, energy, and water sectors were selected to analyze industry heterogeneity. The economic development data of the 31 provinces came from the China Statistical Yearbook and National Economy and Social Development Statistics Bulletin from 2004 to 2019, and the marketization index came from a research report released by the China National Economic Research Institute.

3.2. Variable Descriptions

The total infrastructure investment and number of people employed in the infrastructure sector were taken as input variables, and GDP was taken as an output variable to measure the input–output efficiency of infrastructure. In the regression analysis, GDP and infrastructure input–output efficiency were selected as the explained variables. PPP infrastructure investment was taken as the explanatory variable. Referring to relevant studies [30–32], the fiscal self-sufficiency rate, fiscal burden rate, foreign trade dependence degree, marketization index, level of human capital, and population size were taken as control variables. The fiscal self-sufficiency rate is the ratio of fiscal revenue to fiscal expenditure, which represents the degree of local fiscal self-reliance. China uses a revenue-sharing system between the central government and local governments, that is, the central government will balance the economic development of different regions through the fiscal transfer system. Therefore, the higher the level of local fiscal self-sufficiency, the less dependence on the central government and the stronger the local economic power. The fiscal burden rate is the ratio of fiscal revenue to GDP, which comprehensively reflects the relationship between local governments and other microeconomic entities in occupying and dominating social resources, and also represents the government's capacity for macroeconomic control and the extent to which it affects the allocation of social resources. Consequently, it is necessary to keep the fiscal burden at a reasonable level. According to general practice, the level of human capital is measured by the weighted average of years of schooling for people of different ages. The meanings and descriptive statistics of variables are shown in Tables 1 and 2.

Table 1. Meaning and calculation of variables.

Variable	Meaning	Calculation
GDP	Gross domestic product	Take logarithm
CI	Infrastructure capital input	Take logarithm
LI	Infrastructure labor input	Take logarithm
IE	Infrastructure input–output efficiency	Use SFA method in Section 4.1
PPP	PPP infrastructure investment	Take logarithm
GI	Government infrastructure investment	Take logarithm
SU	Fiscal self-sufficiency rate	Divide revenue by expenditure
BU	Fiscal burden rate	Divide revenue by GDP
OP	Foreign trade dependence degree	Divide total foreign trade by GDP
MI	Marketization index	Taken from research report
CP	Human capital level	Use weighted average of schooling years of people at different ages
PO	Population size	Divide population by land area

Table 2. Descriptive statistics of variables.

Variable	Observations	Mean	Sd	Min	Max
GDP	496	9.135	1.164	5.218	11.485
CI	496	8.556	1.289	4.773	10.941
LI	496	7.509	0.899	4.889	8.819
IE	496	0.449	0.222	0.111	0.977
PPP	496	3.420	2.619	0	9.403
GI	496	8.457	1.468	0	10.930
SU	496	0.498	0.203	0.056	0.951
BU	496	0.098	0.033	0.044	0.227
OP	496	0.045	0.055	0.003	0.259
MI	496	6.255	2.068	−0.230	11.710
CP	496	10.685	1.450	4.524	15.184
PO	496	5.280	1.480	0.788	8.250

3.3. Model Specification

3.3.1. Model for Measuring Input–Output Efficiency of Infrastructure

Production frontier analysis is a mainstream method of efficiency measurement that includes stochastic frontier analysis (SFA) and data envelope analysis (DEA). Both of them construct the possible production frontier and measure the distance between the individual output and the frontier in order to figure out the individual efficiency. Compared with DEA, SFA is a parameter estimation method based on the production function, which has more stringent requirements for model and data accuracy. In addition, SFA considers the impact of random factors on output and can flexibly choose the production function form according to the nature of the research object, in order to make the evaluation more accurate and targeted [33–35]. Therefore, this study used the SFA method to measure the input–output efficiency of infrastructure.

Given that infrastructure investment is a multi-objective, multivariate, and nonlinear input–output system [36], compared to the Cobb–Douglas production function, the assumptions of the trans-log production function are more in line with economic reality. Based on a time-varying model [37], the model is set up as follows:

$$LnY_{it} = \beta_0 + \beta_1 LnK_{it} + \beta_2 LnL_{it} + \beta_3 t + \frac{1}{2}\beta_4 (LnK_{it})^2 + \frac{1}{2}\beta_5 (LnL_{it})^2 + \frac{1}{2}\beta_6 t^2 + \beta_7 LnK_{it} LnL_{it} + \beta_8 t LnK_{it} + \beta_9 t LnL_{it} + v_{it} - u_{it} \quad (1)$$

$$u_{it} = e^{-\eta(t-T)} u_i \quad (2)$$

In Formula (1), Y_{it} is output, K_{it} is capital input, L_{it} is labor input, β_1 is capital output elasticity, and β_2 is labor output elasticity; v_{it}-u_{it} is a composite error term.

In Formula (2), η is a time-varying coefficient and $\eta > 0$ indicates improved efficiency over time.

The input–output efficiency of infrastructure is defined as:

$$IE_{it} = e^{-u_{it}} \quad (3)$$

In Formula (3), when u = 0 and IE = 1, the individual output is equal to the maximum output and there is a state of efficiency. When u > 0 and 0 < IE < 1, it indicates that the individual output is less than the maximum output and there is a state of inefficiency.

3.3.2. Model for Examining the Impact of PPP on Sustainable Economic Development

This paper first sets up model (4) to investigate the impact of PPP on infrastructure input–output efficiency, in order to identify the economic efficiency in terms of sustainability. In order to compare the impact difference between PPP and single government-led investment, the comparison model (5) was also constructed.

$$IE_{it} = \alpha_0 + \alpha_1 PPP_{it} + \alpha_2 SU_{it} + \alpha_3 BU_{it} + \alpha_4 OP_{it} + \alpha_5 MI_{it} + \alpha_6 CP_{it} + \alpha_7 PO_{it} + \gamma_i + \delta_t + u_{it} \quad (4)$$

$$IE_{it} = \alpha_0 + \alpha_1 GI_{it} + \alpha_2 SU_{it} + \alpha_3 BU_{it} + \alpha_4 OP_{it} + \alpha_5 MI_{it} + \alpha_6 CP_{it} + \alpha_7 PO_{it} + \gamma_i + \delta_t + u_{it} \quad (5)$$

In Formulas (4) and (5), IE is the input–output efficiency of infrastructure; GI and PPP, respectively, represent single government and PPP infrastructure investment (these coefficients measure the net effect of the two modes on infrastructure input–output efficiency, which is the focus of the comparison); i represents the province and t represents the year; and γ_i, δ_t represent the fixed effect of province and year, respectively.

Then, the economic growth effect of PPP is verified to provide the necessary premise for the research of the spatial spillover effect of PPP. Without considering the spatial effect, the traditional empirical model of PPP and GDP is constructed as follows:

$$GDP_{it} = \alpha_0 + \alpha_1 PPP_{it} + \alpha_2 SU_{it} + \alpha_3 BU_{it} + \alpha_4 OP_{it} + \alpha_5 MI_{it} + \alpha_6 CP_{it} + \alpha_7 PO_{it} + \gamma_i + \delta_t + u_{it} \quad (6)$$

The spatial economic effect of PPP is not considered in Formula (6), which may lead to imperfect model specification and bias in the parameter estimation. To overcome this defect, Griffith proposed introducing the spatial weight matrix into the traditional model and extended the research perspective to the spatial effect by considering the potential spatial interdependence among variables [38].

The commonly used spatial weight matrix includes adjacency, distance, and economic matrices, which respectively represent geographic adjacency, geographic distance, and differences in the level of economic development between regions. Given the function and attributes of the infrastructure, the distance matrix more appropriately reflects the spatial relationship between PPP and regional economy. The elements of the distance matrix are calculated in this paper as the reciprocal of the square of the geographic longitude and latitude distances between two regions. On the basis of model (6), the distance matrix is added to construct the spatial Durbin model.

$$GDP_{it} = \rho \sum_{j=1}^{N} W_{ij} * GDP_{jt} + \alpha_1 PPP_{it} + \sum \alpha_k Control_{it} + \beta_1 \sum_{j=1}^{N} W_{ij} * PPP_{jt} + \sum \beta_k \sum_{j=1}^{N} W_{ij} * Control_{jt} + \gamma_i + \delta_t + u_{it} \quad (7)$$

In Formula (7), ρ is the spatial lag coefficient, reflecting the spatial dependence between regional economies; Control represents the set of control variables; W represents the N*N dimensional spatial distance matrix; α and β measure the impact of each factor on the economic development of the local and neighboring areas, respectively; and β_1 represents the spatial spillover effect of PPP on economic development.

4. Empirical Analysis

4.1. Measurement and Analysis of Input–Output Efficiency of Infrastructure

Models (1)–(3) were used to measure the input–output efficiency of infrastructure in China's 31 provinces from 2003 to 2018. Model parameter estimates are shown in Table 3. The efficiency calculation results are shown in Table 4.

The likelihood ratio is significant at a level of 1%, indicating that the model has good statistical properties, and $\gamma = 0.9301$, which is close to 1, indicating that the error term has a very obvious composite structure. Thus, it is necessary to use SFA instead of DEA's simple linear programming to analyze economic data over as long as 16 years, which again confirms the reliability of the model. Furthermore, $\eta = 0.0169 > 0$, indicating that the input–output efficiency of infrastructure improves continuously, reflecting an obvious improvement trend.

Table 3. Model parameter estimates of SFA.

Parameter	Coefficient	t-Ratio
β_0	0.933	0.93
β_1	0.396 **	2.02
β_2	1.211 ***	3.91
β_3	0.045	1.26
β_4	0.031	0.76
β_5	−0.023	−0.41
β_6	−0.011 ***	−4.89
β_7	−0.074 **	−2.11
β_8	0.008	0.97
β_9	0.007	0.93
σ^2	0.094 ***	5.57
γ	0.930 ***	100.76
u	0.592 ***	4.24
η	0.017 ***	3.62
Log likelihood function	395.85 ***	
Likelihood ratio	1314.16 ***	

Note: ***, **, * indicate statistical significance of 99, 95, and 90%, respectively.

Table 4. Infrastructure input–output efficiency of provinces from 2003 to 2018.

Province/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average
Beijing	0.717	0.721	0.725	0.729	0.733	0.737	0.740	0.744	0.748	0.751	0.755	0.759	0.762	0.766	0.769	0.772	0.746
Tianjin	0.531	0.536	0.542	0.548	0.553	0.559	0.564	0.570	0.575	0.580	0.586	0.591	0.596	0.601	0.607	0.612	0.572
Hebei	0.468	0.474	0.479	0.485	0.491	0.497	0.503	0.509	0.515	0.520	0.526	0.532	0.538	0.543	0.549	0.554	0.511
Shanxi	0.313	0.319	0.325	0.331	0.338	0.344	0.350	0.356	0.363	0.369	0.375	0.381	0.387	0.394	0.400	0.406	0.359
Inner Mongolia	0.398	0.404	0.410	0.417	0.423	0.429	0.435	0.441	0.447	0.453	0.459	0.465	0.471	0.477	0.483	0.489	0.444
Liaoning	0.522	0.528	0.534	0.539	0.545	0.551	0.556	0.562	0.567	0.572	0.578	0.583	0.588	0.594	0.599	0.604	0.564
Jilin	0.332	0.338	0.344	0.350	0.357	0.363	0.369	0.375	0.382	0.388	0.394	0.400	0.406	0.413	0.419	0.425	0.378
Heilongjiang	0.369	0.375	0.382	0.388	0.394	0.400	0.406	0.413	0.419	0.425	0.431	0.437	0.443	0.449	0.455	0.462	0.416
Shanghai	0.877	0.879	0.881	0.883	0.885	0.886	0.888	0.890	0.892	0.893	0.895	0.897	0.898	0.900	0.902	0.903	0.890
Jiangsu	0.891	0.893	0.894	0.896	0.898	0.899	0.901	0.902	0.904	0.905	0.907	0.908	0.910	0.911	0.913	0.914	0.903
Zhejiang	0.704	0.708	0.712	0.716	0.720	0.724	0.728	0.732	0.736	0.740	0.744	0.747	0.751	0.754	0.758	0.762	0.734
Anhui	0.281	0.287	0.293	0.299	0.305	0.311	0.317	0.324	0.330	0.336	0.342	0.348	0.355	0.361	0.367	0.373	0.327
Fujian	0.469	0.475	0.481	0.487	0.493	0.499	0.505	0.511	0.516	0.522	0.528	0.534	0.539	0.545	0.550	0.556	0.513
Jiangxi	0.269	0.275	0.281	0.287	0.293	0.299	0.305	0.312	0.318	0.324	0.330	0.336	0.342	0.349	0.355	0.361	0.315
Shandong	0.748	0.752	0.756	0.759	0.763	0.766	0.770	0.773	0.776	0.780	0.783	0.786	0.789	0.792	0.795	0.798	0.774
Henan	0.433	0.439	0.445	0.451	0.457	0.463	0.469	0.475	0.481	0.487	0.493	0.499	0.505	0.511	0.517	0.522	0.478
Hubei	0.390	0.397	0.403	0.409	0.415	0.421	0.427	0.434	0.440	0.446	0.452	0.458	0.464	0.470	0.476	0.482	0.436
Hunan	0.368	0.374	0.380	0.386	0.392	0.399	0.405	0.411	0.417	0.423	0.430	0.436	0.442	0.448	0.454	0.460	0.414
Guangdong	0.971	0.971	0.972	0.972	0.972	0.973	0.973	0.974	0.974	0.975	0.975	0.975	0.976	0.976	0.977	0.977	0.974
Guangxi	0.258	0.264	0.270	0.276	0.282	0.288	0.294	0.300	0.307	0.313	0.319	0.325	0.331	0.337	0.344	0.350	0.304
Hainan	0.194	0.199	0.205	0.210	0.216	0.222	0.227	0.233	0.239	0.245	0.250	0.256	0.262	0.268	0.274	0.280	0.236
Chongqing	0.287	0.293	0.299	0.305	0.312	0.318	0.324	0.330	0.336	0.342	0.349	0.355	0.361	0.367	0.374	0.380	0.333
Sichuan	0.367	0.373	0.379	0.385	0.391	0.398	0.404	0.410	0.416	0.422	0.429	0.435	0.441	0.447	0.453	0.459	0.413
Guizhou	0.168	0.173	0.178	0.183	0.188	0.194	0.199	0.205	0.210	0.216	0.221	0.227	0.233	0.238	0.244	0.250	0.208
Yunnan	0.215	0.221	0.226	0.232	0.238	0.244	0.249	0.255	0.261	0.267	0.273	0.279	0.285	0.291	0.297	0.303	0.259
Tibet	0.111	0.115	0.119	0.124	0.128	0.132	0.137	0.142	0.146	0.151	0.156	0.161	0.166	0.171	0.176	0.181	0.145
Shaanxi	0.302	0.308	0.314	0.321	0.327	0.333	0.339	0.345	0.351	0.358	0.364	0.370	0.376	0.383	0.389	0.395	0.348
Gansu	0.165	0.170	0.175	0.180	0.185	0.190	0.196	0.201	0.207	0.212	0.218	0.223	0.229	0.235	0.241	0.246	0.205
Qinghai	0.156	0.161	0.166	0.171	0.176	0.181	0.187	0.192	0.197	0.203	0.208	0.214	0.219	0.225	0.231	0.236	0.195
Ningxia	0.172	0.177	0.182	0.187	0.193	0.198	0.203	0.209	0.214	0.220	0.226	0.231	0.237	0.243	0.249	0.255	0.212
Xinjiang	0.284	0.290	0.297	0.303	0.309	0.315	0.321	0.327	0.333	0.340	0.346	0.352	0.358	0.364	0.371	0.377	0.330

Note: Provinces are ranked according to standard order of China Statistical Yearbook; results were processed by Front 4.1.

The overall average input–output efficiency of infrastructure is 0.449, far below 1, which is a state of inefficiency. Despite this, from 2003 to 2018, the input–output efficiency in each province continuously improved year by year, indicating a good trend of sustainable improvement. The input–output efficiency has obvious differences in different provinces. The highest is 0.974, on average, in Guangdong, the most economically developed province, with its GDP ranking first for 30 consecutive years among all the provinces, and the lowest

is 0.145 in Tibet, which is economically backward, with its GDP ranking last. It can be assumed that the input–output efficiency of infrastructure is closely related to the level of economic development.

To further investigate the regional differences in input–output efficiency, the provinces were grouped into four economic regions according to the classification criteria on socioeconomic development released by the Chinese government. The results are shown in Table 5.

Table 5. Input–output efficiency of infrastructure in four economic regions.

Region	Provinces	Average
East	Guangdong, Jiangsu, Shanghai, Shandong, Beijing, Zhejiang, Tianjin, Fujian, Hebei, Hainan	0.685
Northeast	Liaoning, Heilongjiang, Jilin	0.453
Middle	Henan, Hubei, Hunan, Shanxi, Anhui, Jiangxi	0.388
West	Inner Mongolia, Sichuan, Shaanxi, Chongqing, Xinjiang, Guangxi, Yunnan, Ningxia, Guizhou, Gansu, Qinghai, Tibet	0.283

As can be seen intuitively from Table 5, the input–output efficiency of infrastructure in different regions has obvious heterogeneity and sequencing. It generally presents a distribution trend and characteristics of decrease from east to west. The average efficiency of the eastern region, with the highest economic development, is 0.685 and that of the western region, with the lowest level of economic development, is 0.283. This again shows that the input–output efficiency of infrastructure is related to the level of economic development. These results indicate remarkable discrepancies and imbalance in regional development, which is highly consistent with China's national conditions and economic reality.

4.2. Impact of PPP on Input–Output Efficiency of Infrastructure

Models (4) and (5) were used to test the impact of PPP and single government investment, respectively, on the input–output efficiency of infrastructure. The results are shown in Tables 6 and 7.

Regardless of whether control variables are added, both PPP and single government investment are always positively correlated with the input–output efficiency of infrastructure, highlighting the economic sustainability of infrastructure investment. Hypothesis 1A can be confirmed. Compared to single government investment, PPP has a more significant effect on the input–output efficiency of infrastructure and its coefficient is larger, indicating its inherent advantage in leveraging greater investment efficiency with less capital. Hypothesis 1B can be confirmed. This also confirms that the core significance of PPP is not only to reduce the government's financial burden, but also to improve the economic efficiency of public goods by introducing social capital and its inherent sense of competition, concept of market value investment, and market risk consciousness.

Table 6. Impact of PPP on input–output efficiency of infrastructure.

Explained Variable: IE							
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
PPP	0.022 ***	0.005 ***	0.003 **	0.003 **	0.003 **	0.003 **	0.003 **
	(5.66)	(2.88)	(2.35)	(2.32)	(2.29)	(2.29)	(2.33)
SU		0.963 ***	1.066 ***	0.713 ***	0.779 ***	0.775 ***	0.804 ***
		(41.69)	(42.06)	(23.74)	(14.51)	(14.17)	(14.81)
BU			−1.424 ***	−2.645 ***	−2.764 ***	−2.777 ***	−2.579 ***
			(−7.90)	(−16.13)	(−15.17)	(−15.03)	(−13.70)
OP				1.969 ***	1.991 ***	1.993 ***	1.812 ***
				(16.05)	(16.14)	(16.13)	(13.97)
MI					−0.007	−0.007	0.004
					(−1.49)	(−1.54)	(0.72)
CP						0.017	0.049
						(0.45)	(1.30)
PO							−0.019 ***
							(−4.03)
Year	Control	Control	Control	Control	Control	Control	Control
Province	Control	Control	Control	Control	Control	Control	Control
R^2	26.34%	79.78%	82.12%	88.40%	88.45%	88.46%	88.84%
N	496	496	496	496	496	496	496

Note: Values in parentheses are t statistics. ***, **, * indicate statistical significance of 99, 95, and 90%, respectively. Results were processed by Stata 14.0.

Table 7. Impact of single government investment on input–output efficiency of infrastructure.

Explained Variable: IE							
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
GI	0.002 ***	0.002 **	0.002**	0.001 **	0.001 **	0.001 *	0.001 *
	(3.16)	(2.46)	(2.31)	(2.27)	(2.02)	(1.93)	(1.78)
SU		−0.001	0.009	−0.002	−0.004	−0.005	0.001
		(−0.04)	(0.82)	(−0.20)	(−0.42)	(−0.57)	(0.10)
BU			−0.070 *	−0.033	−0.014	−0.001	0.022
			(−1.81)	(−1.00)	(−0.41)	(−0.02)	(0.64)
OP				0.285 ***	0.288 ***	0.294 ***	0.254 ***
				(12.99)	(13.24)	(13.46)	(10.73)
MI					0.002 ***	0.002 **	0.002 ***
					(3.09)	(2.54)	(2.59)
CP						0.016 **	0.016 **
						(2.20)	(2.15)
PO							−0.030 ***
							(−4.05)
Year	Control	Control	Control	Control	Control	Control	Control
Province	Control	Control	Control	Control	Control	Control	Control
R^2	92.36%	92.36%	92.42%	94.50%	94.61%	94.67%	94.86%
N	496	496	496	496	496	496	496

Note: Values in parentheses are t statistics. ***, **, * indicate statistical significance of 99, 95, and 90%, respectively. Results were processed by Stata 14.0.

4.3. Overall Economic Growth Effect of PPP

Model (6) was used to test the overall impact of PPP on economic development. The results are shown in Table 8.

Table 8. Overall economic growth effect of PPP.

Explained Variable: GDP							
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
PPP	0.005 **	0.004 **	0.004 **	0.004 **	0.004 **	0.004 **	0.003 *
	(2.36)	(2.06)	(2.25)	(2.31)	(2.44)	(2.34)	(1.86)
SU		1.239 ***	1.474 ***	1.485 ***	1.443 ***	1.470 ***	1.530 ***
		(9.83)	(10.48)	(10.52)	(10.40)	(10.72)	(11.05)
BU			−1.668 ***	−1.708 ***	−1.318 ***	−1.463 ***	−1.262 ***
			(−3.59)	(−3.66)	(−2.83)	(−3.17)	(−2.71)
OP				−0.274	−0.227	−0.250	−0.595 *
				(−0.89)	(−0.75)	(−0.84)	(−1.82)
MI					0.040 ***	0.045 ***	0.045 ***
					(4.33)	(4.83)	(4.85)
CP						0.047 ***	0.050 ***
						(3.64)	(3.86)
PO							−0.261 **
							(−2.47)
Year	Control	Control	Control	Control	Control	Control	Control
Province	Control	Control	Control	Control	Control	Control	Control
R^2	97.82%	98.21%	98.26%	98.26%	98.33%	98.38%	98.40%
N	496	496	496	496	496	496	496

Note: Values in parentheses are t statistics. ***, **, * indicate statistical significance of 99, 95, and 90%, respectively. Results were processed by Stata 14.0.

PPP always has a significant and positive correlation with GDP, proving that it has an economic growth effect, which lays the groundwork for the following analysis of the spatial spillover effect. Hypothesis 2 can be confirmed. The coefficient of SU is always significantly positive, while the coefficient of BU is always significantly negative. This suggests that the higher the level of fiscal self-sufficiency, the stronger the ability of local governments to contribute to economic development; in contrast, an excessively high fiscal burden indicates that local governments must concentrate excessive social and financial resources, which is not conducive to stimulating market vitality and thus weakens the sustainability of economic development. The coefficient of CP is significantly positive and the coefficient of PO is significantly negative, indicating that the driving force of economic development is an improved level of human capital rather than population growth. In addition, the marketization level is positively correlated with economic development and the degree of foreign trade dependence is negatively correlated, indicating that economic development is driven by domestic market demand rather than import and export, which conforms with the latest theoretical idea of nurturing a stronger domestic market to establish China's new development pattern.

4.4. Spatial Spillover Effect of PPP

The selection of a spatial econometric model has an important impact on the accuracy of the results. Therefore, the feasibility and reliability of model (7) was tested, as shown in Table 9, proving that the model is appropriate for this study.

It was also necessary to test the spatial dependence of economy between regions as a prerequisite to studying the spatial effect of PPP. Moran's I was used to measure the economic spatial autocorrelation of GDP and IE, as shown in Table 10. The value range of Moran's I is [−1, 1]; a value greater than 0 means positive spatial correlation, and a value less than 0 means negative correlation, and the greater the absolute value, the stronger the spatial correlation, showing a more obvious spatial agglomeration effect.

Table 9. Test of spatial econometric model specification.

Test	Statistic	Coefficient	*p*-Value
Applicability of spatial autoregression model	LM_lag	12.49 ***	0.000
	LM_lag_ro	23.63 ***	0.000
Applicability of spatial error model	LM_err	110.34 ***	0.000
	LM_err_ro	121.48 ***	0.000
Selection of fixed effect types	LR-both_ind	72.43 ***	0.000
	LR-both_time	1662.70 ***	0.000
Comparison of SDM and SAR	Wald_SDM_SAR	26.71 ***	0.000
	LR_SDM_SAR	26.05 ***	0.000
Comparison of SDM and SEM	Wald_SDM_SEM	23.43 ***	0.001
	LR_SDM_SEM	23.64 ***	0.001

Note: ***, **, * indicate statistical significance of 99, 95, and 90%, respectively.

Table 10. Moran's I of GDP and IE.

Year	GDP		IE	
	Moran's I	Z	Moran's I	Z
2003	0.205 ***	2.628	0.019	0.570
2004	0.204 ***	2.619	0.019	0.567
2005	0.195 **	2.532	0.018	0.559
2006	0.191 **	2.487	0.017	0.552
2007	0.189 **	2.458	0.017	0.549
2008	0.188 **	2.453	0.016	0.543
2009	0.195 **	2.534	0.016	0.535
2010	0.193 **	2.529	0.015	0.528
2011	0.191 **	2.506	0.015	0.525
2012	0.188 **	2.475	0.015	0.524
2013	0.186 **	2.455	0.014	0.512
2014	0.187 **	2.460	0.013	0.506
2015	0.195 **	2.545	0.013	0.504
2016	0.205 ***	2.650	0.012	0.498
2017	0.215 ***	2.759	0.012	0.491
2018	0.213 ***	2.733	0.011	0.486

Note: ***, **, * indicate statistical significance of 99, 95, and 90%, respectively.

Moran's I of GDP over the 16-year period is always significantly positive, while that of IE is not significant. This shows that economic development has obvious spatial agglomeration characteristics. Since the efficiency of infrastructure investment is not an indicator of the real economy, it is difficult to form spatial dependence between regions, which is in line with the economic reality. Therefore, GDP was taken as the explanatory variable to study the spatial spillover effect of PPP. Model (7) was used, and the results are shown in Table 11.

Table 11. Spatial spillover effect of PPP.

Variables	Explained Variable: GDP				
	Coefficient		Effect		
	Local	Neighboring	Direct	Indirect	Overall
PPP	0.003 *	0.007 *	0.004 **	0.017 **	0.020 **
	(1.70)	(1.84)	(2.09)	(2.19)	(2.36)
SU	1.541 ***	−0.600 *	1.565 ***	0.509	2.074 ***
	(12.60)	(−1.84)	(12.47)	(0.83)	(3.12)
BU	−1.669 ***	1.962 *	−1.498 ***	2.220	0.723
	(−4.06)	(1.69)	(−3.55)	(0.94)	(0.28)
OP	−0.706 **	1.207 *	−0.617 **	1.634	1.017
	(−2.46)	(1.94)	(−2.01)	(1.24)	(0.68)
MI	0.052 ***	−0.055 **	0.049 ***	−0.053	−0.004
	(6.42)	(−2.13)	(5.93)	(−0.95)	(−0.07)
CP	0.026 **	0.070 **	0.036 ***	0.168 **	0.205 ***
	(2.29)	(2.15)	(3.01)	(2.53)	(2.84)
PO	−0.207 *	0.165	−0.204 *	0.106	−0.098
	(−1.82)	(0.72)	(−1.84)	(0.25)	(−0.23)
ρ	0.536 ***				
	(8.92)				
σ^2	0.005				
Year	Control				
Province	Control				
R^2	76.53%				
Log L	603.84				
N	496				

Note: Values in parentheses are t statistics. ***, **, * indicate statistical significance of 99, 95, and 90%, respectively. Results were processed by Stata 14.0.

The value of ρ is 0.536 and significantly positive, showing a strong regional economic agglomeration effect. In terms of the coefficients, the impact of each factor on local economic development is consistent with Table 9. The coefficients of neighboring areas show that PPP has a positive correlation with the economic development of neighboring areas, as does CP, which indicates that both PPP infrastructure investment and human capital have a positive spatial spillover effect, manifesting external economies. PO is no longer significant, so the population size does not have a spatial spillover effect, which is in line with the economic reality. Comparing the coefficients, the three kinds of effects can more accurately measure the extent to which each factor affects economic development. Direct, indirect, and overall effects reflect the impact degree of each factor on local, neighboring, and overall economic development, respectively. This paper focuses on explaining the direct and indirect effects. The coefficients of the direct effect are more significant compared to those of the indirect effect, indicating that local economic development is driven more by self-support and the contribution of spatial spillover benefits by neighboring areas is limited. In the indirect effect, only PPP and CP are still significantly positive, which further shows that PPP infrastructure investment and human capital have stronger positive spatial spillover effects compared with other factors. Hypothesis 3A can be confirmed.

4.5. Industrial Heterogeneity of PPP

In order to arrive at more comprehensive conclusions, the industry heterogeneity of PPP was further tested, as shown in Table 12.

Table 12. Industrial heterogeneity of PPP.

Explained Variable: GDP									
Variables	**Transportation**			**Energy**			**Water**		
	Direct	**Indirect**	**Overall**	**Direct**	**Indirect**	**Overall**	**Direct**	**Indirect**	**Overall**
PPP	0.004 **	0.016 *	0.020 **	0.002	0.018 **	0.020 **	0.002	0.022 *	0.024 *
	(2.22)	(1.77)	(2.02)	(0.91)	(2.07)	(2.07)	(0.91)	(1.93)	(1.93)
SU	1.552 ***	0.498	2.050 ***	1.577 ***	0.621	2.198 ***	1.575 ***	0.504	2.079 ***
	(12.36)	(0.81)	(3.07)	(12.52)	(0.99)	(3.23)	(12.54)	(0.81)	(3.09)
BU	−1.547 ***	1.991	0.444	−1.505 ***	1.595	0.090	−1.609 ***	1.660	0.051
	(−3.65)	(0.84)	(0.17)	(−3.55)	(0.66)	(0.03)	(−3.76)	(0.69)	(0.02)
OP	−0.649 **	1.559	0.910	−0.606 **	1.831	1.225	−0.628 **	1.469	0.841
	(−2.11)	(1.18)	(0.61)	(−1.97)	(1.35)	(0.80)	(−2.04)	(1.10)	(0.56)
MI	0.047 ***	−0.063	−0.016	0.050 ***	−0.050	−0.001	0.048 ***	−0.064	−0.016
	(5.65)	(−1.10)	(−0.26)	(6.01)	(−0.88)	(−0.01)	(5.69)	(−1.11)	(−0.27)
CP	0.039 ***	0.185 ***	0.224 ***	0.038 ***	0.186 ***	0.224 ***	0.038 ***	0.179 ***	0.217 ***
	(3.26)	(2.78)	(3.12)	(3.12)	(2.76)	(3.07)	(3.12)	(2.66)	(2.97)
PO	−0.215 **	0.026	−0.190	−0.212 *	0.041	−0.171	−0.233 **	0.105	−0.128
	(−1.96)	(0.06)	(−0.45)	(−1.92)	(0.10)	(−0.40)	(−2.15)	(0.24)	(−0.29)
ρ	0.538 ***			0.545 ***			0.541 ***		
	(8.95)			(9.16)			(9.03)		
σ^2	0.005			0.005			0.005		
Year	Control			Control			Control		
Province	Control			Control			Control		
R^2	76.82%			72.21%			74.82%		
Log L	603.62			603.10			602.76		
N	496			496			496		

Note: Values in parentheses are t statistics. ***, **, * indicate statistical significance of 99, 95, and 90%, respectively. Results were processed by Stata 14.0.

After distinguishing industries, the spatial spillover effect of economic development is still significantly positive, and the economic impact of PPP has significant industrial heterogeneity. The direct, indirect, and overall effects of transportation PPP are all significantly positive, indicating that PPP investment in transportation infrastructure not only promotes local economic development, but also creates great external economic benefits for the neighboring areas. PPP improves the regional transportation infrastructure interconnection to consolidate the material carrier foundation for sustainable economic development. The direct effect of energy and water PPP is not significant, but the indirect effect is significant; that is, energy and water PPP have positive external economy. Hypothesis 3B can be confirmed. All of this highlights the extreme importance of transportation infrastructure in the development of a national economy. Transportation infrastructure has become the most important material carrier to promote the flow of economic factors between regions and improve the quality of national economic growth. Therefore, mobilizing private parties to form long-term partnerships with the government to build a modern transportation system has become the general trend in China to ensure high-quality economic development.

5. Discussion

5.1. Evaluation of Infrastructure Input–Output Efficiency and Economic Development

The infrastructure input–output efficiency in China from 2003 to 2018 was measured by using SFA, showing that the overall efficiency is 0.449, far below 1, which is a state of inefficiency. In different regions, it has obvious heterogeneity and sequencing, presenting a distribution trend of decreasing from east (0.685) to west (0.283), consistent with findings from previous research [36,39,40]. The result is also basically in line with the ranking in the White Paper on China's Infrastructure Competitiveness Index (2020) released by the China Fujian Economic Information Center and the research institute of Tsinghua University. China's national conditions determine the imbalance of its regional economic

development. The level of economic development in eastern China is significantly higher than that in central and western China, and infrastructure is the main factor causing the regional differences [41]. The relationship between infrastructure investment and economic development is one of mutual influence and promotion [42]. Focusing on improving the regional layout of infrastructure investment will be essential for the sustainable and balanced development of China's regional economy. The results of this paper show that PPP is positively correlated with the input–output efficiency of infrastructure. This is different from previous research [9], in which the adopted efficiency evaluation method was nonlinear programming, so there are differences in the accuracy of efficiency calculation; the differential method was used to regard PPP as a policy impact and the impact of PPP investment was not studied. These may account for the difference in conclusions.

5.2. Economic Growth Effect of PPP

This paper confirms that PPP can boost economic development, which is consistent with China's policy orientation and the results of current theoretical studies. In recent years, China has actively introduced policies to promote the standardization and rationalization of PPP, making it innovate and develop in the direction of improving quality and efficiency. In March 2019, the Ministry of Finance issued a guideline that gave full play to the positive role of cooperation between the government and private party to promote high-quality economic development of China in the new era. China's 14th Five-Year Plan (2021–2025) once again clearly points to giving full play to the advantages of PPP to support the construction of major projects for the coordinated development of regional economy. Propelled by sound policies, the number and investment of PPP projects in China have achieved a sustained and stable growth trend, which is enough to show that the economic advantage of PPP has been affirmed by the governance layer.

Furthermore, most theoretical studies have recognized that PPP can promote economic development from the analysis aspects of governance mechanism, resource allocation, supply mode, and information efficiency of PPP. PPP is more reflected in the major innovation of public management mode and government governance mechanism in China's practice, which introduces the market mechanism to improve the infrastructure provision efficiency with its built-in advantage, thus to effectively promote economic development [43–45]. According to the principal-agent theory, PPP effectively alleviates the information asymmetry between the government and private party through contract, reduces principal-agent cost and solves the problem of adverse selection. Finally, the PPP data used in the empirical test of this paper are all successful infrastructure PPP projects, which play an indispensable role in China's economic and social development, which also confirms the rationality of the research results of this paper.

5.3. Spatial Spillover Effect and Industrial Heterogeneity of PPP

This paper shows that PPP has a positive spatial spillover effect and significant industrial heterogeneity, suggesting that PPP infrastructure investment can promote regional economic integration development and PPP in transportation can bring greater economic benefits. The research hypothesis is verified by empirical tests based on the theoretical analysis of the infrastructure network, externality, and the spatial dependence of the economy itself, consistent with findings from previous research [14]. Some studies point out that infrastructure investment has a positive spatial spillover effect [46,47], while others indicate a negative effect [29]. The spatial spillover effect of infrastructure has been confirmed by most studies; however, the effect is positive or negative depending on the industry and data used. To be sure, not every kind of investment can produce a positive spatial spillover effect, and identifying efficient investments is the key.

According to the above analysis, infrastructure investment includes not only single government investment, but also PPP investment, as well as separate investment from social capital. The efficiency and quality of different investment types are different, which is also the reason why PPP was selected in this paper. PPP not only has the economic benefits

of investment, but also the social benefits of infrastructure and the cooperative benefits of governments and private parties. Therefore, it can better reflect the efficiency of investment, which is also confirmed in the empirical test in Section 4.2. The conclusion that PPP can produce a positive spatial effect has theoretical support and necessary verification. In terms of the industrial heterogeneity of PPP, the advantages of investing in transportation infrastructure are apparent, which is in line with China's development strategy and the centrality of transportation, which is also widely verified by many studies on the positive role of transportation in regional economic development. The positive externalities of energy and water industries also reflect the public welfare characteristics of infrastructure investment and construction. Therefore, it is necessary to study PPP from the perspective of spatial economics, which will provide a new way of thinking and a new organization mode for its development and innovation in the future.

5.4. Necessity of Long-Term Planning and Investment in Infrastructure through PPP

In the backdrop of COVID-19 and the induced uncertainty of global socio-economic performance, infrastructure construction and investment are an important way to hedge against economic downturn and boost the economy [48], which has huge space for further development. However, the economic downturn has increased the burden on the government's finances, thus exacerbating the imbalance between supply and demand of infrastructure. In this situation, the investment from the social capital is particularly important, and PPP mode has become the inevitable choice [49]. The findings of this paper suggest that PPP can play a sustainable role in infrastructure construction and economic development, which is reflected in stable fund guarantee and efficient resource allocation, thus forming a long-term high-quality infrastructure supply mode [17]. At present, China is vigorously promoting the developmental PPP with regional space as the carrier and industrial development as the core so as to achieve sustainable development of regional economy. It follows that the realization of sustainable economic development under the regional virtuous circle driven by infrastructure investment through PPP is an irresistible general trend. This also highlights the necessity of long-term planning and investment in infrastructure through PPP in the case of economic uncertainty.

5.5. Limitations of the Study

This study has some potential limitations. First, limited by the availability of data from the World Bank PPI Database, the analysis of industrial heterogeneity of PPP only involves three main industries (transportation, energy, and water). Investigating other industries will be the direction of efforts in the future to explore further interesting conclusions, focusing on industry comparisons. Second, this paper focuses on the relationship between PPP and economic development without an in-depth exploration of the intervening influencing factors, which can be further studied. Third, since developmental PPP has just started to be practiced in China, its economic effects have not yet been verified by practice and theory. This will be worth paying attention to in future in-depth studies.

6. Conclusions

This paper takes data with Chinese characteristics as the research sample and empirically tests the impact of PPP on sustainable economic development based on two main research dimensions: evaluating infrastructure input–output efficiency and analyzing the spatial spillover effect. Regarding the former dimension, the input–output efficiency of infrastructure in China's 31 provinces from 2003 to 2018 is evaluated by SFA and regional development differences are discussed. Based on this, the sustainability of infrastructure investment and the economic efficiency of PPP are analyzed and validated. Regarding the latter dimension, taking GDP as the explanatory variable, the overall economic growth effect of PPP is tested. Furthermore, based on examining the spatial autocorrelation of economy, the spatial spillover effect of PPP and its industrial heterogeneity are tested.

The results reveal that PPP indeed plays an important role in promoting sustainable economic development in China, which is manifested in the following three aspects. First, PPP is positively correlated with the input–output efficiency of infrastructure and its impact is more significant than that of single government investment, indicating that PPP in infrastructure investment can play a sustainable role by leveraging less capital to achieve greater economic benefits. Second, PPP has an overall economic growth effect and spatial spillover effect. It not only drives local economic development, but also plays a synergistic role in driving the economic development of neighboring areas to achieve sustainable regional development. Third, the impact of PPP infrastructure investment in different industries varies significantly. Transportation PPP not only has a direct economic growth effect, but also a positive spatial spillover effect. Energy and water PPP have positive economic externalities. Therefore, transportation PPP plays a stronger role in driving the economy, which is determined by the vital position of transportation infrastructure. This is in line with China's strategy of building a country with a strong transportation network: develop the leveraging role of government investment, stimulate the vitality of social capital, drive the construction of major transportation projects with PPP, form network and integration effects, and continue to consolidate the carrier foundation for high-quality integrated regional development.

In the new era, how to make PPP realize greater efficiency for sustainable economic development and form a consensus and influence around the world has become a crucial proposition for its future development and innovation. One important aspect is to prioritize development and cooperation in the area of transport infrastructure. This involves not only the economic development of the country itself, but also the formation of effective cooperation among countries to use PPP as a bridge and to promote the interconnection of transportation infrastructure around the world, in order to lay a solid foundation and guarantee a win-win for all countries. Moreover, it is urgent and necessary to perfect the top-level design of PPP and cultivate a new value system from the perspective of coordinated regional development. Based on the main cycle of the domestic economy, we should improve regional policies and spatial layout, integrate PPP into the overall pattern of interconnected regional development, vigorously promote its development with the goal of sustainable regional development, and further introduce supporting policies and long-term cooperative mechanisms between governments and social capital. Developmental PPP has now become an important means of innovating regional development modes. Based on normative PPP operation, developmental PPP emphasizes the high-quality provision of comprehensive development and infrastructure with regional industrial layout and urbanization as the core, which becomes a new way to integrate old and new infrastructure and upgrade industries. It is still essential to test developmental PPP in practice, taking the Chinese experience as an example to be recognized in the world.

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