Public Health Expenditure and Labour Productivity: A Tentative Interpretation Based on the Science of Brain Cognition

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ABSTRACT

Based on the panel data of China's prefecture-level cities in 2007-2013, this paper empirically studies the relationship between public health expenditure and labour productivity from the perspective of brain cognition, and distinguishes non-agricultural labour productivity and agricultural labour productivity. Results show that public health expenditure is conducive to improving labour productivity and plays a significant role in promoting non-agricultural labour productivity and agricultural labour productivity through improving people's cognitive abilities. Further analysis shows that public health expenditure has a greater impact on areas with lower economic development, which may be due to differences in brain cognition. Besides public health expenditure in the eastern region is negatively correlated with agricultural labour productivity, which may indicate that excessive health investment in rural areas in the eastern region squeezes out physical capital investment; in addition, this paper finds that the lack of infrastructure may make public health expenditure cannot function properly via brain cognition.

Key Words: Public health Expenditure, Brain Cognition, Labour Productivity, China's Prefecture-level Cities

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Introduction

Health problems have been a source of concern. On the one hand, the increasingly high medical costs are unaffordable for ordinary people; on the other hand, health inequality is prevalent among countries and within a country (Balarajan *et al.*, 2011; Olaf *et al.*, 2016). Health problems also interest many researchers from economics, sociology, physiology, etc. Schultz (1961) suggests that health and education are the core two types of human capital, and most of the consumption is the investment in human capital, so the huge differences in income seem to reflect primarily the differences in health and education. The UN Millennium Development Goals in 2000 point out that health is both a goal of economic development and a means of reducing poverty. As a socialist country, China always puts the issue of people's livelihood in the first place. Since 1978, China has been constantly trying to reform the medical system. During the planned economy in 1949-1978, the government establishes a sound rural and urban health service network and achieves remarkable results by adhering to a series of correct guidelines such as prevention-oriented, rural-focused, and the combination of Western & Eastern medicine, so many national integrated health indicators reach the level of middle-income countries.

After the reform and opening-up, market economy policies are introduced into the health

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care system, which reduces ordinary people's access to health care and increase their own expenditure, resulting in widening the health inequality (Wagstaff *et al*., 2009). In addition, although the absolute amount of the government's health investment increases year by year, the proportion of the government's investment in health expenditure declines. According to statistics, the government accounts for 32.16% of total health expenditure in 1978, while it is only 25.06% in 1990 and reaches a record minimum of 15.69% in 2002. However, the proportion began to rise since 2003 and reaches 30.14% in 2013. Meanwhile, the individual's own health care expenditure is rising, which accounts for total health expenditure is 20.4% in 1978 and rises to 57.7% in 2002 and then drops to 36% in 2013. The increase in personal medical expenditure is likely to be catastrophic for many low-income families, which may bring those families into poverty. According to the WHO2016 data (WHO Data, 2016), 100 million people suffer from poverty and 150 million people suffer from economic disasters because of self-paying medical expenditure. Studying the impact of public health expenditure on macroeconomics not only gives us a deeper understanding of the role of public health investment, but also provides a theoretical basis to formulate health care policies.

Since 2010, China has become the world's second largest economy with the total GDP surpassing Japan, which makes China play a more important role in the world economic structure. Since the reform and opening-up, China's economy has maintained rapid growth. China's GDP growth rate reaches 9.63% in 1978-1916, of which the average growth rate in 1978-1999 is 9.85%. In the 21st century, the average growth rate in 2000-2011 reaches 10.22% and then drops to 7.28% in 2012-2016. It can be seen that domestic GDP growth has slowed down since 2012, which is lower than that in 2000-2011 and even that in 1978-1999. There are many reasons for the slowdown in GDP growth. Based on Mitchell (1998, 2007) and Maddison (2006) historical statistical database, Yuan (2012) analyses the growth factors of developed countries. He believes that since the 1970s, the slowdown in economic growth of developed countries is closely correlated with the slowdown in productivity growth; the research group on China's economic growth (2012) forecasts that, since 2016, with the improving urbanization level and structural service, and the decreasing population dividend, if labour productivity cannot continue to improve, the slowdown in China's economy is inevitable. It can be seen that labour productivity is closely correlated with economic growth. Labour productivity is an important reason for economic growth, and lower labour productivity may lead to economic slowdown.

Health will affect people's cognition to a certain extent. Pontifex *et al*., (2014) finds an independent association between fitness and cognitive flexibility in preadolescent children. Many studies also shown that aerobic fitness, physical activity and regular exercise are beneficial to cognitive function in older adults (Hillman *et al*., 2008; Gregory *et al*., 2012; Hyodo *et al*., 2016). Clark *et al*., (2016) have shown that cognitive dysfunction have a negative impact on work productivity. The increase in public health expenditure will improve people's brain cognition by improving the health care environment, thereby increasing labour output.

This paper analyses the impact of public health expenditure on labour productivity from the perspective of brain cognitive science. Previous studies have focused on the impact of health on economic growth or the impact of health investment on economic growth, but few scholars have linked public health expenditure to labour productivity. However, labour productivity is a different concept from economic growth (Matsuyama, 1992; Cao and Birchenall, 2013). Based on the data of prefecture-level cities in China in 2007-2013, this paper analyses the relationship between public health expenditure and labour productivity, and the impact of public health expenditure on non-agricultural labour productivity and agricultural labour productivity by means of brain cognition. The empirical results show that public health expenditure by affecting brain cognitive function is not only positively correlated with labour productivity, but also positively correlated with non-agricultural labour productivity and agricultural labour productivity. The above relationship passes the robustness test, and is still stable after introducing instrumental variable (IV); if public health expenditure is lagged, there is a certain degree of lagging impact of public health expenditure on the three types of labour productivity; in further analysis, we find that public health expenditure is negatively correlated with agricultural labour productivity in the eastern region but not significantly, while it is significantly positively correlated with agricultural labour productivity in the central and

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the western region. The coefficient between public health expenditure and agricultural labour productivity is the maximum and there is a significantly positive correlation in provincial capitals. Public health expenditure and agriculture labour productivity is positively correlated but not significant and the coefficient is the minimum in non-provincial capital cities.

The innovations of this paper are as follows. First, the impact of public health expenditure in macroeconomics is investigated from the perspective of labour productivity. Most of the previous literature correlate health expenditure with economic growth (Van Zon and Muysken, 2001; Gong *et al.*, 2012), while public health expenditure is analysed from the perspective of labour productivity in little literature. Second, the empirical analysis in this paper finds that in the eastern region, there may be too much health investment, which squeezes out physical capital investment in rural areas. This squeezing impact leads to the negative correlation between public health expenditure and agricultural labour productivity. Although the previous literature also suggests that excessive health investment may squeeze out physical capital investment and have a negative impact on economic growth (Van Zon and Muysken, 2001; Gong *et al.*, 2012), but this paper finds that this impact only exists in the rural areas in the eastern region. Third, we try to interpret the relationship between public health expenditure and labour productivity from the perspective of cognitive science.

The rest structure of this paper is as follows: The second part shows the theoretical framework, in which Solow total production function is introduced to derive the mathematical expression of labour productivity. The third part presents model specification, data description and variable introduction. The fourth part is empirical research, looking at the estimation results of regression and discussing the main findings. The fifth part shows the robustness test and the use of 2SLS to reduce endogenous problems. The sixth part shows a further analysis of various regions. The conclusion is in the seventh part.

Theoretical framework

In this paper, based on Wu's (2017) derivation idea, total production function is introduced to derive measurement model of labour productivity, and total production function can be expressed as:

$$Y_{it}=A(x)\times f(K_{it},L_{it}) \quad (1)$$

In equation (1), Y is gross domestic product (GDP); $A(x)$ is total factor productivity function; f(x) is production function; K is the input of capital; L is the input of labour; i means the city and t means period. In terms of total factor productivity, there is no uniform definition and connotation in academia. In view of this, total factor productivity in this paper follows the meaning suggested by Solow (1957), which is the increase in output resulted from other factors like technological progress and ability realization excluding labour and physical capital investment, also known as Solow residual. There are many researches on total factor productivity at home and abroad. According to the previous researches, we find that the main influencing factors of total factor productivity are:

First, the accumulation of human capital plays an important role in economic growth. Wei and Hao (2011) study the role of human capital in the growth of total factor productivity in China in 1985-2004, and find that human capital has a significantly positive impact on total factor productivity growth. The accumulation of human capital, one of the important factors which lead to the output growth excluding the input of labour and capital, has an important impact on total factor productivity. Human capital is mainly determined by health and education. Healthy human capital is basic, and then education turns basic human capital into productive human capital. In order to study the impact of public health expenditure on labour productivity through brain cognition, we assume that human capital investment satisfies the following calculation:

$$HC_{it}=aBC_{it}^{\gamma}\times EDU_{it}^{\delta} \quad (2)$$

$$BC_{it}=bPHE_{it}^{\gamma} \quad (3)$$

In equation (2), HC is human capital investment; BC is Brain Cognition; PHE and EDU respectively represent healthy human capital investment and educated human capital investment.

$$HC_{it}=\theta PHE_{it}^{\gamma}\times EDU_{it}^{\delta} \quad (4)$$

(4) derived from (2) and (3).

Second, the impact of technology and technological progress on total factor productivity has been the focus of macroeconomic research.

Färe *et al*., (1997) analyze productivity growth in 17 OECD countries in 1979-1988 and find that the productivity in the United States is higher than the average is due to technological level. This may explain the reason why the US economy is in the world's first place, i.e., its advanced science and technology. Therefore, technology investment is introduced into total factor productivity function in this paper, and TP is used to represent technological progress in the following.

Third, with the trend of economic globalization, multinational corporations and foreign direct investment play an important role in economic development. Liu and Wang (2003) find that foreign capital is the most important factor to enhance the cost-effectiveness of Chinese industrial enterprises. In this paper, foreign direct investment (FDI) is used to show the impact of foreign capital on total factor productivity.

Fourth, urbanization level is the policy that the Chinese government has been advocating in recent years. With the development of productive forces, the progress of science and technology and the adjustment of industrial structure, China is turning from a traditionally agriculture-based country into a modern non-agriculture-based country which depends on secondary industry and service industry. Kumar and Kober (2012) find a significantly positive correlation between city and total factor productivity through cross-country empirical studies. This paper introduces urbanization level (UL) into total factor productivity function.

Fifth, China has been developing rapidly after the reform and opening-up, and the construction of domestic infrastructure has been changing greatly. Infrastructure has a significant impact on total factor productivity (Vijverberg *et al*., 2011). In this paper, average highway mileage is introduced into total factor productivity function as infrastructure, hereinafter AHM.

The above factors are introduced into total production function, and we get

$$Y_{it}=A(HC_{it},TP_{it},FDI_{it},UL_{it},AHM_{it})\times f(K_{it},L_{it}) \quad (5)$$

In equation (5), HC is human capital investment; *TP* is technological progress; *FDI* is foreign direct investment; *UL* is urbanization level; AHM is infrastructure; *i* is city and *t* is period. In order to facilitate the analysis, we assume that production function is a first-order C-D production function, and total factor productivity function $A(x)$ is a power exponent e^x, then (5) can be

$$Y_{it}=A_{it}\,exp\{\alpha 1lnHC_{it}+\alpha 2lnTP_{it}+\alpha 3lnFDI_{it}+\alpha 4lnUL_{it}+\alpha 5lnAHM_{it}\}\times K_{it}{}^{\alpha}\times L_{it}{}^{\beta} \quad (6)$$

Introduce (4) into (6) and we get:

$$Y_{it}=A_{it}\,exp\{\alpha_1 ln\theta+\alpha_1\gamma lnPHE_{it}+\alpha_1\delta lnEDU_{it}+\alpha_2 lnTP_{it}+\alpha_3 lnFDI_{it}+\alpha_4 lnUL_{it}+\alpha_5 lnAHM_{it}\}\times K_{it}{}^{\alpha}\times L_{it}{}^{\beta}$$

That is:

$$Y_{it}=A_{it}\,exp\{b+\alpha_1 lnPHE_{it}+\alpha_2 lnEDU_{it}+\alpha_3 lnTP_{it}+\alpha_4 lnFDI_{it}+\alpha_5 lnUL_{it}+\alpha_6 lnAHM_{it}\}\times K_{it}{}^{\alpha}\times L_{it}{}^{\beta} \quad (7)$$

In equation (7), A_{it} represents other factors of *i* city in *t* year influencing total factor productivity, and α and β respectively represent output elasticity of capital and labour. The labour productivity obtained from (7) is

$$y_{it}=\frac{Y_{it}}{L_{it}}=A_{it}\,exp\{a+\alpha_1 lnPHE_{it}+\alpha_2 lnEDU_{it}+\alpha_3 lnTP_{it}+\alpha_4 lnFDI_{it}+\alpha_5 lnUL_{it}+\alpha_6 lnAHM_{it}\}\times(\frac{K_{it}}{L_{it}})^{\alpha}\times L_{it}^{\alpha+\beta-1} \quad (8)$$

Get natural logarithm from both sides in (8):

$$ln(y_{it})= lnA_{it}+b+\alpha_1 lnPHE_{it}+\alpha_2 lnEDU_{it}+\alpha_3 lnTP_{it}+\alpha_4 lnFDI_{it}+\alpha_5 lnUL_{it}+\alpha_6 lnAHM_{it}+\alpha\, ln(CP_{it})+(\alpha+\beta-1)lnL_{it}$$

$CP_{it}=\frac{K_{it}}{L_{it}}$ represents the average capital stock of labour force of *i* city in *t* year.

Model specification, data description and variable introduction

Model specification

According to the previous theoretical derivation, the following model is established in this paper to examine the relationship between public health expenditure and labour productivity. In order to examine the impact of public health expenditure on labour productivity in rural and non-rural areas respectively, Model 2 and Model 3 are also introduced in this paper to estimate the impact of public health investment on non-agricultural labour productivity and agricultural labour productivity.

Table 1. The definition of each variable

Variable	Definition	unit
LP	Labour Productivity= $\frac{\text{Actual } GDP}{\text{Total Employed people}}$	yuan / person
NALP	Non-Agriculture Labour Productivity = $\frac{Total\ actual\ GDP\ of\ Second\ and\ Third\ Industries}{Total\ Employment\ of\ Second\ and\ Third\ Industries}$	yuan / person
ALP	Agriculture Labour Productivity = $\frac{Actual\ GDP\ of\ First\ Industry}{Employment\ of\ First\ Industry}$	yuan / person
PHE	Public Health Expenditure= $\frac{Expenditure\ for\ Social\ Safety\ Net\ and\ Employment\ Effort + Expenditure\ for\ Medical\ and\ Health\ Care}{Total\ Population}$	yuan / person
EDU	Education= $\frac{\text{Number of General Secondary School Graduates}}{Total\ Population}$	%
TP	Technological Progress = $\frac{R\&D\ \text{Expenditure}}{Reginal\ GDP\ of\ That\ Year}$	%
FDI	Foreign Direct Investment= $\frac{Actual\ Foreign\ Investment}{Reginal\ GDP\ of\ That\ Year}$	%
UL	Urbanization Level= $\frac{Number\ of\ Urban\ Employment}{Total\ Employment}$	%
AHM	Average highway Mileage= $\frac{highway\ Mileage}{Total\ Population}$	KM/10,000 persons
CP	Capital stock per worker = $\frac{Capital\ Stock}{\text{Total employment}}$	yuan / person
L	Labour= $\frac{\text{Employed people}}{\text{Total Population}}$	%
NAL	Non-Agriculture Labour = $\frac{Total\ Population\ of\ Second\ and\ Third\ Industries}{Total\ Population}$	%
AL	Agriculture Labour= $\frac{\text{Employed people of First Industry}}{Total\ Population}$	%

Model 1:

$$ln(LP_{it}) = \alpha_1 lnPHE_{it} + \alpha_2 lnEDU_{it} + \alpha_3 lnTP_{it} + \alpha_4 lnFDI_{it} + \alpha_5 lnUL_{it} + \alpha_6 lnAHM_{it} + \alpha\, ln(CP_{it}) + (\alpha + \beta - 1)lnL_{it} + \varepsilon_{it}$$

Model 2:

$$ln(NALP_{it}) = \alpha_1 lnPHE_{it} + \alpha_2 lnEDU_{it} + \alpha_3 lnTP_{it} + \alpha_4 lnFDI_{it} + \alpha_5 lnUL_{it} + \alpha_6 lnAHM_{it} + \alpha\, ln(CP_{it}) + (\alpha + \beta - 1)lnNAL_{it} + \varepsilon_{it}$$

Model 3:

$$ln(ALP_{it}) = \alpha_1 lnPHE_{it} + \alpha_2 lnEDU_{it} + \alpha_3 lnTP_{it} + \alpha_4 lnFDI_{it} + \alpha_5 lnUL_{it} + \alpha_6 lnAHM_{it} + \alpha\, ln(CP_{it}) + (\alpha + \beta - 1)lnAL_{it} + \varepsilon_{it}$$

In these Models, i denotes prefecture-level cities; t represents years, and ε_{it} is random disturbance term changing with time and individual. The definition of each variable is shown in Table 1.

Data description

The data in this paper are mainly from *China Statistical Yearbook for Regional Economy*, *China city Statistical Yearbook*, *China Statistical Yearbook* and provincial and municipal statistical yearbooks. In this paper, we study the panel data of the prefecture-level and above cities in 2007-2013. By the end of 2013, there are 290 prefecture-level and above cities in China. In order to obtain balanced panel data, we removed cities with incomplete data and newly-established cities. Finally, our sample eventually contains 279 prefecture-level and above cities, that is, this paper contains 1,953 sample data, accounting for 96.21% of the original sample.

Variable introduction

Labour productivity (LP). Labour productivity is the explanatory variable in this paper, which means the actual output of per unit of labour time (OECD Data, 2017). The calculation of labour productivity is still controversial, mainly concentrating in whether the actual output is measured with actual value increase or actual GDP. Besides, labour time is not easy to access, which leads to that labour time are replaced by labour number to calculate labour productivity in much literature. In most existing literature, labour productivity is calculated by actual GDP/labour number, i.e., average labour GDP, such as Zhang *et al*., (2010)'s study on the impact of educational quality on regional labour productivity, and Najarzadeh *et al*., (2014)'s study on the impact of the Internet on labour productivity. In this paper, labour productivity is calculated by Actual GDP/Employed people, in which Actual GDP is calculated by using the CPI of the provinces and cities in *China Statistical Yearbook* as the CPI of the corresponding prefecture-level cities, and the CPI is used as a deflator to calculate Actual GDP of base period 2007.

Non-Agriculture Labour Productivity and Agriculture Labour Productivity (NALP and ALP)

According to Liu (2009), this paper calculates NALP by dividing Total Employed people of second and third industries by Total actual GDP of second and third industries. And so on, this paper divides Employed people of first industry by

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actual GDP of first industry (Actual GDP is the GDP of base period 2007 which is calculated by using the CPI as the implicit deflator).

Public Health Expenditure (PHE)
We use the sum of social security and employed people expenditure and health expenditure in the fiscal expenditure of *China Statistical Yearbook for Regional Economy* as the sum of public health expenditure. In order to eliminate the impact of inflation and other factors, we use CPI as the implicit deflator to reduce the total public health expenditure on the basis of base period 2007 to obtain the actual total public health expenditure, which shall be divided by the total population to obtain the average public health expenditure. In this paper, the average public health expenditure is used to measure the level of public health expenditure.

Education (EDU)
The proportion of ordinary high school graduates accounting for the total population in the prefecture-level cities each year is used as the proxy variable of education.

Technological Progress (TP)
Since the R & D expenditure data for each prefecture-level city are not disclosed in the corresponding statistical yearbook, we use the proportion of R & D expenditure accounting for the provincial GDP to represent the technological level of the corresponding prefecture-level cities. Because the technology is diffuse, we believe that provincial data can be on behalf of the technological level of prefecture-level city to a certain extent.

Foreign direct investment (FDI)
We use the proportion of the actual use of foreign direct investment in prefecture-level cities in *China Statistics Yearbook for Regional Economy* accounting for the provincial GDP to represent the level of foreign direct investment.

Urbanization level (UL)
Lin *et al*., (2011) argue that city can bring about the agglomeration effect of economic activities, thereby improving efficiency. Broersma and Oosterhaven (2009) find that there is a significantly positive correlation between urbanization level and labour productivity in the 1990s in Holland. In this paper, the proportion of the number of urban employed people in the prefecture-level cities accounting for the total employed people is used to represent city level.

Average highway mileage (AHM). Infrastructure, especially transport facilities, can improve the mobility of goods and has a significant impact on labour productivity. Average highway mileage is used to represent infrastructure in this paper, average highway mileage=total highway mileage/total population.

Physical capital stock per worker (CP)
Physical capital stock per worker is equal to the current physical capital stock of the city divided by the total amount of labour in the city. However, there is no statistics about physical capital stock per worker in China. According to Jun *et al.* (2004), we select 2007 as the base year using the perpetual inventory method to calculate the physical capital stock per worker of the prefecture-level cities at constant price. First, the physical capital stock per worker of the provincial-level cities calculated by Jun *et al.*, (2004) at the price in 2000 multiplied by the proportion of the GDP of the prefecture-level cities accounting for the GDP of the provincial-level cities, which is taken as the physical capital stock per worker of the prefecture-level cities at the price in 2000; second, fixed investments of that year are used as investment of that year. According to Shan (2008), we take the economic depreciation rate as 10.96%, so as to calculate the physical capital stock per worker at the price in 2007; finally, taking 2007 as the base year and the price index of fixed investments as the deflator to deflate investments, we use the perpetual inventory method to calculate the physical capital stock per worker of 2007-2013 for each year.

Labour (L)
In this paper, the proportion of the total number of employed people accounting for the total population is used to measure labour. Non-agricultural labour (NAL), agricultural labour (AL) calculation shall be measured with reference to this method.

Empirical study

Descriptive statistics

The descriptive statistics of each variable are shown in Table 2. From the perspective of the statistical average, non-agricultural labour productivity is the highest among the three types of labour productivity, followed by labour productivity, and agricultural labour productivity in sequence; from perspective of the standard deviation, which of the three types of labour productivity are large, it shows that there are significant differences in the three types of labour productivity among the prefecture-level cities. In addition, the standard deviations of public health expenditure, average highway mileage and physical capital stock per worker are large, indicating big differences in public health expenditure, infrastructure level and physical capital stock per worker among prefecture-level cities.

Table 2. Descriptive statistics (2007 - 2013)

Variable	Obs	Mean	Std.Dev.	Min	Max
Ln(LP)	1,953	10.685	0.642	8.758	12.730
Ln(NALP)	1,953	11.049	0.559	9.191	13.045
Ln(ALP)	1,953	9.533	0.609	7.851	12.951
Ln(PHE)	1,953	6.552	0.567	4.197	8.517
EDU	1,953	0.020	0.005	0.003	0.059
TP	1,953	0.010	0.005	0.001	0.030
FDI	1,953	0.042	0.090	0.000	1.157
UL	1,953	0.281	0.170	0.040	0.999
Ln(AHM)	1,953	3.295	0.469	1.645	5.038
Ln(CP)	1,953	10.562	0.662	8.599	13.005
L	1,953	0.583	0.236	0.094	3.401
NAL	1,953	0.373	0.261	0.039	3.369
AL	1,953	0.209	0.083	0.000	0.608

Note: This table reports descriptive statistics based on 1953 observations over the period from 2007 to 2013. Refer to Table 1 for variable definitions.

Table 3 shows the average statistics for the main variables of different regions in different years. It can be seen from Panel A that the three types of labour productivity in 2007-2013 are gradually increasing. The average annual growth rate of labour productivity is 0.95%, while the average annual growth rate of non-agricultural labour productivity is 0.79%, and the average annual growth rate of agricultural labour productivity is 1.06%. It can be seen that although agricultural labour productivity is the lowest among the three types of labour productivity, its growth rate is the fastest, indicating that the labour productivity gap in rural and non-rural areas is narrowing; in addition, the level of public health expenditure is increasing year by year, while the level of education, which is measured by the proportion of ordinary secondary school graduates accounting for the total population, is decreasing year by year. It is seen from Panel B that the three types of labour productivity are generally decreasing from the eastern to the central and then the western region, and the level of public health expenditure is decreasing from the central to the eastern and then the western region. The labour productivity of the capital cities is higher than that of the non-capital cities, and so is public health expenditure.

Table 3. Distribution of the main variables

Panel A: By Year

Year	N	Ln (LP)	Ln (NALP)	Ln (ALP)	Ln (PHE)	EDU
2007	279	10.359	10.766	9.219	5.934	0.021
2008	279	10.474	10.864	9.336	6.201	0.021
2009	279	10.567	10.941	9.411	6.498	0.020
2010	279	10.697	11.057	9.533	6.572	0.019
2011	279	10.849	11.198	9.678	6.785	0.019
2012	279	10.901	11.246	9.750	6.876	0.019
2013	279	10.947	11.276	9.805	6.997	0.018
Total	1953	10.685	11.049	9.533	6.552	0.020

Panel B: By Region

Region	N	Ln (LP)	Ln (NALP)	Ln (ALP)	Ln (PHE)	EDU
East	826	10.908	11.206	9.753	6.524	0.020
Central	581	10.608	10.948	9.510	6.578	0.019
West	546	10.430	10.920	9.224	6.566	0.020
Provincial capital cities	203	11.262	11.468	9.709	6.861	0.018
Non-provincial capital cities	1750	10.618	11.001	9.512	6.516	0.020
Total	1953	10.685	11.049	9.533	6.552	0.020

Note: The regional division in this paper is in accordance with Wang and Fan (2004). The eastern region include: Beijing, Tianjin, Shanghai, Hebei, Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, Hainan; the central region include: Henan, Shanxi, Anhui, Hubei, Hunan, Jiangxi, Jilin and Heilongjiang; the western region include: Shanxi, Sichuan, Chongqing, Yunnan, Guizhou, Guangxi, Gansu, Qinghai, Ningxia, Tibet, Xinjiang, Inner Mongolia. Refer to Table 1 for variable definitions

Table 4. Pearson Correlation Coefficient Matrix

	Ln(LP)	Ln(NALP)	Ln(ALP)	PHE	EDU	TP	FDI	UL	Ln(AHM)	Ln(CP)
PHE	0.601***	0.588***	0.484***	1						
EDU	-0.168***	-0.180***	-0.177***	-0.229***	1					
TP	0.182***	0.114***	0.154***	-0.138***	0.092***	1				
FDI	0.214***	0.176***	0.194***	0.181***	-0.051**	0.102***	1			
UL	0.699***	0.598***	0.572***	0.491***	-0.123***	0.147***	0.156***	1		
Ln(AHM)	-0.156***	-0.0270	-0.196***	0.125***	0.0160	-0.263***	-0.138***	-0.267***	1	
Ln(CP)	0.699***	0.648***	0.405***	0.154***	-0.039*	0.296***	0.124***	0.594***	-0.207***	1
L	0.181***	0.118***	0.244***	0.251***	0.262***	0.180***	0.120***	0.136***	-0.213***	0.106***
NAL	0.395***	0.266***	0.424***	0.330***	0.240***	0.262***	0.165***	0.346***	-0.326***	0.294***
AL	-0.715***	-0.514***	-0.661***	-0.339***	0.0170	-0.303***	-0.174***	-0.694***	0.421***	-0.602***

*Note: Pearson correlations are presented below the diagonal. * , ** and *** indicate significance at two-tailed probability levels of 10%, 5% and 1% . Refer to Table 1 for variable definitions*

Table 5. Unit root test

	LLC	IPS	ADF	HT	Conclusion
Ln(LP)	-44.3376***	-2.41330***	792.106***	-10.2643***	Stable
Ln(NALP)	-46.7589***	-1.92796**	761.637***	-13.2612***	Stable
Ln(ALP)	-42.2433***	-1.09344	687.584***	-8.0367***	Stable
PHE	-59.4620***	-3.45956***	867.525***	-16.2961***	Stable
EDU	-50.6975***	-2.46898***	807.815***	-12.5547***	Stable
TP	-432.334***	-7.53879***	125.670	-2.3808***	Stable
FDI	-43.2598***	-1.18786	707.911***	-35.8983***	Stable
CL	-56.6750***	-2.47386***	807.277***	-12.1294***	Stable
Ln(AHM)	-49.7405***	-2.15106**	768.246***	-15.0638***	Stable
Ln(CP)	-52.1265***	-2.66541***	814.724***	-14.7173***	Stable
L	-49.6358***	-2.56058***	817.062***	-20.5820***	Stable
NAL	-51.6046***	-2.59829***	819.437***	-8.9149***	Stable
AL	-42.5223***	-0.99481	680.307***	-18.3111***	Stable

*Note: Select the lag period according to AIC guidelines. The estimation equation contains intercepts, hysteresis and time trend. ***, ** and * indicate that the coefficients are statistically significant at 1%, 5% and 10% respectively*

Table 4 is the Pearson correlation coefficient matrix between the variables. For simplicity, we put the matrix of the correlation coefficients of the three models in the same table. It can be seen that the public health expenditure is significantly positively correlated with the three types of labour productivity, and the correlation coefficient between the variables is less than 0.8, indicating that there is no significant multicollinearity between the variables.

Unit root test

In order to avoid pseudo-regression, it is necessary to carry out the unit root test for each variable in the model. In this paper, 4 unit root test methods are used to select the lag period according to the AIC information criterion (see table 5 for detailed results). The results show that all variables are zero-order integration I (0), rejecting the original hypothesis containing the unit root, which shows that the panel is a stationary process. Since there is no unit root in each variable, no co-integration test is required. From the results of the unit root test, we can see that the regression equation in this paper conforms to the modeling requirements.

Regression result

STATA 14.1 software is used to process the panel data in this paper. First, the F test has a P value of 0.0000, indicating that the fixation effect (FE) is significantly better than the mixed regression (OLS), and that each individual should have its own intercept; second, the Hausman test has a P value of 0.0000, indicating that the fixed effect model rather than the random effect model should be used. Two-way FE model introduces the time effect while considering the individual effect, which can be used to solve the problem of two kinds of missing variables, i.e. changing with the individual instead of the time and changing with the time instead of the individual. Thus, Two-way FE model is used in this paper. Before regression analysis, we examine the data to ensure that there was no multicollinearity. From the correlation coefficient matrix of Table 4, we can see that the correlation coefficient between the variables is no more than 0.8, while Gujarati (2003) finds that there may be multicollinearity when the correlation coefficient exceeds 0.8. In addition, we also examine the variance inflation factor (VIF) of each variable. If VIF is greater than 10, there are multicollinearity (Gujarati, 2003). In our 3 models, the maximum VIFs are 3.93, 3.86, 4.13 respectively, all of which are no more than 10. Thus, we think there is no need to consider multicollinearity. Table 6 shows the results of the two-way FE estimation and the PHE lag estimation.

It can be seen from Table 6 that in those two regressions, in addition to (6), labour productivity is significantly positively correlated with public health expenditure, indicating that public health investment which improving cognitive function not only plays a current role in improving the three types of labour productivity but also a lagging role to some degree. In (6), the lagged public health expenditure is positively correlated with agricultural labour productivity but not significantly, indicating that more public health investment is needed to improve the status quo of cognitive control in rural areas behind urban areas. Through the empirical analysis on the basic medical insurance of urban residents in China, Pan *et al.* (2013) find that the medical insurance system has a significant impact on the improvement of the health of the insured residents and has a greater impact on the people in poor socioeconomic status.

Table 6. The result of Two-way FE regression

	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(PHE)	0.0492***	0.0431***	0.0381**			
	(0.0099)	(0.0152)	(0.0156)			
$Ln(PHE)_{t-1}$				0.0488***	0.0295**	0.0173
				(0.0092)	(0.0146)	(0.0158)
EDU	-1.5943**	-1.6366	2.1913**	-1.6153**	-1.8531	1.1556
	(0.6675)	(1.0367)	(1.0606)	(0.7240)	(1.1614)	(1.2497)
TP	-5.2572***	-2.3619*	-5.2694***	-7.3133***	-3.1594**	-7.9742***
	(0.9141)	(1.4139)	(1.4470)	(0.9810)	(1.5615)	(1.6876)
FDI	0.0239	0.0236	0.0086	0.0247	0.0052	0.0067
	(0.0258)	(0.0400)	(0.0409)	(0.0227)	(0.0361)	(0.0390)
UL	0.0453*	0.0797**	0.3618***	0.0113	0.0489	0.2801***
	(0.0256)	(0.0396)	(0.0406)	(0.0241)	(0.0383)	(0.0414)
Ln(AHM)	0.0559***	0.1058***	-0.00005	0.0412**	0.0966***	0.0769**
	(0.0168)	(0.0258)	(0.0264)	(0.0192)	(0.0301)	(0.0326)
Ln(CP)	0.9070***	0.6034***	0.2970***	0.9189***	0.6020***	0.3033***
	(0.0229)	(0.0275)	(0.0285)	(0.0212)	(0.0262)	(0.0296)
L	-0.1511***			-0.1450***		
	(0.0360)			(0.0328)		
NAL		-1.0556***			-0.9628***	
		(0.0620)			(0.0598)	
AL			-3.4562***			-3.4278***
			(0.1318)			(0.1402)
_cons	0.1434	3.9758***	6.4412***	1.2980***	5.0519***	7.0015***
	(0.2611)	(0.3168)	(0.3349)	(0.2321)	(0.2970)	(0.3366)
Region effect	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
N	1953	1953	1953	1674	1674	1674
R^2	0.9374	0.8345	0.8533	0.9410	0.8335	0.8397

*Note: Standard errors are reported in parentheses. * , **, and *** indicate significance at two-tailed probability levels of 10%, 5%, and 1%. Refer to Table 1 for variable definitions.*

The empirical results of this paper also suggest that public health investments should be increased in rural areas with poor socioeconomic conditions so as to promote labour productivity. On the one hand, the majority of rural areas in China are more dependent on labour-oriented farming and the mechanization is low, so the impact of labour sickness on agricultural production is huge; on the other hand, rural residents lack awareness and ability to buy commercial insurance, and more rely on national health insurance, so public health expenditure shoulder the responsibility to promote the health and reduce the risk of sickness of rural residents.

The study of education human capital investment has been a hot topic in literature. It is found that educational human capital investment is significantly positively correlated with ALP, while significantly negatively correlated with LP and negatively correlated with NALP but not significantly; this shows that the increase in the number of ordinary middle school graduates can improve agricultural labour productivity, but has a negative impact on non-rural areas. The reason may be that the rapid increase of the number of education without increasing the supply of teachers may not be the most efficient allocation of educational resources (Zhang *et al*., 2010).

It is worth noting that there is a significantly negative correlation between technological progress and the three types of labour productivity in our regression results, among which the correlation coefficient of ALP is the largest, indicating that the negative impact of technological progress on ALP is the most serious. This may indicate that there is a waste of R & D funding. Therefore, how much of the investment in technology is converted to productivity is worth thinking about.

In addition, FDI is positively correlated with the three kinds of productivity but not significantly. AHM is negatively correlated with ALP. There is significantly positive correlation between physical capital stock per worker and the three types of labour productivity. While labour is significantly negatively correlated with the three kinds of productivity.

Robustness test and endogenous problems

Robustness test

First, other variables that may affect labour productivity are introduced in this paper to test the stability of the regression results. There are a large number of previous studies on the relationship between economic activity density and labour productivity (Ciccone and Hall, 1996; Broersma and Oosterhaven, 2009; Lin *et al*., 2011). As one of the most important factors influencing economic activity density, population density has been studied by a large number of scholars, such as Smoluk and Andrews (2005), who study the labour productivity of 48 states in the United States in 1993 and find that the states with higher population density have higher labour productivity. In this paper, population density (PD) is added to the control variables to examine the relationship between public health expenditure and labour productivity. The results are shown in Table 7 (population density (PD)=resident population/built-up area, unit: million persons/square Km. The data are from the *China Statistical Yearbook for Regional Economy*). Compared with the regression results in Table 6, after adding PD, the regression coefficient and the significance of the regression results do not significantly change, indicating that the regression results in Table 6 are robust and the conclusion that the public health expenditure is significantly positively correlated with the three types of labour productivity is robust.

Table 7. Robustness test: add PD

	Model 1	Model 2	Model 3
	Ln(LP)	Ln(NALP)	Ln(ALP)
Ln(PHE)	0.0458***	0.0432***	0.0510***
	(0.0099)	(0.0153)	(0.0153)
EDU	-1.3698**	-1.6424	1.2032
	(0.6693)	(1.0416)	(1.0438)
TP	-4.8832***	-2.3726*	-6.8437***
	(0.9189)	(1.4255)	(1.4271)
FDI	0.0254	0.0235	0.0027
	(0.0258)	(0.0400)	(0.0400)
UL	0.0486*	0.0796**	0.3481***
	(0.0256)	(0.0397)	(0.0397)
Ln(AHM)	0.0483***	0.1060***	0.0288
	(0.0169)	(0.0260)	(0.0260)
Ln(CP)	0.9072***	0.6034***	0.3222***
	(0.0228)	(0.0275)	(0.0281)
PD	-0.2874***	0.0084	1.2051***
	(0.0893)	(0.1391)	(0.1387)
L	-0.1428***		
	(0.0360)		
NAL		-1.0560***	
		(0.0623)	
AL			-3.3844***
			(0.1292)
_cons	0.1837	3.9745***	5.9744***
	(0.2607)	(0.3177)	(0.3320)
Region effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
N	1953	1953	1953
R^2	0.9378	0.8345	0.8597

*Note: Standard errors are reported in parentheses. *, **, and *** indicate significance at two-tailed probability levels of 10%, 5%, and 1%. Refer to Table 1 for variable definitions and PD is population density*

Table 8. Robustness test: Change the measurement of dependent variables

	Model 1	Model 2	Model 3
	Ln(PGDP)	Ln(PWU)	Ln(PWR)
Ln(PHE)	0.1129***	0.0473***	0.0445***
	(0.0356)	(0.0098)	(0.0070)
EDU	-2.8708	-2.5493***	0.0940
	(2.3988)	(0.6649)	(0.4788)
TP	-8.2266**	-2.3720***	-2.6190***
	(3.2957)	(0.9105)	(0.6550)
FDI	-0.3901***	-0.0343	0.0031
	(0.0924)	(0.0255)	(0.0183)
UL	-0.2708***	-0.0365	-0.0946***
	(0.0926)	(0.0256)	(0.0184)
Ln(AHM)	-0.0194	0.0221	-0.0072
	(0.0608)	(0.0167)	(0.0120)
Ln(CP)	0.1439*	0.0907***	0.0772***
	(0.0844)	(0.0180)	(0.0129)
PD	-2.6142***	-0.6807***	0.0089
	(0.4628)	(0.1318)	(0.0886)
L	-0.0577		
	(0.1374)		
NAL		0.0055	
		(0.0439)	
AL			-0.0664
			(0.0593)
_cons	7.9639***	8.6998***	7.3652***
	(0.9616)	(0.2073)	(0.1530)
Region effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
N	1946	1946	1946
R^2	0.6386	0.9471	0.9757

*Note: Standard errors are reported in parentheses. *, **, and *** indicate significance at two-tailed probability levels of 10%, 5%, and 1%. Due to the lack of PWR data in Shenzhen, the samples excluded Shenzhen. Refer to Table 1 for variable definitions. PGDP is GDP per capita, here as LP. PWU is per wage urban, here as NALP. PWR is per wage rural, here as ALP*

Second, we change the measurement ways of the three types of labour productivity to test the robustness of the results. In this paper, the actual per GDP (PGDP) in 2007 is used to replace labour productivity; the per wage urban (PWU) and the per wage rural (PWR) are used to replace non-agricultural labour productivity and agricultural labour productivity respectively. PGDP, PWU, PWR are derived from *China Statistical Yearbook for Regional Economy*. The regression results are shown in Table 8.

Table 8 shows the regression results of PGDP, PWU, PWR representing labour productivity, non-agricultural labour productivity, and agricultural labour productivity, respectively. The empirical results show that public health expenditure is significantly positively correlated with the three types of labour productivity, which is consistent with the basic regression results in Table 6, indicating that the previous analysis in this paper is robust.

Endogenous problems

Endogeneity means that the explanatory variables in the model are correlated with random disturbance term. The main causes of endogeneity include: the missing variables are correlated with other explanatory variables in the model; the explanatory variables interact with the explanatory variables and the measurement errors. After reverse regression, we find that the main explanatory variable PHE in this paper is significantly correlated with LP and ALP, while not significantly correlated with NALP, which suggests that there is endogenity in model 1 and model 3. We will introduce instrumental variables to reduce endogeneity. The selection of the instrumental variable must satisfy: the instrumental variable is correlated with the endogenous variable but not correlated with labour productivity.

Table 9. The results of 2SLS regression

Dependent variable	Ln(PHE)	Ln(LP)	Ln(PHE)	Ln(ALP)
	First stage	Second stage	First stage	Second stage
Ln(BHI)	0.4355***			
	(0.0350)			
$Ln(PHE)_{t-1}$			0.7900***	
			(0.0186)	
Ln(PHE)		0.2717***		0.1029*
		(0.0527)		(0.0563)
EDU	-13.4164***	4.1056***	1.9254**	-10.6577***
	(1.5636)	(1.4168)	(0.9615)	(3.0310)
TP	-1.7987	-0.4554	-0.4022	-12.2891***
	(1.7693)	(1.3746)	(1.1467)	(2.8947)
FDI	0.2175**	-0.2459***	0.0693*	0.0516
	(0.0889)	(0.0592)	(0.0383)	(0.1231)
UL	0.7245***	0.0993	0.1867***	0.3771***
	(0.0731)	(0.0685)	(0.0520)	(0.1179)
Ln(AHM)	0.1965***	-0.0793***	0.0478***	0.1101***
	(0.0178)	(0.0176)	(0.0112)	(0.0388)
Ln(CP)	0.0926***	0.7905***	0.0373***	0.0995***
	(0.0224)	(0.0188)	(0.0129)	(0.0303)
L	0.4112***	-0.0566	0.0495	-3.4411***
	(0.0493)	(0.0407)	(0.0791)	(0.1974)
_cons	2.6462***	0.3117*	0.9029***	8.7566***
	(0.2015)	(0.1769)	(0.1421)	(0.3185)
Region effect	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes
N	1953	1953	1674	1674
R^2	0.7304	0.8912	0.8915	0.5849

*Note: Standard errors are reported in parentheses. *, **, and *** indicate significance at two-tailed probability levels of 10%, 5%, and 1%. Refer to Table 1 for variable definitions. BHI is the number of the beds of health institutions per 10,000 persons*

Inspired by Gong *et al*., we select the number of the beds of health institutions per 10,000 persons (BHI) as an instrumental variable for public health expenditure in the model 1, and the lagged public health expenditure as an instrumental variable for public health expenditure in model 3. The reason is that, on the one hand, BHI are not affected by labour productivity; from Table 6, it can be seen that there is no significant correlation between public health expenditure and agricultural labour productivity. On the other hand, the first stage regression results in Table 9 show that BHI and the lagged public health expenditure are significantly correlated with public health expenditure at 1% statistical level.

Before the regression with the instrumental variable, we test the instrumental variables. First, the P value of hausman test is 0.0000, which strongly rejects the original hypothesis that all explanatory variables are exogenous in model 1 and model 3, suggesting that PHE is an endogenous variable. Second, the test of the weak instrumental variables show that the minimum eigenvalues in model 1 and model 3 are larger than the corresponding critical values. Besides, the F statistic of the first stage regression in model 1 is much larger than 10 and the P value is 0, indicating that there is no weak instrumental variable problem. In summary, we believe that the selection of the instrumental variables in this paper is appropriate. The regression results using instrumental variables with two stage least squares (2SLS) are shown in Table 9.

The results of the first stage show that the instrumental variables are significantly correlated with the endogenous variable PHE. The regression results of the second stage show that PHE is significantly positively correlated with LP and NALP, which is consistent with the basic regression results in Table 6.

Further discussion

The test on the relationship between public health expenditure and labour productivity in different region

The previous empirical results show that public health expenditure is significantly positively correlated with the three types of labour productivity. In different cases, the correlation degree between public health expenditure and labour productivity may be different. Here are regression analysis on the eastern cities, the central cities and the western cities, and the results are shown in Table 10.

According to the results in Table 10, PHE has a significant impact on promoting LP and NALP in the eastern region, while a negative impact on ALP. As found by Gong *et al*., (2012), health investment has a positive impact on economic growth by increasing labour productivity, but may squeeze out physical capital investment and thus have a negative impact on economic growth. The empirical study in this

Table 10. The result of regression: Based on eastern, central and western cities

	Model 1			Model 2			Model 3		
	East	Mid	West	East	Mid	West	East	Mid	west
Ln(PHE)	0.0268*	0.0077	0.0735***	0.0410*	0.0223	0.0417	-0.0164	0.0569**	0.0924***
	(0.0150)	(0.0169)	(0.0180)	(0.0243)	(0.0233)	(0.0273)	(0.0250)	(0.0268)	(0.0269)
EDU	-1.1895	-0.3257	-1.8586	-4.3344**	0.2345	0.3811	11.2859***	1.1654	0.8199
	(1.0807)	(1.2181)	(1.1575)	(1.8070)	(1.6881)	(1.7337)	(1.8282)	(1.9766)	(1.7036)
TP	-8.5659***	5.9092***	4.6934	-7.6325***	7.9189***	12.2125***	-13.5573***	-6.7833***	7.9777*
	(1.5140)	(1.3413)	(2.9683)	(2.4655)	(1.8563)	(4.5038)	(2.5578)	(2.1644)	(4.4709)
FDI	0.0124	-0.0377	0.1367*	0.0315	-0.0818	0.0488	-0.0264	-0.0717	0.0749
	(0.0290)	(0.0658)	(0.0702)	(0.0472)	(0.0908)	(0.1067)	(0.0487)	(0.1059)	(0.1048)
UL	-0.0336	0.1127**	0.1726***	-0.0318	0.0305	0.2346***	0.1904***	0.3548***	0.5059***
	(0.0351)	(0.0453)	(0.0511)	(0.0569)	(0.0625)	(0.0777)	(0.0588)	(0.0714)	(0.0767)
Ln(AHM)	0.0985***	-0.0234	0.0229	0.2895***	-0.0553*	0.1919***	0.0741	0.0639*	-0.0770
	(0.0369)	(0.0218)	(0.0379)	(0.0575)	(0.0302)	(0.0559)	(0.0603)	(0.0351)	(0.0550)
Ln(CP)	0.9101***	0.8552***	0.8659***	0.5600***	0.5781***	0.2204***	0.0103	0.5030***	0.1945***
	(0.0497)	(0.0429)	(0.0662)	(0.0519)	(0.0415)	(0.0556)	(0.0464)	(0.0540)	(0.0487)
L	-0.1235***	-0.1020	-0.2657*						
	(0.0471)	(0.1356)	(0.1372)						
NAL				-0.7082***	-1.5833***	-2.8690***			
				(0.0680)	(0.1787)	(0.1702)			
AL							-4.3557***	-3.8927***	-3.0225***
							(0.2480)	(0.3029)	(0.1854)
_cons	0.2219	1.0285**	0.3628	4.0905***	4.8105***	7.9213***	9.9651***	4.0357***	7.1408***
	(0.5606)	(0.5169)	(0.7484)	(0.6161)	(0.4870)	(0.6489)	(0.5624)	(0.6354)	(0.5790)
Time effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	826	581	546	826	581	546	826	581	546
R^2	0.9288	0.9604	0.9459	0.7958	0.9138	0.8637	0.8450	0.9044	0.8645

*Note: Standard errors are reported in parentheses. *, **, and *** indicate significance at two-tailed probability levels of 10%, 5%, and 1%. Refer to Table 1 for variable definitions*

paper also shows that there may be too many health investments in the eastern region that cause the squeezing impact on physical capital, especially in rural areas, which has a negative impact on agricultural labour productivity.

In the central and the western region, PHE is significantly positive correlated with ALP at 5% level and 1% level respectively, and the coefficients are larger than NALP, indicating that PHE has a greater impact on labour productivity in rural areas with poor socioeconomic status in the central and the western region, this may be due to the underlying differences in brain cognition. The coefficient between PHE and NALP in the central and the western region is positive but not significant and the value is small. This may be due to the fact that, on the one hand, the production of non-rural areas is not highly dependent on the health of the workers; on the other hand, in non-rural areas, the awareness and ability to buy commercial insurance is stronger than those in rural areas, so the health of the residents depends less on the government's investment in public health.

The test on the relationship between public health expenditure and labour productivity in provincial capitals, non-provincial capital cities

Because of the large difference in the industrial structure and the economic gap between provincial capitals, non-provincial capital cities in China, it is very common that a large population migrate from rural or third-tier cities to provincial capitals or first-tier cities. Table 11 shows the results of the regression results of provincial capitals and non-provincial capitals.

From Table 11, we find that for provincial capitals, the coefficients between PHE and LP, NALP are positive but not significant. The coefficient between PHE and ALP is 0.14, the largest in the three types of labour productivity and significant at 1% level, indicating that public health expenditure has a greater impact on labour productivity in rural areas where economic conditions are poor. Interestingly, the regression results of non-provincial capitals are different from that of provincial capitals, that is, the PHE of non-provincial capital cities is significantly positively correlated with LP and NALP while it is positively correlated with ALP but not significantly, which may be due to: first, the public health investment via cognitive function affect output is not effectively implemented in rural areas of non-provincial capital cities, leading to that the impact of public health expenditure on non-provincial agricultural labour productivity is not significant; second, Yao *et al.*, (2001) argue that human capital, public infrastructure, policies and openness have a significant impact on economic growth. Thus, we believe that agricultural labour productivity in non-provincial

Table 11. The result of regression: Based on capital cities and non-capital cities

	Model 1		Model 2		Model 3	
	provincial capitals	non-capital cities	provincial capitals	non-capital cities	provincial capitals	non-capital cities
Ln(PHE)	0.0396	0.0485***	0.0493	0.0359**	0.1432***	0.0090
	(0.0298)	(0.0108)	(0.0348)	(0.0169)	(0.0492)	(0.0170)
EDU	2.9377	-2.0077***	5.6483*	-2.6181**	3.7178	1.9427*
	(2.4713)	(0.6970)	(2.8951)	(1.0962)	(4.1220)	(1.0984)
TP	-3.3887	-5.2943***	-0.9588	-2.3375	-2.4215	-5.6517***
	(2.5396)	(0.9745)	(2.9907)	(1.5259)	(4.1742)	(1.5295)
FDI	0.1174*	0.0136	0.0678	0.0392	-0.0614	0.0148
	(0.0639)	(0.0286)	(0.0758)	(0.0448)	(0.1075)	(0.0449)
UL	0.0994	0.0310	0.1900**	0.0380	0.2098*	0.4023***
	(0.0647)	(0.0282)	(0.0765)	(0.0442)	(0.1075)	(0.0443)
Ln(AHM)	0.2743***	0.0405**	0.3107***	0.0834***	0.1828*	-0.0300
	(0.0592)	(0.0177)	(0.0707)	(0.0275)	(0.0931)	(0.0276)
Ln(CP)	0.7640***	0.9186***	0.2790***	0.6632***	0.1927***	0.2967***
	(0.0705)	(0.0248)	(0.0524)	(0.0306)	(0.0713)	(0.0315)
L	-0.5913***	-0.1394***				
	(0.1591)	(0.0375)				
NAL			-1.4638***	-1.0163***		
			(0.1739)	(0.0658)		
AL					-4.9773***	-3.4180***
					(0.6464)	(0.1364)
_cons	1.3172	0.0858	7.2267***	3.4469***	6.3342***	6.7474***
	(0.8340)	(0.2838)	(0.6442)	(0.3523)	(0.9048)	(0.3689)
Region effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
N	203	1750	203	1750	203	1750
R^2	0.9402	0.9383	0.8811	0.8358	0.8249	0.8591

*Note: Standard errors are reported in parentheses. *, **, and *** indicate significance at two-tailed probability levels of 10%, 5%, and 1%. Beijing, Tianjin, Shanghai, Chongqing are included in provincial capital cities. Refer to Table 1 for variable definitions*

capital cities are also affected by other important factors (transport infrastructure, medical infrastructure, openness, etc.). The lack of these important factors limits the role of public health expenditure, so its impact on the agricultural labour productivity of non-provincial capital cities is not significant.

Conclusions

In this paper, through theoretical model and empirical study, we choose panel data of prefecture-level cities in China in 2007-2013 to analyze the relationship between public health expenditure and labour productivity based on the science on brain cognition in China, and discuss the impact on non-agricultural labour productivity and agricultural labour productivity respectively. We find that public health expenditure is significantly positively correlated with the three types of labour productivity. Being lagged, public health expenditure is still significantly positively correlated with labour productivity and non-agricultural labour productivity while is positively correlated with agricultural labour productivity but not significantly, suggesting that China's current public health expenditure can promote labour productivity and to certain degree plays a lagging role in promoting labour productivity. Through further analysis, it is found that public health expenditure has a greater impact on rural areas with poor economic conditions than non-rural areas with better economic conditions. In addition, we find that public health expenditure is negatively correlated with agricultural productivity in the eastern region, which may indicate that excessive health investment in the eastern region squeezes out physical capital investment in rural areas. Finally, we note that the agricultural labour productivity in non-provincial capitals is positively correlated with public health expenditure but not significantly. It is probably because of the lack of the infrastructure in non-provincial capitals, leading to the fact that public health expenditure cannot function properly.

From the above conclusions, the following inspiration are obtained in this paper: first, generally speaking, the impact of public health expenditure on labour productivity is positive in China. However, there are still a large number of people fall poor or dead because of illness. We shall continue to improve the social security system, and increase the proportion of public health expenditure accounting for the total health expenditure, so as to reduce the pressure on people's livelihood, which may help build a harmonious society on the one hand and also improve labour productivity and increase social output on the other hand. Second, we should pay attention to the construction of infrastructure, especially medical supporting infrastructure in non-provincial capital cities, reduce the gap of people's cognitive function between regions, so that public health expenditure can be made most uses of, thereby narrowing the gap of health level among various areas. Finally, excessive health investment in the eastern region has a negative impact on its agricultural labour productivity, suggesting that we should focus on the efficiency of public health expenditure and avoid wasting resources.

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