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Does the Growth of R&D Promote the TFP Increasing —Empirical Analysis Based on 22 Industrial Sectors of China

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Abstract:

By using the panel data of the 22 industries from 2006~2012 the research shows that large R&D investment scale didn't bring the fast increase of TFP as expected in China. In order to analyze the reason of this contradiction, this paper made the game model of division of labor between the upper and lower reaches of the industries to analyze the influence of human capital and vertical specialization to TFP. Then the paper use system GMM to make empirical analysis to inspect the game model. The results show that human capital does not help increasing allocative efficiency of R&D and vertical specialization does not promote the increase of TFP.

Keywords: Vertical specialization; Human Capital; TFP; System GMM; Game Model.

1. Introduction

Since the beginning of twenty-first Century，China's R&D investment has shown a breakthrough growth in both funds and the number of technology personnel. In the period covered by the 11th five-year plan, the R&D cost growth averaged 23.8% per annum, which was 5.3 percentage points way above that in " 10th five-year " period. In2013,China's R&D scale had been leapt to 1190.6 billion yuan from1035.78 billion yuan in the previous year. China has become one of the world's most important R & D investment countries from the standard of R&D investment scale. According to the theory of developing economic and the experience of developed countries, the increase of R & D investment should promote the upgrading of China's TFP to further stimulate economic growth（Krugman，1994）[1] 。However, more and more scholars believe that China's total factor productivity is lower than expected. The TFP growth is slowing down when the input doubled under the existing circumstances. For instance, Shunjia Liu（2008）[2] found that TFP is generally low in all industries of our country and decreased obviously. China's economy is mainly driven by capital, labor and the middle input elements. Shengwen Li（2008）[3] also made research into input-output efficiency and found China's TFP growth of industries is from slow to fast and then stagnated.

Why our country under the condition of the input multiplied, TFP growth slowed markedly?

According to the theory of classical economics and foreign scholars of recent studies, TFP depends on two factors:

The first aspect is the input factor, including R&D and human capital investment, not just the R&D investment; The second aspect is the production degree of division of labor, namely the degree of vertical specialization. Human capital as the important carrier of knowledge and information, vertical specialization as the realization form of economic activities, both of them will have a major impact on economic growth. Therefore, this article will put the r&d, human capital and vertical specialization into an unified framework and construct a dynamic game model of upstream and downstream enterprises which engaged in production of division, focusing on the analysis of human capital, the vertical specialization mechanisms influence on TFP. Paper uses Chinese data to prove the truth of the deductions.

2. Review of Literature

Scholars' results about the influence factors of total factor productivity are abundant enough. This article mainly review from three aspects of r&d, vertical specialization and human capital.

2.1 Research Input

According to the Solow model, the growth of r&d is the important factor causing output growth. Theoretically, Battese (2004) [4] supposes R&D's effect of TFP depends on three aspects :the form of production function, estimate Solow residual value based on the number of assumptions and data integration level. Empirically, Dominique (1995) [5] had data analysis both in Canada and Japan, the results showed that domestic R&D spillover effect more apparent than international, but both if them have the positive effection. But the domestic empirical study found that China's total factor productivity is low. Shunjia Liu（2008）[2] found that TFP is generally low in all industries of our country and decreased obviously. China's economy is mainly driven by capital, labor and the middle input elements. Shengwen Li （2008）[3] also made research into input-output efficiency and found China's TFP growth of industries is from slow to fast and then stagnated.

2.2 Vertical Specialization

Many scholars found theoretically and empirically research on the general conclusion, that the vertical specialization promotes the technology progress through a variety of ways, so as to improve the production efficiency. For example, the new trade theory is an important channel of technology spillover of specialization, by avoiding the repeated labor and specialization to improve the research and production efficiency. Zhaoling Hu (2007) [6] used industry panel data to do empirical analysis on the relationship between vertical specialization and technological innovation, the results show that the vertical specialization promotes technology progress, so as to promote the growth of total factor productivity.

On the other hand, the researches show that the integration is more powerful to promote enterprise technology progress. Robert C.'s (1998) [7] study suggests that in order to maintain absolute superiority of the market, relying on large-scale r&d for product innovation, and integration can hinder the technology spillover effect in the process of specialization, formate the barriers to entry and increase the income.

Also we have the researches think we could not statically look at the the relationship between vertical specialization and the total factor productivity, we need to find the balance to maximize the output efficiency in all kinds of restriction conditions . For example, Grossman and Helpman [8], using the theory of transaction cost, analyzes how the intermediate inputs should be orgnized in the process of production to make a maximum output efficiency. Xiaodi Zhang Jingwei Sun (2006) [8] used China's industries to analyze vertical specialization influence on industrial competitiveness, the results show that in the long run, vertical specialization promotes the total factor productivity, but at the same time, different industries also have difference, capital and technology intensive industry of vertical specialization degree is higher than labor-intensive industries.

2.3 Human Capital

Theoretically， represented by Paul Romer (1986) [10] and Robert Lucas (1988) [11], the "new growth theory" which starts from increasing return to scale, extended the category of "labor" in the neoclassical model to the human capital investment. Therefore, human capital can be thought of as an important factor to total factor productivity. Empirically, Mingyong Lai (2005) [12] introduced human capital and foreign R&D cross variables to analyze its influence on economic growth, which found that human capital is helpful to enhance absorptive capacity.

3. Model and Inferences

This paper, by constructing a dynamic game model of upstream and downstream enterprises engaged in production of division of labor, focused on analyzing how mechanism of vertical specialization and human capital effect the total factor productivity.

First of all, the model assumes that there are four companies, A_1, A_2, B_1, B_2, downstream of A for the importer, the subscript 1, 2, respectively mean the downstream enterprises and downstream potential entrants. B the upstream the exporter, the subscript 1, 2, respectively mean in the upstream enterprise and upstream potential entrants.

The initial state, A_1 profit is zero, when the production cost of B is lower than A_1, A_1 considers transferring products part or all of them to B, which can make profit greater than zero. B sales products to A_1 after completion of production. When A chooses produce in their own rather than importing, cost of production for A_1 is c_1, cost of production for A_2 is c_2, $c_2 < c_1$, this is due to the technical differences between different enterprises and scale reward. When A choose to shift part of its production to B and import from B，it will have fixed investment to B for technology transferring, assuming it as M. A affords λwhen B affords 1-λ.B sales its products to A at the price of w. Then the marginal cost of A_1 to sell the product is $c_1 + w$. In the initial state, there is no technological spillover. Only B_1 gets A's technology diffusion, the marginal cost of B_1 is c_3. In the presence of technology spillover, the probability of B_2 to get technology spillover is ρ, $0<\rho<1$， And its cost for production is c_4, because of the technology gap, $c_4 > c_3$. Assuming demand curve A_1 facing is Q (p),
The profit maximization is expressed as:

$$Max\ \prod_o(p) = (p - c_1 - w)Q(p)$$

According to the condition of profit maximization, we get:

$$Q(p) + (p - c_1 - w)\frac{dQ(p)}{dp} = 0$$

Assume optimum solution for profit maximization as $p^m(\alpha)$， the equilibrium output is：

$$Q^m(\alpha) = Q(p^m(w))$$

When A_1 shifts production to B_1 and there is no technology diffusion, the B_1 profit maximization is:

$$Max\ \prod_1(w) = (w - c_2)Q(p^m(w))$$

Assuming that to maximize profit of B_1, the optimal solution is w_1, the maximum profit of B_1 is:

$$Max\ \prod_1^*(w) = (w_1 - c_3)Q^m(w_1)$$

At this time the largest profit for A_1 is:

$$\prod_o^*(w_1) = (p^m(w_1) - c_1 - w)Q^m(w_1)$$

When A_1 shifts production to B_1, B_1 will cut down the price to c4 to prevent potential entrants B_2 .

Due to the existence of a high enough fixed input of technology transfer, suppose it as M， which makes A_1 chooses a supplier to produce the products. At this point A_1 's biggest net profit on average is:

$$Y = (1-\rho)\prod_o^*(w_1) + \rho\prod_o^*(c_4)$$

The first order derivative of Y: $dY / d\rho = \prod_o^*(c_4) - \prod_o^*(w_1)$， due to $w_1 > c_4$， then $\prod_o^*(w_1) < \prod_o^*(c_4)$，

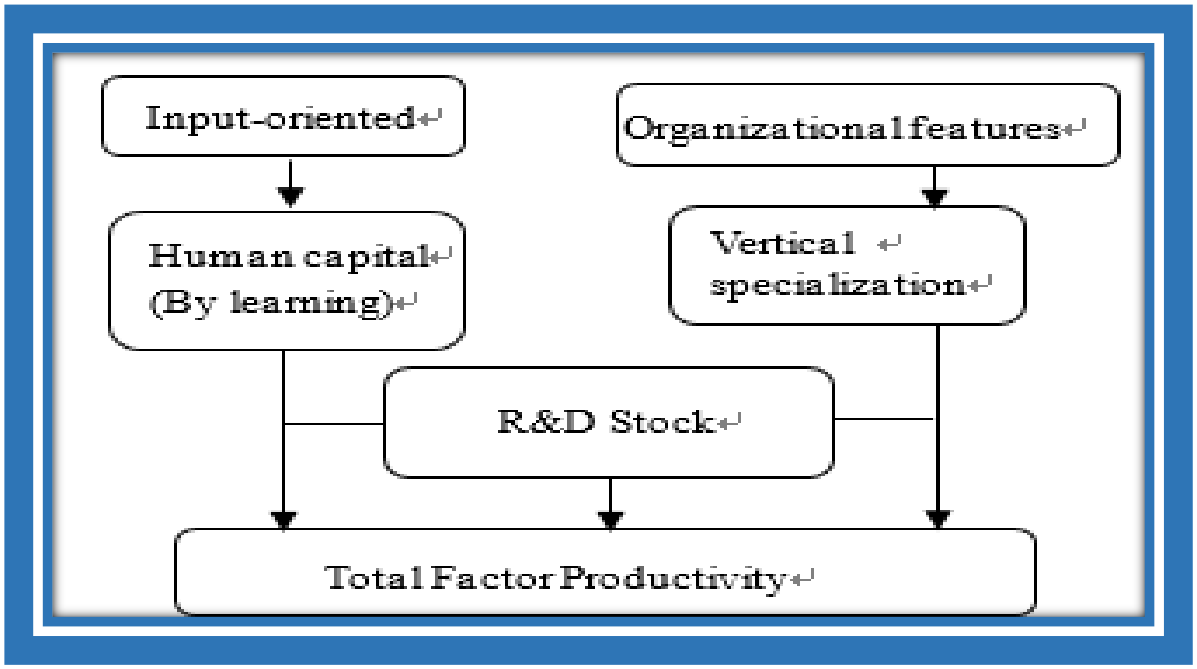
$dY / d\rho > 0$。

By proof above , on the improvement of technology spillovers, the higher the ρ state, the more profits of A1 makes, which results the economic benefits more obvious. Human capital can produce horizontal spillover effect through learning and absorbing advanced technology, so as to improve the level of industry technology and enhance the total factor productivity. And the higher the vertical specialization degree is, the easier to make the technology diffusion between the industries. And once the level of the technology spillovers improved, the more revenue can be made by division of labor. The effects of the three on total factors on productivity mechanism are shown in figure 1. So we can make inferences are as follows:

Inference 1: Human capital, vertical specialization can both promote the growth of total factor productivity.

Inference 2: The more human capital investment, the higher degree of vertical specialization, the efficiency of r&d investment in the total factor productivity is higher.

Fig 1: The Influence Mechanism of Human Capital and Vertical Specialization to the Total Factor Productivity



4. Empirical Analysis

4.1 Econometric Model

According to the "Frontier Production Function", The output which is brought by labor input, capital stock and intermediate input function of Industry I can be wrote as : $Y_t=Ae^{\lambda t}K_{it}^{\alpha}L_{it}^{\beta}R_{it}^{\gamma}e^{\theta}$ (1) . Y is output, K is capital, L is labor input, R is the intermediate input in time t, α、β、γ respectively are the elastic coefficient of the capital stock, labor input and intermediate input.

A measure to estimate the contribution of intermediate input level is growth in total factor productivity, its motivations include technological progress, organization innovation, specialization, and production innovation, and is often as measure index of scientific and technological progress. Therefore, total factor productivity is often regarded as index of scientific and technological progress. We define total factor productivity as $TFP = Y_t / K_{it}^{\alpha}L_{it}^{\beta}$, then we get $TFP= A_t R_t^{\gamma}$.

Take the logarithm of equation(1) and take the derivative of time:

$$\Delta TFP_t / TFP_{t-1} = \gamma\rho(\Delta R_t / \Delta R_{t-1}) + \lambda + \theta$$

By referring to many documents(Xiaoping Li,2008 etc.),we replace its output elasticity variable by using the return on the intermediate input to output to get:

$$\Delta TFP_t / TFP_{t-1} = \gamma\rho(\Delta R_t / \Delta Q)$$

But by research and analysis of the third part we found that only from the perspective of intermediate input is not enough to study the relationship between R&D and technical progress.

This paper will also introduce two variables of human capital, vertical specialization and consider the interaction between human capital and R&D, vertical specialization and R&D. So the regression model is defined as:

$$InTFP_t^i = \lambda_0 + \lambda_1 InR_t^i + \lambda_2 InH_t^i + \lambda_4 InR_t^i InVSI_t^i + \lambda_5 InR_t^i InH_t^i + \varepsilon$$

This is the regression model for the panel data below.

4.2 Empirical Results

To ensure the availability of data and statistical caliber of consistency, this paper will divide all state-owned and non-state-owned but above designated size industrial enterprises into 22 industries according to the classification of the input-output table. All the original data are from the China Statistical Yearbook.

Measuring the results of the quantitative analysis:

In order to study further the mechanism of influence of the vertical specialization, human capital to the total factor productivity, this paper respectively defines total factor productivity change, technological progress efficiency index (TC), efficiency change index(EC) as explained variable. in the econometric model. Most existing research uses fixed effect or random effect model to analyze the measured data, but due to the existence of endogenous variables and the related issues, the OLS estimators may be biased. Therefore, to avoiding such problems, we choose system GMM method to estimate dynamic panel data. System GMM method takes a difference of econometric model to make variables which do not change with time can not be estimated, then we get:

$$\Delta tfp_{it}=a\Delta tfp_{it-1}+b\Phi_{it}+\lambda_t+\varepsilon_{it}$$

Among them, the TFP and other explanatory variables Φ are the value after taking the natural logarithm of them, which in order to remove the industry effect of those that do not change with time and reduce lag and residual autocorrelation.

Table 1: Basic Model Regression Results			
Variables	**In（TFP）**	**In(TC)**	**In(EC)**
One Period Lagged	0.23（0.08）*	0.09（0.10）**	0.54（0.05）**
In（R）	-0.06（0.03）	0.15（0.07）**	-0.12（0.04）*
In（H）	0.11（0.01）	0.11（0.03）*	0.2（0.02）*
In（VSI）	-0.08（0.15）*	0.12（0.13）	-0.19（0.1）**
In（VSI）*In（R）	0.19（0.06）**	0.08（0.05）*	0.23（0.11）
In（H）*In（R）	-0.07（0.03）**	0.05（0.12）*	-0.12（0.32）
Sargan Test	18.65[0.18]	22.09[0.05]	26.12[0.06]
AR（1）	-1.54[0.13]	-2.45[0.06]	-1.98[0.03]
AR（2）	1.14[0.32]	-1.63[0.11]	1.26[0.22]

Annotations：（1）Measurement regression results are got by using Stata10.0

（2）“*”“**”“***” respectively represent significant level of t statistic under 10%, 5% and 1%

（3）Numbers in parentheses is standard errors of the coefficient estimation

（4）Numbers in square brackets is the value of P

Through the analysis of the model, we can get the following conclusions:

4.3 Conclusions

Firstly, human capital plays a significant positive role in promoting the total factor productivity, technology change index and efficiency change index. The higher the level of human capital is, the faster the total factor productivity increases, which is consistent with the most scholars research conclusions. On one hand, when science and technology workers get high level of education, their subjective initiative about vocational skills are better than those who don’t. As a result the input and output efficiency is improved directly. On the other hand, as a carrier of knowledge and information, science and technology personnel play a key role in R&D activities, so as to improve technological change to promote long-term sustainable economic growth.

Secondly, a negative correlation is found between vertical specialization and total factor productivity, which means vertical specialization, does not improve total factor productivity. According to the efficiency change index ， vertical specialization is blocks the rise of efficiency change. On one hand vertical specialization distracted the economies of scale in production. On the other hand, integration of production, management, and marketing may be broken by division of labor cooperation resulting in conflicts of communication, trust, interest between all parties and reduction of the production efficiency. The correlation between vertical specialization and technology change index is positive. In other words, vertical specialization promotes the technology change index as expected. That’s because the industry gets technology spillovers through vertical specialization which significantly promotes the technological progress of the industry. Nonetheless, the positive effects of vertical specialization on the technology change index still cannot offset the negative effects brought by efficiency change index, that’s why on the whole taking everything into consideration,

vertical specialization by no means promote the total factor productivity.

Thirdly, according to interaction terms in the model, vertical specialization can promote absorption of R&D input better compared with human capital, which means the improvement of the degree of vertical specialization promotes the effect of R&D input on total factor productivity growth. This is due to the division of industry production makes technology transfer and spillover, vertical specialization became an important impetus of promoting the transformation and absorption of R&D so as to improve the nations technology capability. But human capital does not promote the absorption of R&D as expected , the reason is that there exists a "displacement" phenomenon between the human capital accumulation and R&D investment in industry. Although the R&D inputs have increased rapidly in recent years,it's not hard to find that R&D input concentrated in a minority of capital and technology-intensive industry. When R&D inputs is too large compared with the human capital inputs, the R&D ability of absorption will be weakened according to the law of diminishing marginal returns.

Therefore, according to the conclusions above, the configuration structure of R&D input should be changed to match the human capital input. Considering that excessive R&D input in technology intensive industry will cause the scale efficiency to decline, more R&D should be put into basic industries to ease "displacement" situation between R&D and human capital investment and improve the spillover effects of R&D to the whole industry. In the second place, we should keep increasing investment in human capital because high quality talent team is still the mainstay of promoting technological progress in the long run. We can improve productivity efficiency in use of these human resource. In the meanwhile, even though vertical specialization can help promoting diffusion and spillover of technology, we can't just pursue specialization or integration unilaterally and blindly but rather subdivide the industries based on their characteristics, factor endowments, production efficiency totally to improve the organization structure and achieve the goal of improve production efficiency Ultimately.

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