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The Relationships between Research and Development (R&D) Investment and Regional Economic Growth

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ABSTRACT The impact of R&D investment on economic growth has become a hot study in the economic geography and economics, and most of researchers observed that R&D investment has a significant impact on regional growth, and the positive correlation confirmed, however, the evaluation of R&D investment and spatial differences remain to be further studied. This paper is based on the model of Cobb-Douglas production function. With the help of the panel data of 110 cities between 1990-2013, the researchers build the relationship model of R&D investment and regional growth. The results show the long-term and stable relationship of R&D investment and regional economic growth. R&D talent plays more role in the process of regional economic growth, and the impact of R&D investment on regional economic growth show that there exists large differences in sample regions.

INTRODUCTION

More and more studies have shown that economic growth is the result of the interaction among the production, distribution and use of knowledge, which is not limited to the internal economy, but the knowledge flows across economies also play an important role (Zucker et al. 2007; Harris 2001; Vaz and Nijkamp 2009; Ibert 2007; Antonelli et al. 2011; Huggins and Thompson 2017). It is generally believed that the knowledge encompasses areas and linkages centered on activities and resources (Romer 2007). Many scholars believe that the keys to economic growth are material capital and labor supply (Andersson and Karlsson 2007), but according to the model of endogenous growth proposed firstly by Romer (1990) argued that the firm will organize R&D activities to make a profit, from which knowledge can be accumulated and which could promote long-term economic growth. As the antithesis of traditional growth theory emphasis on material capital accumulation, endogenous growth theory further emphasizes the importance of knowledge, which can increase the productivity and economic development (Huggins and Thompson 2015). The model of endogenous growth has been considered to better explain the fundamental elements of economic development by most of the theorists who majored in economics, the knowledge stocks in the form of human capital or R&D activities promote regional economic growth, which is the basic assumption of endogenous economic growth theory (Huggins and Thompson 2014). Innovation is the sustained source of economic growth, and the R&D activity is an important form of innovation, so it is of great significance to explore the relationship between economic growth and R&D investment (Zong and Gao 2017).

The relationships between R&D investment and economic growth has become a priority in the field of geography, management and economics (Bergenholtz and Waldstrøm 2011), and it could be observed through the existed research that the correlation of R&D investment and economic growth is positive. With the help of data gathered from ten major countries in OECD, Charles (1998) argues that R&D investment play an important role in promoting the growth of total factor productivity. Sterlacchini (2008) takes the European countries as a case, probes into the impact of R&D expenditure and education investment on regional economic growth, and

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the results show that the intensity of R&D investment and the proportion of the adult population educated higher are the key factors of economic growth but the correlation of R&D expenditure investment and regional economic growth only appears in the northern areas of the European countries. From the perspective of firms in the process of regional growth, the stock of regional knowledge represented by R&D expenditure investment and the absorption capacity of enterprises represented by R&D personnel investment, presents and determines the quality of regional economic growth (Fitjar and Rodrý´guez-Pose 2015). Based on the case study of China, R&D investment is also the important force of the regional economic growth, and presents a positive correlation (Dang and Zhang 2011; Cao et al. 2016; Hu et al. 2017). R&D investment has different effects on the eastern, central and western regions in China (Fan et al. 2013). Taking the Yangtze River Delta in China as a case, the innovation investment has an important impact on regional development, and the internal spatial difference is gradually reduced (Wang and Sun 2017). However, there are still some disadvantages in this present research, such as R&D expenditure on behalf of R&D investment, the case region chosen lack city space scale, and this research does not delve into the specific relationship between R&D investment and regional growth.

The key objectives of this paper is to solve three questions, firstly, how R&D expenditure and personnel investment will bring regional economic growth, so as to determine which one is more important to regional economic growth, money and talent (person with ability)? Secondly, to observe whether the impact of R&D investment on regional growth is short-term or long-term. Thirdly, to examine why the impact of R&D investment on regional growth seems to be different among the sample regions. R&D expenditure and personnel investment will represent R&D investment, the researchers analyzed the impact of R&D investment on regional economic growth with the help of the panel data of 110 cities Yangtze River Economic Zone (YREZ) between 1990-2013.

The remaining part of the paper is structured as follows: Section 2 provides the characteristics of economic development in YREZ; Section 3 introduces the methods and shows the data source; Section 4 is an empirical analysis, which contains the impact of R&D expenditure investment and R&D personnel on regional growth, the spatial differences, and the short-term volatility of R&D investment on regional growth; and Section 5 highlights some concluding comments and remarks.

The Characteristics of Economic Development in Yangtze River Economic Zone

There are huge differences in economic development rates among the cities in the YREZ, and the cities are in different stages of industrialization. The YREZ contains three regions, the western region (Chongqing, Sichuan, Yunnan and Guizhou), the middle region (Jiangxi, Hubei, Anhui and Hunan) and the eastern region (Shanghai, Jiangsu, and Zhejiang). According to Chenery who is an American economist, the industrialization stage can be divided into six, the 110 cities of the Yangtze River Economic Zone are in the six different stages of industrialization, and the eastern region has entered the late industrialization, but the western region is still at the initial level of industrialization. Figure 1 shows the spatial differentiation of per capita GDP of the YREZ in 2013.

Table 1 shows the comparison of R&D investment between the YREZ and China in 2013. The proportion for GDP of the YREZ in China is 45.6 percent, R&D expenditure is 45.5 percent, R&D personnel is 44.2 percent. The proportion of R&D expenditure of theYREZ in GDP is the same as China, but there are vast differences in the intensity of R&D investment among the YREZ.

Generally speaking, the development level and the intensity of R&D investment of the YREZ is higher than those of the other regions in China, but there are vast differences in the YREZ, because the city is more conducive to observe the innovation phenomenon (Zeng and Cao 2015), so this paper takes 110 cities in the Yangtze River Economic Zone as an example, and there is a very strong typicality in discussing the influence of R&D investment on regional growth.

METHODOLOGY

Methods

Model and Variable

There are many factors which will influence regional economic growth, and the relationship

Table 1: The comparison of R&D investment between the Yangtze River economic zone and China in 2013

Region	*GDP (billion dollar)*	*R&D expenditure (billion dollar)*	*R&D personnel (thousand people year)*	*The proportion of R&D expenditure in GDP(%)*
Shanghai	348	12	16.6	3.4
Jiangsu	954	23	36.5	2.4
Zhejiang	606	21	26.3	3.5
Anhui	307	6	9.6	1.8
Jiangxi	231	2	5.7	0.9
Hunan	395	5	10.3	1.3
Hubei	398	7	13.3	1.8
Sichuan	424	6	14.9	1.5
Chongqing	204	3	5.5	1.5
Yunnan	189	1	2.9	0.6
Guizhou	129	1	1.9	0.6
the YREZ	4186	87	143.6	2.1
China	9175	192	324.7	2.1
The proportion of the YREZ in China (percent)	45.6	45.5	44.2	

of these factors and regional growth has always been the focus of theorists, especially the relationships between regional growth and R&D investment. Cobb-Douglas production function employed to research this relationship.

$$Y=AK^{\alpha}L^{\beta} \tag{1}$$

Where Y is total output; A is the factor exclude labor and capital; L and K represent labor and capital investment; α and β is the output elasticity of capital and labor investment. This

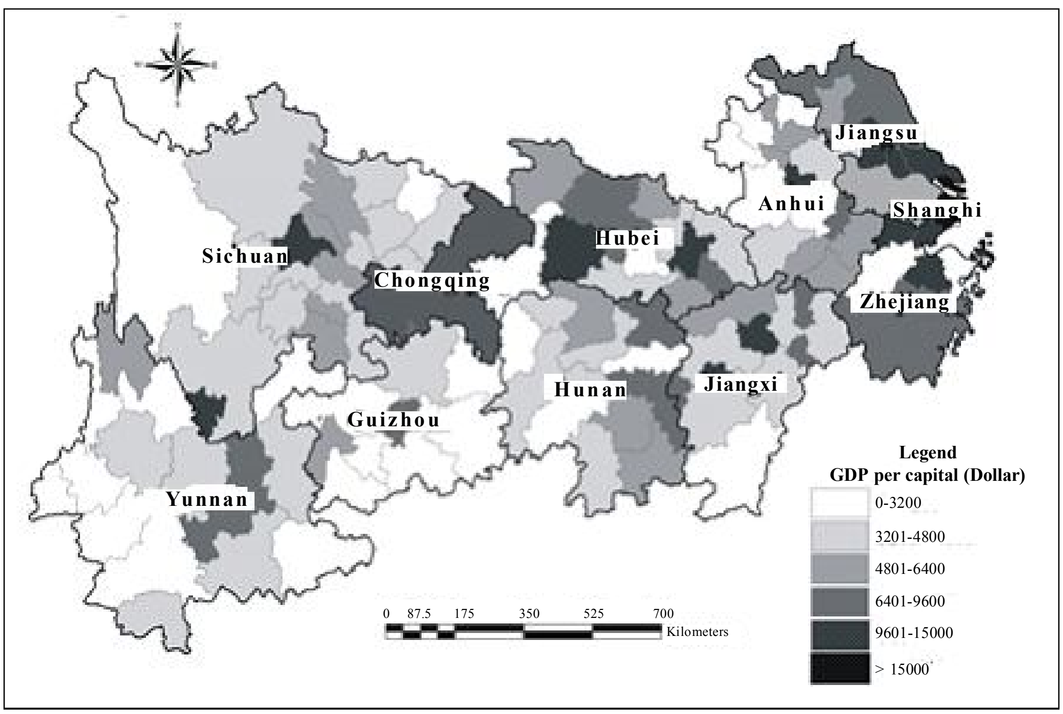

Fig. 1. The spatial differentiation of per capita GDP of the Yangtze River Economic Zone in 2013

paper discusses the impact of R&D investment on regional growth, but we cannot ignore capital, labor, and other many factors, so we can separate R&D investment from A.

$$Y=AL^{\alpha} L^{\beta} R^{\theta} \quad (2)$$

Where R is the factor of R&D investment, which contains R&D expenditure and R&D personnel investment. Take logarithm on both sides of the equation (2).

$$InY=InA+\alpha InK+\beta InL+\theta InR \quad (3)$$

In order to analyze the panel data of 110 cities, so the researchers could correct and build panel data model which is established based on equation (3).

$$InY_{it}=C_i+\alpha InK_{it}+\beta i InL_{it}+\theta IR_{it}+u_{it} \quad (4)$$

According to word equation 4 *i* is the individual of cross section (i=1,2,3,...,110) *t* is time; c is intercept; μ is random error; R is R&D investment, which contains R&D expenditure (M) and R&D personnel investment (P); α, β and θ is the elasticity of factor investment. Based on equation (4), Eviews 7.2 is used for the test of Hausman and F, which help us to build the fixed effect variable coefficient model. According to word equation (6) and (7)

$$InY_{it}=C+C_{it}\ \alpha_t InK_{it}+\beta_i InL_{it}+\theta_i InR_{it} + u_{it} \quad (5)$$

Where $(c+c_i)$ as the degree of impact on regional economic growth excludes R&D investment, capital and labor investment, the more $(c+c_i)$, the more impact on the other factors (excluding R&D investment, capital and labor investment) on regional economic growth; c_i is the difference of 110 cities of YREZ.

Equation (5) mainly reveals a long-term equilibrium correlation of regional growth and R&D investment, but not the short-term, so this paper uses the residual error sequence (ECM_{it}) which comes from Equation (5), and build PVECM model.

$$\Delta InY_{it}=\lambda_{1i} ECM_{i,t-1}+\delta_{1i}\ \Delta InM_{it}+\mu_{1it} \quad (6)$$

$$\Delta InY_{it}=\lambda_{2i} ECM_{i,t-1}+\delta_{2i}\ \Delta InP_{it}+\mu_{2it} \quad (7)$$

Where Δ is the first order differential that reveals the impact of short-term, λ_{1t} and λ_{1t} is the coefficient of error correction, if the null hypothesis of equal to zero is refused, the mechanism of error correction will work, and the long-term equilibrium is reliable, by comparison, the short-term relationship is unreliable. If the null hypothesis S_{1i} and S_{2i} equal to zero is rejected, the short-term impact will exist among the variables, but the opposite is not.

Where total output (Y) is measured by GDP; Labor (L) and capital (K) investment are measured by employed population and fixed-asset investment; R&D expenditure (M) and R&D personnel investment (P) are measured by R&D interior expenditure and the full-time R&D personnel. Table 2 which shows the descriptive statistics of five variables.

Table 2: The descriptive statistics of variable

Variable	*Max*	*Min*	*Mean*	*SD*
lnY	9.9	0.9	5.9	1.8
lnK	9.3	-1.4	5.0	2.4
lnL	6.3	1.8	3.5	0.8
lnM	6.6	-6.9	0.7	2.4
lnP	2.8	-6.1	-1.4	1.6

Unit Root Test

The purpose of unit root test is to ensure the validity of parameter estimation, and to avoid false regression. With the help of Eviews 7.2, the researchers can choose Breitung, IPS, Fisher-ADF, LLC, Fisher-PP, which can be used for testing the panel data of 110 cities in YREZ between 1990-2013. The results show that unit root existed in the original data. However, the unit root of the first order differential is smooth and steady, which is showed in Table 3.

Cointegration Test

The results of unit root test show that LnY, LnK, LnL, LnM and LnP are the single integer variables, the purpose of cointegration test is to determine whether the relationship between each variable and LnY is long-term cointegration or not. The null hypothesis states that the relationship between each variable and LnY is not long-term cointegration. The results of Pedroni test and Kao test show that the relationship among the variables is long-term stable (Table 4).

Data Source

The major source of data was different kinds of statistics yearbooks. The data were collected in 2015, which contain China statistics yearbook (1991-2014), the statistics yearbooks of 110 cities between 1991-2014 in YREZ, China cities statistics yearbook (1991-2013), China science and technology statistical yearbook (1991-2013), and the first and second R&D resources inventory communiqué of China and province. There is some data from scientific papers and the government website. Furthermore, the researchers estimated that there was some missing data when average of before and after was taken.

Table 3: The results of pool data unit root test

Variables	*Breitung*	*IPS*	*LLC*	*Fisher-ADF*	*Fisher-PP*	*Results*
LnY	8.1 (1.0)	-65.0 (0.0***)	-378.7(0.0***)	401.2 (0.0***)	552.9 (0.0***)	Steady
LnK	7.3 (1.0)	3.2 (0.9)	-29.8(0.0***)	67.8 (1.0)	114.3 (1.0)	Unsteady
LnL	2.5 (0.9)	-30.3 (0.0***)	-136.3(0.0***)	669.8 (0.0***)	989.9 (0.0***)	Steady
LnM	9.6 (1.0)	2.7 (0.9)	-85.9(0.0***)	72.5 (1.0)	77.8 (1.0)	Unsteady
LnP	16.1 (1.0)	5.8 (1.0)	-29.4(0.0***)	56.2 (1.0)	60.9 (1.0)	Unsteady
ΔLnY			-356.2(0.0***)	454.2 (0.0***)	563.2 (0.0***)	Steady
LnK			-37.2(0.0***)	575.9 (0.0***)	735.1 (0.0***)	Steady
LnL			-119.4(0.0***)	809.4 (0.0***)	970.8 (0.0***)	Steady
LnM			-49.6(0.0***)	434.2 (0.0***)	477.1 (0.0***)	Steady
LnP			-17.3(0.0***)	461.2 (0.0***)	472.5 (0.0***)	Steady

*Significant at the 0.1 level; **Significant at the 0.05 level; ***Significant at the 0.01 level

Table 4: The results of pool data cointegration test

Test methods	*Statistics*	*lnY and lnK*	*lnY and lnL*	*LnY and lnM*	*lnY and lnP*
Pedroni	Panel v-Statistic	-2.7 (0.9)	-1.5 (0.9)	-2.2 (0.9)	4.2 (0.0***)
	Panel rho-Statistic	-2.4 (0.0***)	-2.9 (0.0***)	-2.9 (0.0***)	-0.5 (0.3)
	Panel PP-Statistic	-25.1 (0.0***)	-11.0 (0.0***)	-20.2 (0.0***)	-8.4 (0.0***)
	Panel ADF-Statistic	-16.3 (0.0***)	-4.4 (0.0***)	-29.2 (0.0***)	-28.6 (0.0***)
	Group rho-Statistic	2.6 (0.9)	5.3 (1.0)	3.1 (0.9)	5.3 (1.0)
	Group PP-Statistic	-34.6 (0.0***)	-13.1 (0.0***)	-18.6 (0.0***)	-8.0 (0.0***)
	Group ADF-Statistic	-174.4 (0.0***)	-10.3 (0.0***)	-62.5 (0.0***)	-142.1 (0.0***)
Kao	ADF	-18.7 (0.0***)	-2.9 (0.0***)	-17.9 (0.0***)	-19.1 (0.0***)

The estimate results of the fixed effect variable coefficient model by the statistical software of Eviews7.2 is showed in Tables 5 and 6. The average intercept (-1.8, -9.1) and the average correlation coefficient (0.6, 2.4) of capital investment and labor investment show that the influence of capital investment and labor investment on regional growth is significant.

R&D Expenditure Investment and Regional Economic Growth

Equation (8) is the estimation equation between R&D expenditure investment (lnM) and regional economic growth (lnY).

According to word quation (8)

$$InY=5.4+C_i+\alpha INK+\beta INL+\theta InM \quad (8)$$

Where R^2=0.9, F-statistic=40.0, Prob (F-statistic)=0.0, DW=3.1. So the Equation (8) fitted very well, and is not autoregressive. Table 5 is the result of t test, and the result is significant under confidence level of one percent, which shows that the influence of R&D expenditure investment is significant.

From the result of parameter estimation of the model between lnY and lnM we can deduce the following (Table 5); Firstly, the influence of the other factors (excluding R&D personnel, capital and labor) on regional growth in the developed regions is less than the impact in the undeveloped regions. Such as the intercepting of Guangan, Bijie, and Puer (undeveloped regions) which is more than Shanghai, Nanjing, Hangzhou, Chongqing, Wuhan (developed regions); Secondly, the higher the economic growth rate in the regions, the more influence of R&D expenditure investment on regional growth in the regions, which have the higher elasticity coefficient of R&D expenditure, such as Nanchong, Yaan, Suzhou (in Anhui province), Dazhou, Bazhong, Shangrao, Zhaotong and so on, where the elasticity of R&D expenditure investment is more than 1.5, because the economic growth rate is upto 23.9 percent in Nanchong between 1990-2013, but the R&D expenditure investment growth rate is only upto 9.9 percent, so the influence of R&D expenditure investment on regional growth in Nanchong is more significant than the other regions. In the same way, the regions which have the lower elasticity coefficient, such as Changde, Quzhou, Deyang, Tongling, Huzhou and so on, where the elasticity coefficient is less than 0.7, because the rate of R&D expenditure investment growth rate is up to 23.9 percent in Changde between 1990-2013, but the economic growth rate is only up to 14.8 percent, so the influence of R&D expenditure

Table 5: The estimate results of variable coefficient model between lnY and lnM

Cities	*Intercept* C_i	*lnM* *coeffi-cient*	*lnM* *t*	*Cities*	*Intercept* C_i	*lnM* *coeffi-cient*	*lnM* *t<P*	*Cities*	*Intercept* C_i	*lnM* *coeffi-cient*	*lnM* *t*
Shanghai	-0.5	0.8	6.4***	Luan	0.5	0.9	9.7***	Huanggang	0.7	1.2	8.8***
Nanjing	-1.5	1.0	7.3***	Bozhou	1.1	1.5	7.7***	Xianning	-0.7	1.3	9.2***
Wuxi	-1.0	0.9	7.2***	Chizhou	0.7	0.7	8.0***	Suizhou	0.6	1.2	8.7***
Xuzhou	-0.3	0.8	6.9***	Xuancheng	-0.6	1.1	8.2***	Chengdu	-1.9	1.1	7.4***
Changzhou	-1.2	1.0	7.2***	Nanchang	-1.6	1.0	7.5***	Zigong	-0.4	1.3	6.4***
Suzhou	-0.2	0.8	7.8***	Jingdezhen	-1.2	0.9	6.8***	Panzhihua	-0.5	1.0	7.1***
Nantong	-0.1	0.7	6.9***	Pingxiang	-0.6	1.1	7.7***	Luzhou	0.0	0.9	6.6***
Lianyugang	-0.2	0.8	6.7***	Jiujiang	0.4	1.0	7.1***	Deyang	-0.3	0.6	6.1***
Huaian	0.1	0.8	7.1***	Xinyu	-2.0	1.1	8.2***	Mianyang	-2.5	1.0	6.1***
Yancheng	0.3	0.8	6.6***	Yingtan	-1.2	1.1	7.7***	Guangyuan	1.2	0.8	5.8***
Yangzhou	-0.5	0.8	5.9***	Ganzhou	0.4	1.4	9.9***	Suining	0.5	1.1	6.3***
Zhenjiang	-1.1	0.9	7.1***	Jian	-0.1	1.4	9.8***	Neijiang	0.6	0.8	5.6***
Taizhou	-0.6	0.8	7.4***	Yichun	1.1	1.3	9.1***	Leshan	0.4	1.0	5.6***
Suqian	0.3	0.8	7.6***	Fuzhou	0.5	1.1	8.3***	Nanchong	1.1	2.4	9.5***
Hangzhou	-0.9	0.8	7.2***	Shangrao	1.5	1.6	11.2**	Meishan	0.8	1.2	8.5***
Ningbo	0.0	0.7	7.2***	Changsha	-1.4	1.0	8.3***	Yibin	-0.4	0.9	8.8***
Wenzhou	-0.2	0.8	7.1***	Zhuzhou	-0.8	0.9	6.7***	Guangan	2.8	1.5	8.5***
Jiaxing	-0.4	0.7	6.8***	Xiangtan	-0.7	0.8	6.7***	Dazhou	1.8	1.8	9.9***
Huzhou	-0.2	0.7	6.4***	Hengyang	0.4	0.7	6.5***	Yaan	0.5	1.9	8.3***
Shaoxing	-0.7	0.9	7.1***	Shaoyang	0.5	0.9	5.8***	Bazhong	1.7	1.6	8.1***
Jinhua	-0.5	0.8	6.9***	Yueyang	-0.2	0.7	6.7***	Ziyang	0.2	1.4	8.7***
Quzhou	0.5	0.6	6.5***	Changed	0.5	0.6	6.2***	Chongqing	-0.7	1.0	7.7***
Zhoushan	-0.2	0.7	7.0***	Zhangjiajie	2.2	1.1	6.6***	Kunming	-0.9	1.0	6.6***
Taizhou	-0.8	0.9	6.9***	Yiyang	0.2	0.9	8.8***	Qujing	1.2	0.8	8.1***
Lishui	0.2	1.1	9.7***	Chenzhou	0.0	1.1	9.4***	Yuxi	0.3	0.8	6.6***
Hefei	-2.1	1.2	8.5***	Yongzhou	1.0	1.0	8.6***	Baoshan	1.8	1.1	8.1***
Wuhu	-1.1	1.0	7.9***	Huaihua	0.8	1.4	9.2***	Zhaotong	2.2	1.5	7.7***
Bengbu	-0.3	0.8	6.0***	Loudi	-0.9	1.0	9.1***	Lijiang	1.9	1.0	7.8***
Huainan	-0.7	0.8	6.5***	Wuhan	-1.7	1.0	7.5***	Puer	2.3	1.0	7.8***
Maanshan	-0.3	0.7	7.4***	Huangshi	-0.4	0.9	6.8***	Lincang	1.7	0.7	8.1***
Huaibei	-0.4	0.9	6.3***	Shiyan	-1.9	1.0	7.2***	Guiyang	-1.0	1.0	7.2***
Tongling	-0.8	0.7	7.5***	Yichang	-0.6	1.3	9.1***	Liupanshui	2.2	0.9	7.5***
Anqing	0.1	1.0	6.5***	Xiangyang	-0.7	0.9	6.5***	Zunyi	-0.6	1.3	8.7***
Huangshan	0.1	0.8	6.2***	Ezhou	-0.6	1.0	7.1***	Anshun	-0.8	0.7	7.3***
Chuzhou	0.9	0.7	7.8***	Jinmen	-0.5	1.0	7.1***	Bijie	2.6	0.8	5.8***
Fuyang	0.4	1.5	9.2***	Xiaogan	0.3	1.1	8.1***	Tongren	1.6	1.0	9.1***
Suzhou	1.5	1.9	10.7**	Jinzhou	-1.6	1.2	8.8***				

Table 6: The estimate results of variable coefficient model between lnY and lnP

Cities	*Intercept* C_i	*lnM*		*Cities*	*Intercept* C_i	*lnM*		*Cities*	*Intercept* C_i	*lnM*	
		coeffi-cient	*t*			*coeffi-cient*	*t<P*			*coeffi-cient*	*t*
Shanghai	-6.9	2.7	4.7***	Luan	4.8	3.1	7.9***	Huanggang	-3.8	2.8	7.1***
Nanjing	-3.9	2.0	5.9***	Bozhou	3.6	2.3	6.0***	Xianning	-1.6	2.9	7.3***
Wuxi	-2.5	1.1	5.8***	Chizhou	4.3	2.5	6.5***	Suizhou	-1.5	2.8	7.0***
Xuzhou	-2.0	1.7	5.6***	Xuancheng	-0.1	2.5	6.5***	Chengdu	-4.8	2.3	5.8***
Changzhou	-3.4	2.1	5.8***	Nanchang	-3.8	2.3	6.0***	Zigong	-0.8	2.0	5.1***
Suzhou	-4.5	2.1	6.3***	Jingdezhen	-0.6	2.1	5.4***	Panzhihua	-0.5	2.2	5.6***
Nantong	-3.3	2.0	5.5***	Pingxiang	0.1	2.4	6.1***	Luzhou	-0.5	2.0	5.2***
Lianyugang	-1.7	2.0	5.3***	Jiujiang	0.6	2.2	5.6***	Deyang	-2.3	1.9	4.9***
Huaian	-0.4	2.2	5.6***	Xinyu	-1.2	2.5	6.4***	Mianyang	-3.9	1.8	4.7***
Yancheng	-1.8	2.1	5.3***	Yingtan	0.9	2.4	6.1***	Guangyuan	1.5	1.8	4.6***
Yangzhou	-2.8	1.9	4.7***	Ganzhou	3.1	3.0	7.8***	Suining	1.6	2.0	5.1***
Zhenjiang	-3.7	3.7	5.4***	Jian	3.8	3.0	7.7***	Neijiang	-0.3	1.7	4.4***
Taizhou	-3.1	2.4	5.4***	Yichun	2.7	2.8	7.2***	Leshan	-0.2	1.7	4.5***
Suqian	-0.8	2.0	5.9***	Fuzhou	3.0	2.5	6.5***	Nanchong	3.4	2.9	7.4***
Hangzhou	-3.7	1.8	5.7***	Shangrao	4.7	3.4	8.9***	Meishan	4.1	2.6	6.7***
Ningbo	-3.6	1.8	5.8***	Changsha	-4.7	2.4	6.5***	Yibin	-1.3	2.8	7.1***
Wenzhou	-3.0	2.4	5.8***	Zhuzhou	-2.0	1.8	5.2***	Guangan	5.4	2.6	6.6***
Jiaxing	-2.9	1.7	5.5***	Xiangtan	-2.0	2.4	5.4***	Dazhou	4.8	3.0	7.6***
Huzhou	-2.5	1.7	4.9***	Hengyang	0.0	2.4	5.1***	Yaan	2.1	2.5	6.4***
Shaoxing	-2.4	1.1	5.5***	Shaoyang	0.9	1.9	4.6***	Bazhong	4.9	2.4	6.2***
Jinhua	-2.8	2.1	5.5***	Yueyang	-0.4	2.5	5.5***	Ziyang	2.6	2.7	6.9***
Quzhou	-0.2	2.0	5.2***	Changed	-0.9	2.1	5.0***	Chongqing	-5.8	3.3	6.2***
Zhoushan	-2.0	1.4	5.2***	Zhangjiajie	8.4	2.6	5.3***	Kunming	-2.9	2.0	5.2***
Taizhou	-2.8	1.5	5.4***	Yiyang	4.4	3.7	7.4***	Qujing	2.5	2.5	6.5***
Lishui	2.2	2.9	7.7***	Chenzhou	3.2	3.3	7.7***	Yuxi	0.4	2.1	5.3***
Hefei	-4.4	2.6	6.8***	Yongzhou	5.0	3.4	7.1***	Baoshan	3.5	2.5	6.4***
Wuhu	-2.6	2.4	6.3***	Huaihua	4.3	2.7	7.1***	Zhaotong	2.9	2.3	6.0***
Bengbu	-1.8	1.9	4.8***	Loudi	1.8	2.7	7.2***	Lijiang	5.3	2.4	6.3***
Huainan	-1.2	2.0	5.2***	Wuhan	-2.0	2.4	6.1***	Puer	5.7	2.4	6.3***
Maanshan	0.0	2.3	5.9***	Huangshi	-1.4	2.2	5.5***	Lincang	5.7	2.6	6.6***
Huaibei	-1.3	1.9	5.0***	Shiyan	-2.1	2.3	5.8***	Guiyang	-2.1	2.2	5.7***
Tongling	-1.3	2.3	5.9***	Yichang	-1.3	2.9	7.3***	Liupanshui	3.4	2.3	6.0***
Anqing	0.4	2.0	5.1***	Xiangyang	-2.4	2.1	5.2***	Zunyi	0.6	2.7	6.9***
Huangshan	-0.1	1.9	4.9***	Ezhou	0.0	2.3	5.6***	Anshun	-0.5	2.3	5.9***
Chuzhou	1.3	2.5	6.4***	Jinmen	-1.6	2.3	5.7***	Bijie	4.1	1.8	4.6***
Fuyang	1.5	2.8	7.2***	Xiaogan	-2.9	2.6	6.4***	Tongren	9.7	2.9	7.4***
Suzhou	5.8	3.2	8.3***	Jinzhou	-3.5	2.8	7.1***				

investment on regional growth in Nanchong is less significant than the other regions; Thirdly, the regions which have the medium elasticity coefficient, such as Changzhou, Wuhu, Jiujiang, Kunming, Ezhou, Nanjing and so on, where the elasticity coefficient is between 0.7 and 1.5.

R&D Personnel Investment and Regional Economic Growth

Equation (9) is the estimation equation between R&D personnel investment (lnP) and regional growth (lnY).

According to word equation (9)

$$InY=9.6+C_i+\alpha INK+\beta INL+\theta InP \quad (9)$$

Where R^2=0.9, F-statistic=25.5, Prob (F-statistic)=0.0, DW=2.2. So the Equation (9) fitted very well, and is not autoregressive. Tab.6 is the result of t test, and the result is significant under confidence level of one percent, which shows that the influence of R&D personnel investment is significant.

From the result of parameter estimation of the model between lnP and lnM, we can deduce the following (Table 6); Firstly, the impact of the other factors (excluding R&D expenditure, capital and labor) on regional growth in the developed regions is less than the undeveloped regions. Such as the intercept of Tongren, Suzhou (Anhui province), Zhangjiajie (undeveloped regions) which is more than Shanghai, Nanjing, Hangzhou, Chongqing, Wuhan (developed regions); Secondly, the higher the economic growth rate in the regions, the more influence of R&D personnel investment in the regions, which have the higher elasticity coefficient, such as Zhenjiang, Luan, Suzhou (Anhui province), Chenzhou, Chongqing, Yongzhou, Shangrao, Yiyang and so on, where the elasticity coefficient is more than 3, because the average rate of economic growth is upto 17.2 percent between 1990-2013 in Zhenjiang, but the R&D personnel investment rate is only upto 4.5 percent, so the influence of R&D personnel investment in Zhenjiang is more significant than the other regions. In the same way, the regions which have the lower coefficient elasticity, such as Shaoxing, Wuxi, Zhousan, Taizhou (Zhejiang province), where the elasticity coefficient is less than 1.7, because the R&D personnel investment growth rate is upto 14.2 percent in Shaoxing between 1990-2013, but the economic growth rate is only upto 8.6 percent, so the influence of R&D personnel investment in Shaoxing is less significant than the other regions; Thirdly, the regions which have the medium elasticity coefficient of R&D personnel investment, such as Liupanshui, Bozhou, Nanchang, Zhaotong, Shiyan, Pingxiang, Yingtan, Changsha and so on, the elasticity coefficient is between 1.7 and 3.

In other words, the relationships among R&D expenditure investment, personnel investment and regional growth are significant positive correlation, but the elasticity coefficient of R&D personnel investment (the average of YREZ is 2.3) is higher than R&D expenditure investment (the average of YREZ is 1.0).

The Spatial Differences of R&D Investment on Regional Economic Growth

The spatial differentiation of correlation index between R&D investments (lnM, lnP) on regional growth (lnY) are shown in Figures 2 and 3. As a whole, the middle area of Yangtze River (1.0, 2.5), where the elasticity coefficient of R&D investment is higher than the upper area of Yangtze River (1.1, 2.3), and the elasticity coefficient of R&D investment in the upper area of Yangtze River is higher than the lower area of Yangtze River (0.8, 2.2); There exists huge spatial differences in the R&D investment in the YREZ, and R&D investment in the lower area of Yangtze River is the highest, but the influence of R&D investment in the lower area of Yangtze River is the lowest.

The whole YREZ has different economic development stages, so the influence of R&D investment is different from the difference of economic development in the YREZ. From economic development stages, while the most of regions in the lower area of Yangtze River have been in the late stage of industrialization, most regions in the middle and upper area of Yangtze River are only still in the early or middle stage of industrialization (Zeng and Cao 2015). The development stage is different, so the impact factors of economic growth are also different, and the influence factors of economic growth in the lower area of Yangtze River (the network of regional economic growth) are more complex than the other regions (Lyu et al. 2014).

The Short-Term Volatility of R&D Investment and Regional Economic Growth

The estimated results of PVECM model (6) between R&D expenditure investment (lnM) and

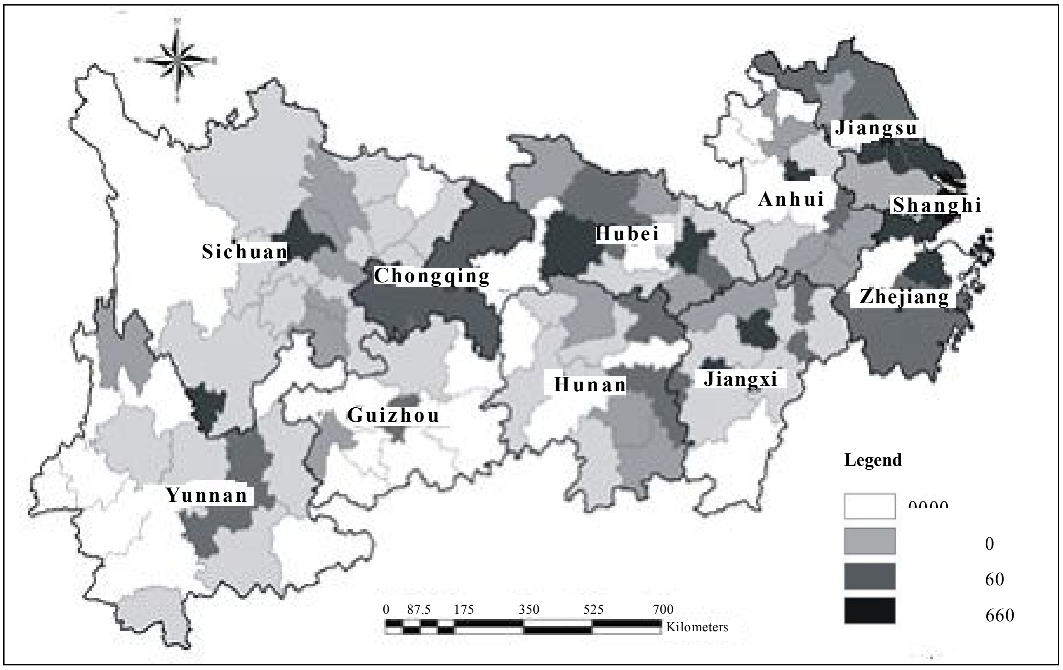

Fig. 2. The spatial differentiation of correlation index between lnM and lnY

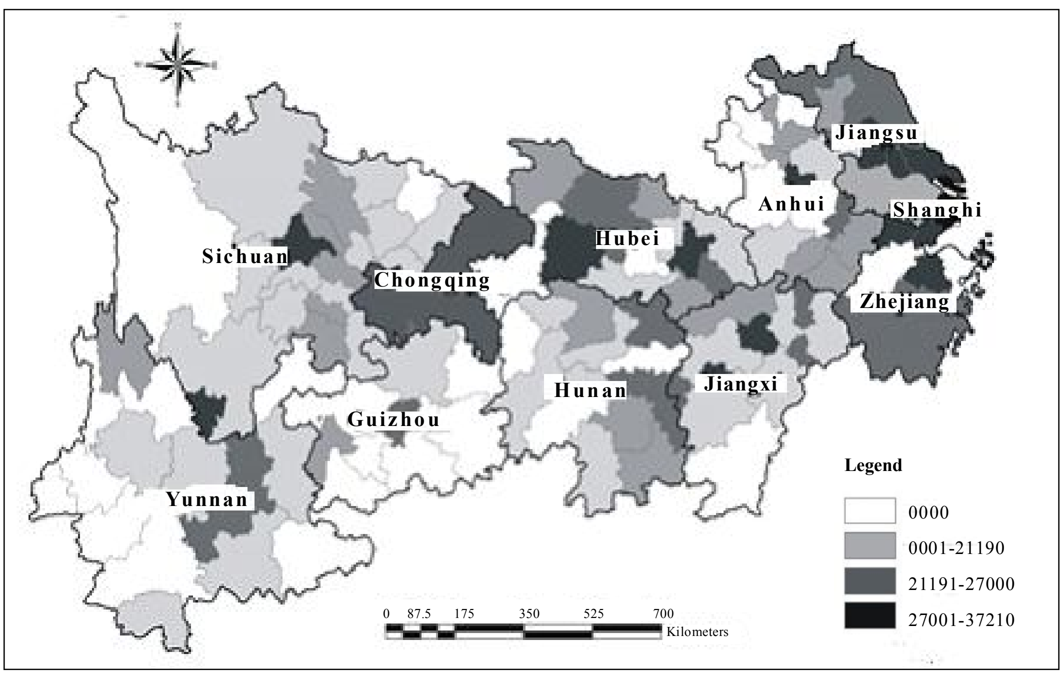

Fig. 3. The spatial differentiation of correlation index between lnP and lnY

Table 6: The estimate results of variable coefficient model between lnY and lnP

Cities	*Intercept*	*lnM*		*Cities*	*Intercept*	*lnM*		*Cities*	*Intercept*	*lnM*	
		coeffi-cient	*t*			*coeffi-cient*	*t<P*			*coeffi-cient*	*t*
Shanghai	-6.9	2.7	4.7^{***}	Luan	4.8	3.1	7.9^{***}	Huanggang	-3.8	2.8	7.1^{***}
Nanjing	-3.9	2.0	5.9^{***}	Bozhou	3.6	2.3	6.0^{***}	Xianning	-1.6	2.9	7.3^{***}
Wuxi	-2.5	1.1	5.8^{***}	Chizhou	4.3	2.5	6.5^{***}	Suizhou	-1.5	2.8	7.0^{***}
Xuzhou	-2.0	1.7	5.6^{***}	Xuancheng	-0.1	2.5	6.5^{***}	Chengdu	-4.8	2.3	5.8^{***}
Changzhou	-3.4	2.1	5.8^{***}	Nanchang	-3.8	2.3	6.0^{***}	Zigong	-0.8	2.0	5.1^{***}
Suzhou	-4.5	2.1	6.3^{***}	Jingdezhen	-0.6	2.1	5.4^{***}	Panzhihua	-0.5	2.2	5.6^{***}
Nantong	-3.3	2.0	5.5^{***}	Pingxiang	0.1	2.4	6.1^{***}	Luzhou	-0.5	2.0	5.2^{***}
Lianyugang	-1.7	2.0	5.3^{***}	Jiujiang	0.6	2.2	5.6^{***}	Deyang	-2.3	1.9	4.9^{***}
Huaian	-0.4	2.2	5.6^{***}	Xinyu	-1.2	2.5	6.4^{***}	Mianyang	-3.9	1.8	4.7^{***}
Yancheng	-1.8	2.1	5.3^{***}	Yingtan	0.9	2.4	6.1^{***}	Guangyuan	1.5	1.8	4.6^{***}
Yangzhou	-2.8	1.9	4.7^{***}	Ganzhou	3.1	3.0	7.8^{***}	Suining	1.6	2.0	5.1^{***}
Zhenjiang	-3.7	3.7	5.4^{***}	Jian	3.8	3.0	7.7^{***}	Neijiang	-0.3	1.7	4.4^{***}
Taizhou	-3.1	2.4	5.4^{***}	Yichun	2.7	2.8	7.2^{***}	Leshan	-0.2	1.7	4.5^{***}
Suqian	-0.8	2.0	5.9^{***}	Fuzhou	3.0	2.5	6.5^{***}	Nanchong	3.4	2.9	7.4^{***}
Hangzhou	-3.7	1.8	5.7^{***}	Shangrao	4.7	3.4	8.9^{***}	Meishan	4.1	2.6	6.7^{***}
Ningbo	-3.6	1.8	5.8^{***}	Changsha	-4.7	2.4	6.5^{***}	Yibin	-1.3	2.8	7.1^{***}
Wenzhou	-3.0	2.4	5.8^{***}	Zhuzhou	-2.0	1.8	5.2^{***}	Guangan	5.4	2.6	6.6^{***}
Jiaxing	-2.9	1.7	5.5^{***}	Xiangtan	-2.0	2.4	5.4^{***}	Dazhou	4.8	3.0	7.6^{***}
Huzhou	-2.5	1.7	4.9^{***}	Hengyang	0.0	2.4	5.1^{***}	Yaan	2.1	2.5	6.4^{***}
Shaoxing	-2.4	1.1	5.5^{***}	Shaoyang	0.9	1.9	4.6^{***}	Bazhong	4.9	2.4	6.2^{***}
Jinhua	-2.8	2.1	5.5^{***}	Yueyang	-0.4	2.5	5.5^{***}	Ziyang	2.6	2.7	6.9^{***}
Quzhou	-0.2	2.0	5.2^{***}	Changed	-0.9	2.1	5.0^{***}	Chongqing	-5.8	3.3	6.2^{***}
Zhoushan	-2.0	1.4	5.2^{***}	Zhangjiajie	8.4	2.6	5.3^{***}	Kunming	-2.9	2.0	5.2^{***}
Taizhou	-2.8	1.5	5.4^{***}	Yiyang	4.4	3.7	7.4^{***}	Qujing	2.5	2.5	6.5^{***}
Lishui	2.2	2.9	7.7^{***}	Chenzhou	3.2	3.3	7.7^{***}	Yuxi	0.4	2.1	5.3^{***}
Hefei	-4.4	2.6	6.8^{***}	Yongzhou	5.0	3.4	7.1^{***}	Baoshan	3.5	2.5	6.4^{***}
Wuhu	-2.6	2.4	6.3^{***}	Huaihua	4.3	2.7	7.1^{***}	Zhaotong	2.9	2.3	6.0^{***}
Bengbu	-1.8	1.9	4.8^{***}	Loudi	1.8	2.7	7.2^{***}	Lijiang	5.3	2.4	6.3^{***}
Huainan	-1.2	2.0	5.2^{***}	Wuhan	-2.0	2.4	6.1^{***}	Puer	5.7	2.4	6.3^{***}
Maanshan	0.0	2.3	5.9^{***}	Huangshi	-1.4	2.2	5.5^{***}	Lincang	5.7	2.6	6.6^{***}
Huaibei	-1.3	1.9	5.0^{***}	Shiyan	-2.1	2.3	5.8^{***}	Guiyang	-2.1	2.2	5.7^{***}
Tongling	-1.3	2.3	5.9^{***}	Yichang	-1.3	2.9	7.3^{***}	Liupanshui	3.4	2.3	6.0^{***}
Anqing	0.4	2.0	5.1^{***}	Xiangyang	-2.4	2.1	5.2^{***}	Zunyi	0.6	2.7	6.9^{***}
Huangshan	-0.1	1.9	4.9^{***}	Ezhou	0.0	2.3	5.6^{***}	Anshun	-0.5	2.3	5.9^{***}
Chuzhou	1.3	2.5	6.4^{***}	Jinmen	-1.6	2.3	5.7^{***}	Bijie	4.1	1.8	4.6^{***}
Fuyang	1.5	2.8	7.2^{***}	Xiaogan	-2.9	2.6	6.4^{***}	Tongren	9.7	2.9	7.4^{***}
Suzhou	5.8	3.2	8.3^{***}	Jinzhou	-3.5	2.8	7.1^{***}				

Table 7: The estimate results of PVECM model between lnY and lnM

Cities	δ_{1t}	λ_{1t}	*Cities*	δ_{1t}	λ_{1t}	*Cities*	δ_{1t}	λ_{1t}	*Cities*	δ_{1t}	λ_{1t}
Shanghai	0.9^{***}	-1.1^{**}	Huainan	0.9^{***}	-1.6^{***}	Shaoyang	1.1^{***}	-1.1^{***}	Suining	1.2^{***}	-0.2
Nanjing	0.9^{***}	-2.1^{***}	Maanshan	0.7^{***}	-2.0^{***}	Yueyang	1.0^{***}	-1.7^{***}	Neijiang	0.6^{***}	-1.8^{***}
Wuxi	1.2^{***}	-2.1^{***}	Huaibei	0.9^{***}	-1.3	Changed	0.7^{***}	-2.1^{***}	Leshan	0.6^{***}	-1.7^{***}
Xuzhou	1.1^{***}	-1.6^{***}	Tongling	0.8^{***}	-2.0^{***}	Zhangjiajie	1.1^{***}	-1.7^{***}	Nanchong	2.1^{***}	-1.3^{***}
Changzhou	1.1^{***}	-1.8^{***}	Anqing	1.2^{***}	-1.0^{**}	Yiyang	1.4^{***}	-2.0^{***}	Meishan	1.6^{***}	-1.7^{***}
Suzhou	1.0^{***}	-2.0^{***}	Huangshan	0.9^{***}	-1.7^{***}	Chenzhou	1.9^{***}	-1.7^{***}	Yibin	1.3^{***}	-2.0^{***}
Nantong	0.9^{***}	-1.8^{***}	Chuzhou	1.1^{***}	-2.0^{***}	Yongzhou	1.6^{***}	-1.9^{***}	Guangan	2.0^{***}	-0.8^{***}
Lianyungang	1.0^{***}	-1.9^{***}	Fuyang	2.2^{***}	-1.4^{***}	Huaihua	2.2^{***}	-1.5^{***}	Dazhou	2.5^{***}	-1.1^{***}
Huaian	0.9^{***}	-1.9^{***}	Suzhou	2.9^{***}	-1.3^{***}	Loudi	1.6^{***}	-1.9^{***}	Yaan	1.9^{***}	-1.1^{***}
Yancheng	0.9^{***}	-1.9^{***}	Luan	1.4^{***}	-2.0^{***}	Wuhan	1.2^{***}	-1.7^{***}	Bazhong	2.2^{***}	-0.4
Yangzhou	0.8^{***}	-0.8	Bozhou	1.9^{***}	-0.7^{***}	Huangshi	1.2^{***}	-1.8^{***}	Ziyang	1.8^{***}	-1.4^{***}
Zhenjiang	1.1^{***}	-1.7^{***}	Chizhou	0.9^{***}	-2.0^{***}	Shiyan	1.3^{***}	-1.6^{***}	Chongqing	1.2^{***}	-1.8^{***}
Taizhou	1.1^{***}	-1.7^{***}	Xuancheng	1.7^{***}	-1.8^{***}	Yichang	1.7^{***}	-1.8^{***}	Kunming	1.2^{***}	-1.7^{***}
Suqian	1.0^{***}	-2.0^{***}	Nanchang	1.2^{***}	-1.6^{***}	Xiangyang	0.9^{***}	-1.9^{***}	Qujing	1.1^{***}	-2.0^{***}
Hangzhou	1.1^{***}	-1.9^{***}	Jingdezhen	1.1^{***}	-1.5^{***}	Ezhou	1.1^{***}	-1.7^{***}	Yuxi	1.3^{***}	-1.9^{***}
Ningbo	1.1^{***}	-1.9^{***}	Pingxiang	1.3^{***}	-1.6^{***}	Jinmen	1.4^{***}	-1.8^{***}	Baoshan	1.5^{***}	-1.8^{***}
Wenzhou	1.2^{***}	-1.9^{***}	Jiujiang	1.1^{***}	-1.6^{***}	Xiaogan	1.7^{***}	-1.7^{***}	Zhaotong	2.0^{***}	-0.9^{***}
Jiaxing	1.0^{***}	-1.9^{***}	Xinyu	1.3^{***}	-0.1	Jinzhou	2.0^{***}	-1.7^{***}	Lijiang	1.3^{***}	-1.9^{***}
Huzhou	1.0^{***}	-1.9^{***}	Yingtan	1.1^{***}	-1.3^{*}	Huanggang	2.0^{***}	-1.7^{***}	Puer	1.3^{***}	-1.9^{***}
Shaoxing	1.2^{***}	-1.9^{***}	Ganzhou	2.1^{***}	-1.7^{***}	Xianning	1.9^{***}	-1.7^{***}	Lincang	1.0^{***}	-2.1^{***}
Jinhua	1.1^{***}	-1.8^{***}	Jian	2.0^{***}	-1.7^{***}	Suizhou	1.8^{***}	-1.7^{***}	Guiyang	1.1^{***}	-1.8^{***}
Quzhou	0.7^{***}	-2.1^{***}	Yichun	1.7^{***}	-1.7^{***}	Chengdu	1.3^{***}	-1.6^{***}	Liupanshui	0.9^{***}	-2.0^{***}
Zhoushan	0.9^{***}	-1.7^{***}	Fuzhou	1.5^{***}	-1.6^{***}	Zigong	1.1^{***}	-1.6^{***}	Zunyi	1.8^{***}	-1.7^{***}
Taizhou	1.3^{***}	-1.6^{***}	Shangrao	2.4^{***}	-1.7^{***}	Panzhihua	1.1^{***}	-1.9^{***}	Anshun	0.9^{***}	-2.0^{***}
Lishui	1.7^{***}	-1.8^{***}	Changsha	1.2^{***}	-1.6^{***}	Luzhou	1.0^{***}	-1.7^{***}	Bijie	0.7^{***}	-0.9
Hefei	1.2^{***}	-0.9	Zhuzhou	1.2^{***}	-1.2^{***}	Deyang	0.7^{***}	-2.1^{***}	Tongren	1.5^{***}	-2.0^{***}
Wuhu	1.1^{***}	-1.9^{***}	Xiangtan	1.1^{***}	-1.7^{***}	Mianyang	1.2^{***}	-1.3^{***}			
Bengbu	0.8^{***}	-1.9^{***}	Hengyang	0.8^{***}	-2.0^{***}	Guangyuan	0.8^{***}	-1.9^{**}			

Table 8: The estimate results of PVECM model between lnY and lnP

Cities	δ_{1t}	λ_{1t}	*Cities*	δ_{1t}	λ_{1t}	*Cities*	δ_{1t}	λ_{1t}	*Cities*	δ_{1t}	λ_{1t}
Shanghai	4.4^{***}	-2.1^{***}	Huainan	3.5^{***}	-0.6	Shaoyang	2.8^{***}	-0.9	Suining	3.3^{***}	-0.7
Nanjing	2.1^{***}	-1.9^{***}	Maanshan	3.8^{***}	-0.6	Yueyang	2.8^{***}	-0.9	Neijiang	2.1^{**}	-1.2
Wuxi	1.4^{***}	-2.0^{***}	Huaibei	3.1^{***}	-0.7	Changed	2.4^{***}	-2.1^{**}	Leshan	2.1^{**}	-1.3
Xuzhou	2.0^{***}	-2.0^{***}	Tongling	4.0^{***}	-0.7	Zhangjiajie	2.6^{***}	-1.7	Nanchong	5.8^{***}	-1.1^{***}
Changzhou	2.1^{***}	-1.8^{**}	Anqing	3.5^{***}	-0.8	Yiyang	4.6^{***}	-1.8^{***}	Meishan	5.1^{***}	-1.0^{***}
Suzhou	2.8^{***}	-1.6^{***}	Huangshan	3.2^{***}	-0.7	Chenzhou	4.5^{***}	-1.5^{***}	Yibin	5.6^{***}	-1.1^{***}
Nantong	4.0^{***}	-0.8^{*}	Chuzhou	5.5^{***}	-1.3^{***}	Yongzhou	3.4^{***}	-1.9^{***}	Guangan	5.0^{***}	-1.1^{***}
Lianyungang	3.7^{***}	-0.9^{*}	Fuyang	6.1^{***}	-1.2^{***}	Huaihua	5.6^{***}	-1.1^{***}	Dazhou	6.3^{***}	-1.1^{***}
Huaian	3.6^{***}	-0.7	Suzhou	7.4^{***}	-1.2^{***}	Loudi	3.1^{***}	-1.4^{***}	Yaan	5.1^{***}	-1.1^{***}
Yancheng	3.3^{***}	-0.7	Luan	6.9^{***}	-1.2^{***}	Wuhan	3.6^{***}	-1.2^{**}	Bazhong	5.0^{***}	-1.1^{***}
Yangzhou	2.7^{***}	-0.8	Bozhou	4.6^{***}	-1.2^{***}	Huangshi	3.3^{***}	-1.2^{**}	Ziyang	5.0^{***}	-1.0^{***}
Zhenjiang	1.7^{**}	-1.1^{***}	Chizhou	4.6^{***}	-0.9^{**}	Shiyan	3.6^{***}	-1.2^{**}	Chongqing	2.5^{***}	-1.3^{**}
Taizhou	0.6	-0.9^{***}	Xuancheng	5.2^{***}	-1.2^{***}	Yichang	4.8^{***}	-1.3^{***}	Kunming	3.5^{***}	-1.0^{**}
Suqian	4.7^{***}	-1.1^{***}	Nanchang	4.1^{***}	-0.8^{*}	Xiangyang	2.7^{***}	-1.1	Qujing	4.7^{***}	-1.0^{***}
Hangzhou	2.1^{***}	-1.9^{***}	Jingdezhen	3.6^{***}	-0.7	Ezhou	3.2^{***}	-1.1^{*}	Yuxi	4.3^{***}	-1.2^{***}
Ningbo	2.7^{***}	-1.7^{***}	Pingxiang	4.2^{***}	-0.8	Jinmen	3.8^{***}	-1.3^{***}	Baoshan	4.7^{***}	-1.1^{***}
Wenzhou	3.9^{***}	-1.1^{***}	Jiujiang	3.6^{***}	-0.7	Xiaogan	4.6^{***}	-1.3^{***}	Zhaotong	4.7^{***}	-1.2^{***}
Jiaxing	2.2^{***}	-2.0^{***}	Xinyu	4.2^{***}	-0.7	Jinzhou	5.4^{***}	-1.4^{***}	Lijiang	4.4^{***}	-1.1^{***}
Huzhou	2.6^{**}	-1.0^{***}	Yingtan	3.9^{***}	-0.7	Huanggang	5.5^{***}	-1.4^{***}	Puer	4.6^{***}	-1.1^{***}
Shaoxing	1.7^{***}	-2.0^{***}	Ganzhou	6.6^{***}	-1.2^{***}	Xianning	5.1^{***}	-1.3^{***}	Lincang	4.7^{***}	-1.2^{***}
Jinhua	4.1^{***}	-1.0^{**}	Jian	6.3^{***}	-1.1^{***}	Suizhou	5.1^{***}	-1.3^{***}	Guiyang	3.5^{***}	-0.9
Quzhou	3.6^{***}	-0.7	Yichun	5.5^{***}	-1.1^{***}	Chengdu	4.0^{***}	-0.9^{*}	Liupanshui	3.5^{***}	-0.7
Zhoushan	1.4^{**}	-1.1^{***}	Fuzhou	4.8^{***}	-1.0^{***}	Zigong	3.3^{***}	-0.7	Zunyi	5.3^{***}	-1.2^{***}
Taizhou	2.5^{***}	-1.8^{***}	Shangrao	7.6^{***}	-1.2^{***}	Panzhihua	3.3^{***}	-0.9	Anshun	3.9^{***}	-1.0^{**}
Lishui	6.3^{***}	-1.1^{***}	Changsha	3.7^{***}	-1.3^{***}	Luzhou	3.3^{***}	-0.7	Bijie	2.4^{**}	-0.8
Hefei	4.2^{***}	-0.7	Zhuzhou	3.8^{***}	-1.1^{***}	Deyang	3.3^{***}	-0.8	Tongren	5.8^{***}	-1.2^{***}
Wuhu	3.9^{***}	-0.6	Xiangtan	2.8^{***}	-1.6	Mianyang	3.3^{***}	-1.0^{*}			
Bengbu	2.9^{***}	-0.7	Hengyang	2.5^{***}	-2.8^{*}	Guangyuan	2.7^{***}	-0.6			

regional growth (lnY) are shown in Table 7. The coefficients of error correcting (λ_{1i}) are significantly negative (the absolute value is greater than 1), and the mechanism of error correcting is working, which shows that the influence of R&D expenditure investment is unstable and the amplitude of fluctuation is large in the short-term. The coefficients of $\Delta InM(\delta_{1i})$ are positive significantly under confidence level of one percent, which shows that R&D expenditure investment is beneficial to regional growth. The elasticity of R&D expenditure investment in the short-term is higher than the long-term, but the hysteresis effect is significant in the short-term.

The estimated results of PVECM model (7) between R&D personnel investment (lnP) and regional economic growth (lnY) are shown in Table 8. The coefficients of error correcting (λ_{2i}) are significantly negative (the absolute value is greater than 1), and the mechanism of error correcting is working, which shows that the influence of R&D personnel investment is unstable and the amplitude of fluctuation is large in the short-term. The coefficients of $\Delta InM(\delta_{2i})$ are significant positive under confidence level of one percent, this shows that R&D personnel investment can be helpful to regional growth. The short-term elasticity of R&D personnel investment is higher than the long-term, but the short-term hysteresis effect is significant.

DISCUSSION

The Chinese government proposed the YREZ development strategy in September 2014, with the GDP proportion of YREZ in China being 45.6 percent, and some scholars expect the proportion will reach fifty percent by 2020. The relationship between R&D investment and regional growth has been a hot study in the economic geography fields, and researchers have found that R&D investment plays an important role in the process of regional growth.

The concept of network capital is noticed by more and more scholars (Huggins 2010; Kramera and Revilla 2012). Huggins and Thompson (2014) incorporate the network capital into the regional economic growth model, and argue that the styles of inter-organizational network and the nature of knowledge flow will have an important influence on regional growth. The regional growth will result from the balance of network capital between local and global (non-local) (Huggins and Johnston 2010; Huggins and Thompson 2014; Kramera et al. 2011; Lawton et al. 2012), but the model are short of being tested. So, Huggins and Thompson (2017) used a group data regression method to empirically analyze the economic growth in the regions of the United Kingdom, and find the regional and intraregional network patterns in the process of regional growth, highlighting the role of embedded localization and the importance of acquiring more distant knowledge. However, the R&D investment of this paper is local, and the cities in the lower area of Yangtze River have more export-oriented economy, so the influence of R&D investment in the lower area of Yangtze River is less significant than the middle and upper area.

CONCLUSION

Taking the panel data of 110 cities in YREZ from 1990 to 2013 as the example, the researchers have built the relationship model between regional growth and R&D investment. The results show that: Firstly, there exists a certain hysteresis effect between the relationship of R&D long-term and stable investment and regional growth, and R&D short-term investment; the elasticity of the short-term is higher than the long-term; Secondly, the influence of R&D investment on regional growth is significant positive correlation, but the elasticity of R&D personnel investment (the average of YREZ is 2.351) is higher than R&D expenditure investment (the average of YREZ is 1.013), which shows that regional growth depends much more on R&D personnel. That is to say, talent, not money, is more conducive to regional growth; Thirdly, the significant differences of R&D investment in the different cities in YREZ, and R&D investment in the eastern region of Yangtze River is the highest, however, the influence of R&D investment in the eastern region of Yangtze River is the lowest. Why the influence of R&D investment is different among the regions in the YREZ? The regional growth will result from the balance of network capital between local and global, however, the R&D investment of this paper is local, and the cities in the eastern region of Yangtze River are more export-oriented economy, so the influence of R&D investment in the eastern regions of Yangtze River is less significant than the middle regions.

RECOMMENDATIONS

In order to promote regional growth, the researchers believe that the government should put forward suggestions to improve R&D investment intensity, formulate long-term R&D investment planning, and improve the conversion rate of innovation achievements. In the future, the researchers can introduce the network capital of global into regional growth models, which can study better on the influence of innovation and regional growth.

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