

## RESEARCH ARTICLE

# How investment in public health has impacted the prevalence of tuberculosis in China: A study of provincial variations between 2005 and 2015

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**Abstract**

How do public investments in public health actually impact health outcomes? This question has not been investigated enough, especially regarding infectious diseases. This study investigates the correlations between public health expenditure and the incidence of tuberculosis in China using a provincial panel dataset. The analysis focuses on the correlations between public health expenditure and tuberculosis incidence, using the fixed effects models and Two Stage Least Squares (2SLS) method. Overall, a 10% increase of public health expenditure per capita is associated with a 0.0019% decrease of tuberculosis incidence. A series of robustness tests show that the correlation between public health expenditure and TB incidence is valid. Future research should focus more on the performance of public health, particularly infectious diseases like tuberculosis, and provide references for health policymakers.

**KEYWORDS**

China, cost-effectiveness, infectious disease, public health expenditure, tuberculosis

## 1 | INTRODUCTION

The return of public health investment is an ongoing topic of public health affairs and management.<sup>1</sup> Public health spending is believed to have the function of improving the public's health and promoting economic growth and

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development, as well as the public's general well-being.<sup>2-4</sup> However, both the effectiveness and efficiency of public health expenditure have been questioned, especially under the views of ongoing new public administration reform worldwide.<sup>5</sup> These skeptics tend to believe that public health institutions will innately be plagued by problems of low efficiency.<sup>6</sup> These authors claim that the improvement in the public's health and well-being is more due to the economic development rather than the increase of public health expenditure, and thus they argue that maintaining or rising economic development should be the most crucial objective.<sup>3,7</sup> Meanwhile, other scientific voices argue that public health spending is essential for the equity and affordability of health service and thus that public health spending is necessary.<sup>8,9</sup>

Regarding the outcomes of public health spending, some studies use single indicators like mortality (eg, all-cause mortality, infant mortality, maternal mortality) or life expectancy,<sup>3,4,10-12</sup> while others focus on public health expenditure's effects of curbing epidemics because the epidemics have the nature of being "public."<sup>13-15</sup> In this article, we use tuberculosis (TB), a severe and prevalent disease, as the key indicator of health outcomes to evaluate the cost-effectiveness of public health expenditure.

Tuberculosis (TB) is one of the world's top 10 causes of death and a leading cause of death from a single infectious agent, surpassing even HIV/AIDS globally.<sup>16</sup> The outbreaks of infectious diseases, including multidrug-resistant tuberculosis, have heightened concerns about global health security and global economic stability.<sup>17</sup> The number of TB-related deaths in 2017 was about 1.6 million across the world.<sup>16</sup> The End TB Strategy advocated by the World Health Organization (WHO) aimed to reduce TB incidence ratio by 90% and mortality by 95% by 2035 compared with 2015.<sup>18</sup> China is one of the most affected countries by TB, accounting for 9% of the developed TB cases in 2017, ranked the second globally.<sup>16</sup>

China is the most populous nation in the world, and it has invested a lot to control TB's occurrence and spread. Efforts like the National TB Control Program (NTP), the Directly Observed Treatment Short-Course (DOTS) strategy, free TB diagnosis and treatment, and DOTS-plus, are proposed and implemented by the national government.<sup>19</sup> The reform of the health system initiated since 2009 has also been proven to improve the efficiency performance of the health care delivery system.<sup>20</sup> Benefiting from these interventions, the prevalence of smear-positive tuberculosis has decreased from 170 cases per 100 000 in 1990 to 59 cases per 100 000 population in 2010.<sup>21</sup>

Efforts on examining the impact of public health expenditure on TB incidence have been made globally. However, the conclusions are inconsistent, and there is a lack of cost-effectiveness evidence from China which sharing about 1/5 of the world's population and having the second large number of TB cases. A study of 146 countries revealed that a 1% increase in social protection expenditure as a percentage of gross domestic product (GDP) was associated with an 18.33, 8.16, and 5.48 decrease in TB prevalence, incidence, and mortality per 100 000 people, respectively.<sup>22</sup> Lessons from Brazil also demonstrated that the government's cash transfer program could reduce the TB incidence and the municipalities with high program coverage had much lower TB cases.<sup>23</sup> However, analysis from Reeves et al did not support such evidence, and the social expenditure was not associated with TB prevalence.<sup>24</sup> Therefore, this paper narrows this knowledge gap by evaluating the effects of public health expenditure on the control of epidemics, with the specific case of tuberculosis, using a dataset that compares Chinese provinces between 2005 and 2015.

## 2 | METHODS

### 2.1 | Research hypothesis

Wang et al<sup>19</sup> summarized the efforts made by the Chinese government to strengthen public health investment to curb infectious diseases such as tuberculosis after the severe acute respiratory syndrome (SARS) epidemic was brought under control. In addition, the revision of the law of the control of infectious disease also urged local governments to increase public health investment; as a result, contributing to the prevention of tuberculosis.

Besides, some other socioeconomic development factors can also influence the occurrence of TB epidemics. For example, the health system capacity, the economic development of an area, and the financial status of local government can also affect the overall health service capacity and efficacy, and ultimately impact the occurrence of infectious disease such as TB. Therefore, we hypothesized that:

**Hypothesis H1** *With an increase in the public health expenditure per capita at the provincial level, there will be a lower incidence of tuberculosis.*

**Hypothesis H2** *Changes in the health capacity, socioeconomic indicators, and government capacity are associated with changes in TB incidence.*

## 2.2 | Data resources

A panel database covering provincial information from 31 provincial-level administrative units of China from 2005 to 2015 was constructed for analysis due to the constraints of data availability on smaller geographical areas and more years. We did not find more publicly available data beyond the period we included. Meanwhile, data from Hong Kong, Macao special administrative regions, and Taiwan were excluded due to the inconsistent quality and statistical standards. Data were primarily collected from (a) the data sharing website of the Chinese Center for Disease Control and Prevention; (b) China's Health and Family Planning Statistical Yearbook; and (c) China and provincial statistical yearbooks.

## 2.3 | Measurements

### 2.3.1 | Dependent variable

The dependent variable, TB incidence (TBIN) was collected from the Center for Disease Control and Prevention.<sup>25</sup> TB incidence in  $i$  province in  $t$  year is defined as:

$$TBIN_{it} = \frac{\text{Cumulative number of cases reported}_{it}}{\text{The average population exposed tuberculosis}_{it}} \times 100\% \quad (1)$$

### 2.3.2 | Explanatory variable

The explanatory variable is the public health expenditure per capita (PHEPC) from the provincial government. This information was collected from each province's statistical yearbooks<sup>26</sup> and China's Health and Family Planning Statistical Yearbook.<sup>27</sup> Public health expenditure was adjusted to the 2016 Chinese yuan according to inflation.

### 2.3.3 | Control variables

The control variables contain three types of indicators: the health capacity indicators, the socioeconomic indicators, and the government capacity indicators. The health capacity indicators are the ratio of public hospitals to the number of total hospitals (RPH) and the debt ratio of health institutions (DR) because they represent the performance of the health system.<sup>28</sup> The sociodemographic attributes include income per capita (PCI)<sup>29</sup> and population density (PD).<sup>20</sup> The provincial government's ability is measured by the financial scale of the provincial government (SPG).<sup>30</sup> It is

defined as the ratio of fiscal expenditure to the total GDP of a province. All the information were obtained from the National Bureau of Statistics of China<sup>26</sup> as well as China's Health and Family Planning Statistical Yearbook.<sup>27</sup>

### 2.3.4 | Instrumental variable

We used the one-year-lagged value of the explanatory variable as the instrumental variable in our analysis, as suggested in prior study.<sup>31</sup>

## 2.4 | Analysis

We conducted panel data statistical analyses while accounting for the endogenous and measurement errors of explanatory variables. We first described the trends of public health expenditure per capita and TB incidence from 2005 to 2015 (Table 1). The regional differences of public health expenditure in 2005 and 2015 were mapped (Figure 1 and Figure 2). Panel unit root tests and cointegration tests were conducted (Table 2). Then, the fixed effects models and the two stages least square (2SLS) models were used to estimate the relationship between public health expenditure per capita and the incidence of TB. The basic model used to estimate the incidence of TB in  $i$  province at  $t$  year is defined as:

$$TBIN_{it} = \alpha + \ln(PHEPC_{it})\beta + \gamma C_{it} + \mu_i + \theta_t + \varepsilon_{it} \quad (2)$$

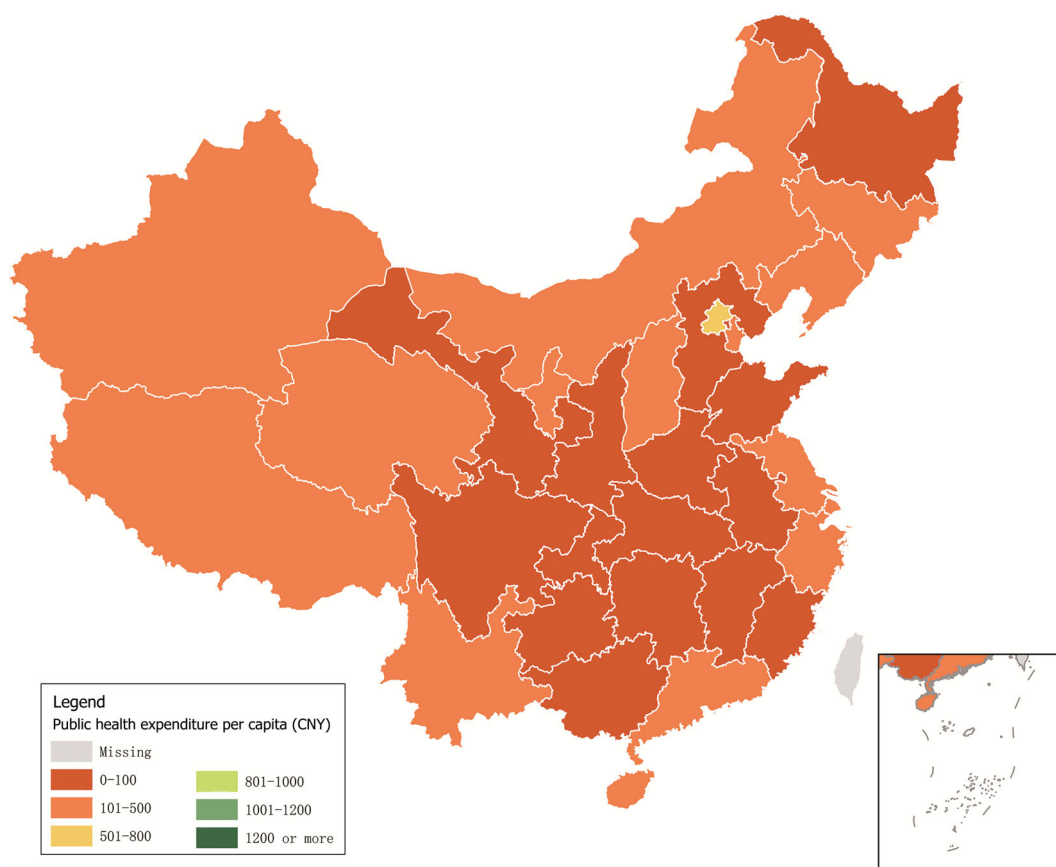
where  $PHEPC_{it}$  indicates provincial public health expenditure per capita,  $C_{it}$  represents control variables,  $\mu_i$  and  $\theta_t$  capture provincial fixed effects and time fixed effects, respectively.  $\varepsilon_{it}$  is a random error term. On this basis, the 2SLS models were implemented due to the possibility that provincial public health expenditure levels were endogenously influenced by unobserved characteristics that may influence the incidence of TB. An ancillary multivariate model, including the instrumental variable in the analysis, is estimated, and the estimation of the public health expenditure level in  $i$  province at  $t$  year as:

$$\ln(PHEPC_{it}) = \ln(PHEPC_{i,t-1}) + \gamma C_{it} + \mu_i + \theta_t + \varepsilon_{it} \quad (3)$$

**TABLE 1** Descriptive statistics (mean)

	TBIN <sup>a</sup>	PHEPC (CNY)	RPH (%)	DR (%)	PCI (CNY)	PD	SPG
2005	100	140	84.4	27.2	6687	393	0.17
2006	90	172	81.7	28.3	7519	400	0.18
2007	92	251	80.2	28.7	8719	409	0.19
2008	91	308	79.9	30.1	10 037	417	0.21
2009	84	433	77.8	30.8	11 009	427	0.24
2010	78	503	68.3	32.3	12 545	438	0.25
2011	75	614	64.5	33.8	14 585	444	0.26
2012	83	665	60.8	40.0	16 633	450	0.27
2013	72	733	57.7	40.8	18 533	456	0.27
2014	70	871	54.5	40.0	20 489	459	0.27
2015	69	1009	50.3	42.6	22 421	461	0.30

<sup>a</sup>Original data were processed into the number of cases per 100 000 population to make it easier for reading.



**FIGURE 1** Provincial public health expenditure per capita and tuberculosis incidence in 2005. Graphic abstract: The public health expenditure per capita of each province was at a low level, most of which did not exceed 500 yuan [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

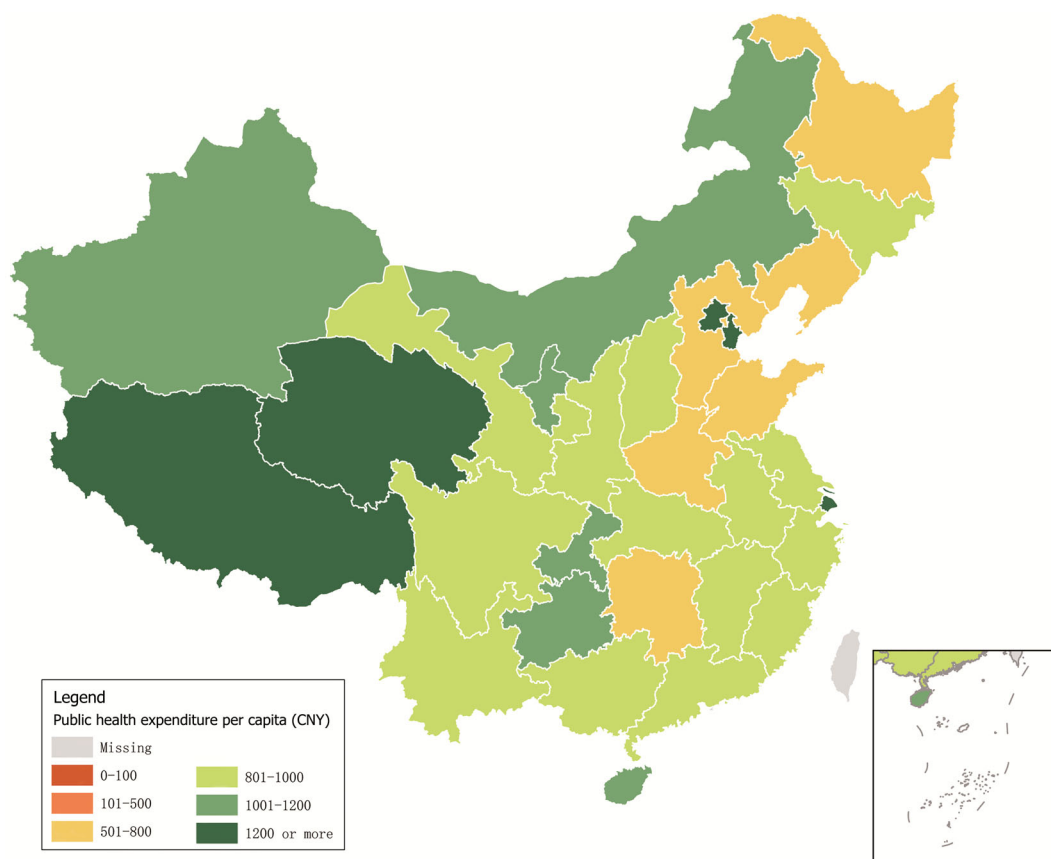
where  $\ln(PHEPC_{i,t-1})$  represents the instrumental variable. Estimations from Equation (3) are used as the predicted values of public health expenditure, and then they were used for the unbiased estimation (Equation (2)) between expenditure and TB incidence, instead of the actual expenditure.

Finally, the placebo test and a series of robustness tests were used to examine the placebo effects and measurement errors. The dependent variable was not converted numerically, and logarithms were taken for explanatory variable and partial control variables. Regression results report the relationship between the degree of change of explanatory variable, control variables, and the degree of change of the dependent variable. Stata/SE version 15.0 was used to perform all statistical analyses, and ArcMap version 10.5 was used for data visualization.

### 3 | RESULTS

#### 3.1 | Summary statistics

Table 1 provides an overview of the data. Public health expenditure per capita continued to increase from 2005 to 2015, taking inflation into account. Overall, provincial governments spent 140 Chinese yuan per capita in 2005, while this number increased to 1009 Chinese yuan in 2015. The TB incidence in 2005 was 100 cases per 100 000



**FIGURE 2** Provincial public health expenditure per capita and tuberculosis incidence in 2015. Graphic abstract: The public health expenditure per capita of provinces exceeds 800 yuan except for 6 provinces [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

people, and it declined to 69 cases per 100 000 people in 2015. The provincial public health expenditure per capita after inflation adjustment and tuberculosis incidence by provinces are demonstrated in Figures 1 and 2. Each province experienced a substantial increase in public health expenditure during the study period.

The panel data used in the study is strongly balanced. Table 2 demonstrated the dependent variable and the explanatory variable are stationary in their initial status, though some control variables are not; some of them can be stationary after the first difference adjustment. Three tests for the null hypothesis of no cointegration were conducted, and the results showed that all null hypotheses were rejected.

### 3.2 | Regression results of fixed effects models

The results from the fixed effects models (Table 3) demonstrate that the increase in public health expenditure per capita has significantly reduced TB incidence. According to the results of column (4) with complete control variables, for every 10% increase of public health expenditure per capita is associated with a 0.0017% decrease of TB incidence ( $P < .1$ ). Though the effectiveness of public health expenditure was questioned before,<sup>6</sup> the result of this analysis proves its positive influence. Furthermore, as shown in column (1)-(4), the coefficients of public health expenditure per capita gradually increase with the addition of control variables, meaning that there are high

**TABLE 2** The results of panel unit root tests and cointegration tests

Variables	Testing method				
	LLC	IPS	Breitung	Fisher-ADF	Fisher-pp
TBIN	-10.88***	-2.73***	-1.76**	167.32***	186.12***
LnPHEPC	-9.37***	-2.11**	0.41	132.89***	92.42***
RPH	-6.57***	-1.69	1.73	74.18	38.79
D.RPH	-8.98***	-3.06***	-5.72***	71.62	201.89***
DR	-4.72***	-2.53***	-1.31*	50.27	109.73***
LnPCI	-7.21***	-1.62	2.43	73.41	38.84
D.LnPCI	-10.05***	-3.43***	-4.73***	128.77***	249.17***
LnPD	-3.98***	-1.74	2.19	53.22	42.68
D.LnPD	-10.35***	-3.18***	-5.34***	107.76	200.66***
SPG	-5.64***	-1.45	2.12	85.63**	39.97
D.SPG	-8.50***	-3.14***	-2.03**	97.94***	221.23***
Cointegration tests		H0: No cointegration			
Kao test		P < .001			
Pedroni test		P < .001			
Westerlund test		P < .01			

Note: D. represents the first difference.

\*\*\*P < .01.

\*\*P < .05.

\*P < .1.

**TABLE 3** Fixed effects models: Impact of changes in public health expenditure on tuberculosis incidence

Dependent variable: tuberculosis incidence	Percent change in tuberculosis incidence per 10% increase in public health expenditure (SE)			
	(1)	(2)	(3)	(4)
Public health expenditure per capita ( <i>ln</i> )	0.0023 (0.0001)**	0.021 (0.0001)***	-0.0024 (0.0001)*	-0.0017 (0.0001)*
The ratio of public hospitals	-	0.002 (0.0002)	0.002 (0.0002)	-0.001 (0.0002)
The debt ratio of health institutions	-	-0.002 (0.0002)	-0.002 (0.0002)	-0.001 (0.0002)
Income per capita ( <i>ln</i> )	-	-	-0.00003 (0.0003)	-0.00003 (0.0003)
Population density ( <i>ln</i> )	-	-	-0.0002 (0.0005)	0.0002 (0.0003)
Scale of provincial government	-	-	-	0.013 (0.0002)***
Constant	0.021 (0.002)***	0.020 (0.0004)***	0.038 (0.005)	0.010 (0.003)
Time effects	YES	YES	YES	YES
Individual effects	YES	YES	YES	YES
N	341	341	341	341
R <sup>2</sup> (within)	0.528	0.533	0.535	0.649
F-test (sig.)	30.56 (0.00)	33.06 (0.00)	32.58 (0.00)	29.89(0.00)
Hausman test (sig.) <sup>a</sup>	0.046	0.005	0.000	0.017

\*P < .1.

\*\*P < .05.

\*\*\*P < .01.

<sup>a</sup>Bootstrap was used to conduct robust hausman tests.

correlations between the public health expenditure and the control variables, and the independence of public health expenditure to TB incidence.

For the control variables, however, considering the complete regression results in column (4), all characteristics were statistically insignificant in the model except the significant positive correlation between the scale of government and TB incidence ( $P < .01$ ).

### 3.3 | Regression results of 2SLS models

Considering the possibility of endogenous bias in the fixed effects model and the possibility of inverse causality between public health expenditure and TB incidence, we used the one-year-lagged variable of public health expenditure per capita as an instrument to evaluate the previous results, and use the Two Stage Least Squares (2SLS) method based on the fixed effects model. The correlation between the instrument and public health expenditure per capita is shown in the scatter plot (Appendix 1). It is initially considered that this instrument is reasonable.

Table 4 reports the results of regression and the measurements of instrumental variable validity. All the test results show that it is reasonable to select the instrumental variable. In terms of the second stage empirical results of the 2SLS method, it is obvious that the coefficient of the explanatory variable is negative and significant under each model, and the result is stable with the addition of control variables. It is consistent with the regression results of the fixed effects model, which verifies that the increase in the public health expenditure per capita can significantly reduce TB incidence. Thus, H1 is supported, that the increase in public health expenditure per capita is significantly associated with a decline in TB incidence. Besides, comparing the results of column (4) in Table 4 with column (4) in Table 3, a 10% increase in public health expenditure per capita in the 2SLS model resulted in a 0.0019% decrease in TB incidence ( $P < .01$ ), suggesting that the fixed effects model slightly underestimated the improvement in TB incidence from public health expenditure. For the control variables, the debt ratio of health institutions was negatively correlated with TB incidence ( $P < .05$ ), while the per capita income and population density were negatively correlated with TB incidence ( $P < .01$ ). No significant relationship was found between the ratio of public hospitals and TB incidence, nor between the scale of provincial governments and TB incidence. Therefore, H2 is only partially supported, that the increase in socioeconomic indicators and the debt ratio of health institutions are associated with the decline in TB incidence, while other indicators found no such relationship.

### 3.4 | Robustness test

The above empirical analysis shows that the increases in public health expenditure per capita will reduce TB incidence. We further take a placebo test to confirm our findings. By choosing a variable that has no direct correlation with the explanatory variable, we conduct a contraceptive operation ratio to replace TB incidence as the dependent variable. Table 5 column (2) shows the results based on the fixed effects model with the 2SLS method. Public health expenditure per capita is not a significant determinant of contraceptive operation ratio. Therefore, this study found no placebo effects.

The empirical model controls for socioeconomic factors, but may still leave out other variables related to economic activity. Climate, for example, is linked to economic activity<sup>32</sup> and potentially affects health.<sup>33</sup> To address this issue, the winter mean temperature (January, February, and December) is used as an additional control variable. The result in Table 5 column (3) indicates a positive correlation between winter mean temperature and TB incidence. Further, compared with the result in column (1), the correlation between public health expenditure per capita and TB incidence remains unchanged substantially. Therefore, the effect of public health expenditure per capita on TB incidence is robust to the inclusion or exclusion of winter mean temperature.



**TABLE 4** 2SLS models: Impact of changes in public health expenditure on tuberculosis incidence

Dependent variable: tuberculosis incidence	(1)	(2)	(3)	(4)
Public health expenditure per capita ( <i>ln</i> )	-0.0011 (0.0001)**	-0.0020 (0.00005)***	-0.0016 (0.0001)***	-0.0019 (0.0001)***
The ratio of public hospitals	-	0.008 (0.0002)***	0.0001 (0.0002)	-0.0004 (0.0002)
The debt ratio of health institutions	-	-0.010 (0.0003)***	-0.006 (0.0002)***	-0.005 (0.0003)**
Income per capita ( <i>ln</i> )	-	-	-0.0026 (0.0001)***	-0.0023 (0.0001)***
Population density ( <i>ln</i> )	-	-	-0.0008 (0.00003)***	-0.0007 (0.00003)***
Scale of provincial government	-	-	-	0.001 (0.0002)
Constant	0.014 (0.001)***	0.016 (0.002)***	0.048 (0.005)***	0.046 (0.005)***
Time effects	YES	YES	YES	YES
Individual effects	YES	YES	YES	YES
N	310	310	310	310
R <sup>2</sup>	0.065	0.173	0.442	0.443
Instrumental variable in the first stage of 2SLS model	0.896 (0.02)***	0.885 (0.02)***	0.889 (0.02)***	0.869 (0.02)***
F-test (sig.)	2.08 (0.03)	5.59 (0.00)	27.97 (0.00)	27.93 (0.00)
Cragg-Donald Wald F statistic (10% maximal IV size)	6239.277 (16.38)	4594.017 (16.38)	2915.557 (16.38)	1945.315 (16.38)
Kleibergen-Paap rk LM statistic (sig.)	54.112 (0.00)	56.403 (0.00)	69.827 (0.00)	59.875 (0.00)

Note: 2SLS: Two Stage Least Squares method.

\* $P < .1$ .

\*\* $P < .05$ .

\*\*\* $P < .01$ .

**TABLE 5** Robustness test of 2SLS model

Dependent variable	Percent change in dependent variable per 10% increase in explanatory variable (SE)			
	(1) Tuberculosis incidence (Ref.)	(2) Contraceptive operation ratio	(3) Tuberculosis incidence	(4) Tuberculosis incidence
Public health expenditure per capita ( <i>ln</i> )	-0.0019 (0.0001)***	0.0124 (0.007)	-0.0014 (0.0001)***	-
The ratio of public health expenditure of total fiscal expenditure ( <i>ln</i> )	-	-	-	-0.0007 (0.0001)
The ratio of public hospitals	-0.0004 (0.0002)	0.642 (0.01)***	-0.0007 (0.0002)	0.0005 (0.0002)
The debt ratio of health institutions	-0.005 (0.0003)**	-1.517 (0.03)***	-0.002 (0.0003)	-0.006 (0.0003)**
Income per capita ( <i>ln</i> )	-0.0023 (0.0001)***	0.304 (0.009)***	-0.0018 (0.0001)**	-0.0041 (0.0001)***
Population density ( <i>ln</i> )	-0.0007 (0.00003)***	0.065 (0.001)***	-0.0012 (0.00003)***	-0.0005 (0.00003)**
Scale of provincial government	0.001 (0.0002)	-0.671 (0.02)***	-0.0002 (0.0002)	-0.002 (0.0002)
Winter mean temperature	-	-	0.0001 (0.00001)***	-
Constant	0.046 (0.005)***	2.807 (0.06)***	0.041 (0.004)***	0.049 (0.0006)***
Time effects	YES	YES	YES	YES
Individual effects	YES	YES	YES	YES
N	310	310	310	310
R <sup>2</sup>	0.443	0.200	0.491	0.433

Note: Ref.: reference group. 2SLS: Two Stage Least Squares method.

\**P* < .1.

\*\**P* < .05.

\*\*\**P* < .01.

So far, public health expenditure per capita has been used as the core explanatory variable. Taking the measurement error into account, we replace the core explanatory variable with the ratio of public health expenditure to total fiscal expenditure (PHEOTFE), and Table 5 column (4) shows the regression result. While the estimations of other variables were basically the same as that of the reference group, the correlation between the core explanatory variable and TB incidence was statistically insignificant. This testifies that using public health expenditure per capita as the core explanatory variable is more effective.

## 4 | DISCUSSION

Using provincial panel data in China from 2005 to 2015, we assess the effects of public health expenditure on tuberculosis incidence. We used the fixed effects models and Two Stage Least Squares (2SLS) method as analytical strategies. The results demonstrate that the increase of public health expenditure per capita is significantly associated with the reductions of tuberculosis in terms of incidence. This study is one of the early results of a cost-effectiveness assessment of public health expenditure using tuberculosis.

This study's key contribution was to investigate the correlation between public health expenditure and TB incidence, controlling for health capacity, socioeconomic indicators, and government capacity. Prior studies have provided similar observations from other countries.<sup>23,34</sup> Furthermore, Gianella et al<sup>35</sup> found that the public health

expenditure can reduce the TB outcomes within the vulnerable groups, while some other studies<sup>24,36</sup> discovered the reduced public health expenditure impacted the TB case detection and increased the long-term risk of TB recurrence.

TB treatment imposes a substantial economic burden,<sup>37</sup> especially in rural and impoverished areas of China.<sup>38,39</sup> Thus, the investment of public health expenditure can reduce the incidence of diseases, as in the case of TB, and eventually reduce the financial burden of medical treatment. Furthermore, beyond the purely economic return on investment, these investments into public health can positively impact many citizens' quality of life in ways that are still difficult to quantify.

## 5 | LIMITATION

This study has several limitations. First, data from various sources were only collected at the provincial level, thus detailed information from the lower geographical area/administrative level is needed in future studies. Second, we did not include other influencing factors of TB occurrence due to the unavailable of data, such as the age, occupation, alcohol and tobacco consumption, poor nutrition, and household crowding.<sup>40</sup> Lastly, due to the limitation of data availability, the explanatory variable-public health expenditure per capita can only partially represent the investment for TB control. Thus, the real impact of public health investment on TB prevention can be underestimated.

## 6 | CONCLUSION

China has invested lots of effort to reduce the prevalence of tuberculosis during the last decades. Using a panel dataset at the provincial level from 2005 to 2015, the results of this study show that public health expenditure per capita at the provincial level in China increased by 621% during the study period, while the TB cases fell from 100 to 69 per 100 000 population. The fixed effects model and the 2SLS model further confirm the correlation between the rising in public health expenditure and the reduction in TB incidence. Future research should focus more on the performance of public health in improving the condition of infectious diseases such as tuberculosis, and provide a reference for policymakers to formulate more effective public health investment decisions.

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## CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, or publication of this paper.

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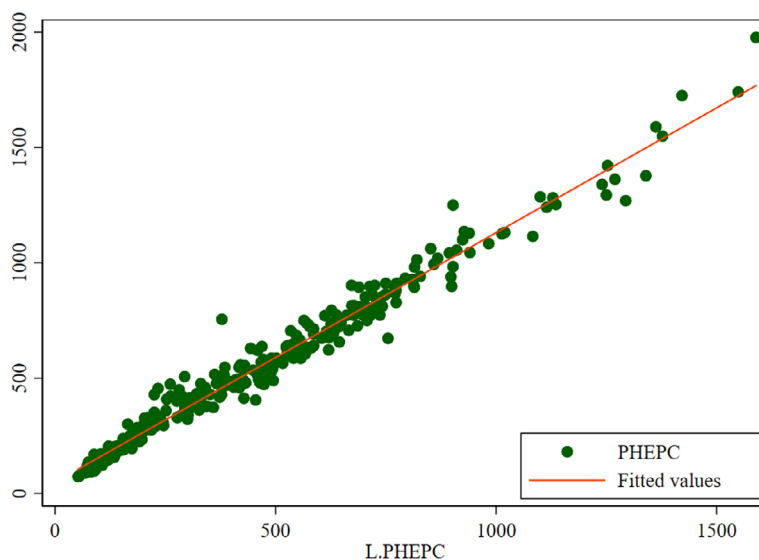
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#### APPENDIX A1. SCATTER PLOT OF THE LAG VARIABLE OF PUBLIC HEALTH EXPENDITURE



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