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Economic and productivity growth decomposition: An application to post-reform China

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ABSTRACT

This paper examines and applies the theoretical foundation of the decomposition of economic and productivity growth to the thirty provinces in China's post-reform economy. The four attributes of economic growth are input growth, adjusted scale effect, technical progress, and efficiency growth. A stochastic frontier model with a translog production and incorporated with human capital is used to estimate the growth attributes in China. The empirical results show that input growth is the major contributor to economic growth and human capital is inadequate even though it has a positive and significant effect on growth. Technical progress is the main contributor to productivity growth and the scale effect has become important in recent years. The impact of technical inefficiency is statistical insignificant in the sample period. The relevant policy implication for a sustainable post-reform China economy is the need to promote human capital accumulation and improvement in technical efficiency.

1. Introduction

In studying the technical change in the U.S., Solow (1957) differentiated the movements along the production function, which is caused by the input growth, from the shifts of the production function, which is defined as technical progress. With the assumption of constant returns to scale and perfect competition in the product market, the growth of output per unit of labor can be decomposed into technical progress and the weighted growth of capital per unit of labor. Technical progress has often been estimated by time series data of output and capital per unit of labor and the share of capital. Such a measure is referred to as "Solow residual." For a multiple inputs production function, the total factor productivity (TFP) growth is widely used as a measure of productivity change. While the classical approach in the TFP analysis often assumes optimality in production capacity, the output-oriented stochastic frontier production approach (Aigner et al., 1977) argues that, with given sets of factor inputs and due to possible technical inefficiency, there can be deviation between actual and optimal output. The measure of technical inefficiency can thus be added to the analysis of TFP growth by using the stochastic frontier model.[1]

There are at least three different ways to measure TFP growth: the index–number approach, the production function approach, and the cost function approach (Cowing and Stevenson, 1981; Denny et al., 1981; Bauer, 1990). The index–number approach has been used mostly in the early studies. The production function approach is more convenient than the cost function approach since it does not require any cost information. In spite of different measurement approaches, the TFP growth is composed of technical progress, technical efficiency change, and a scale economies effect (Bauer, 1990; Kumbhakar and Lovell, 2000). Technical progress refers to an outward shift of the production frontier due probably to greater use of technology and innovation that yields a larger production capacity. Technical efficiency change refers to an overall movement from a position within the production frontier towards the production frontier. The scale economies effect contributes to the output and productivity growth due to increasing returns to scale. With increasing returns to scale in production, output increases at a higher percentage with respect to input increases and induces productivity improvement.[2]

This paper extends the production function approach in Solow's (1957) classical model and follows Denny et al. (1981), Bauer (1990), and Kumbhakar and Lovell (2000) to examine the theoretical

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[1] Both the data envelopment analysis (DEA) (Charnes et al., 1978) and the distance function approach (Fu, 2005; Brummer et al., 2006) are the alternative measures of technical efficiency, but due to their non-parametric and deterministic nature, the stochastic frontier analysis tends to be the more popular approach.

[2] The empirical study of this decomposition of the TFP growth has earlier been applied to Korea with the production function approach by Kim and Han (2001) and with the cost function approach by Kwack and Sun (2005), and to the U.S. with the production function approach by Sharma et al. (2007).

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foundation of the decomposition of economic and productivity growth. We relax the assumption of constant returns to scale and consider technical inefficiency in a stochastic frontier model. The output growth is then decomposed into: input growth, adjusted scale effect, technical progress, and efficiency growth. Furthermore, TFP growth is decomposed into: adjusted scale effect, technical progress, and efficiency growth (Kumbhakar and Lovell, 2000).

The empirical study on the post-reform China economy is based on the stochastic frontier model with a translog production function (Christensen et al., 1971) that incorporates a human capital variable. Although the production stochastic frontier analysis has been used in other studies on the Chinese economy, most studies have focused on one or two components of productivity growth, while technical progress and/or returns to scale have been absent (Kalirajan et al., 1996; Carter and Estrin, 2001; Hu and McAleer, 2005; Tong, 1999; Dong and Putterman, 1997; Wu, 1995; H.X. Wu, 2000; Y. Wu, 2000).

Lacking a distinct method of constructing China's physical and human capital stocks in recent studies (Bai et al., 2006; He et al., 2007; Funke and Yu, 2009; Perkins and Rawski, 2008; Qian and Smyth, 2006; Urel and Zebregs, 2009), this paper chooses to extend, revise and update the dataset and the methodology used in deriving the national and provincial physical capital and human capital stocks in Chow and Li (2002), Liu and Li (2006), Li (2003, 2009), and Li et al. (2009) and estimates the components of the economic and productivity growth for China's thirty provinces for the sample period of 1985–2006. China's national and provincial capital are approximated from investment figures (Chow, 1993), while a perpetual inventory approach adjusted by provincial migration and mortality rates is used in the construction of the human capital stock (Wang and Yao, 2003; Barro and Lee, 2001; Howitt, 2005).

Section 2 discusses the theoretic foundation of the decomposition of economic and productivity growth, Section 3 elaborates on the data used for empirical estimation of the growth experience in post-reform China and introduces the empirical model. Section 4 presents the empirical results, while Section 5 concludes the study.

2. Decomposing growth and productivity

Although classical economic growth models assume technical efficiency and production always occurs on the production frontier, the occurrence of technical inefficiency in a production function can be shown by using a stochastic frontier model (Aigner et al., 1977; Battese and Coelli, 1988, 1992; Greene, 2005),

$$Y_t = F(X_{1t}, X_{2t}, \cdots, X_{nt}, t)e^{-u_t}, \tag{1}$$

where Y is the actual level of output; F is the potential production function with n inputs; X_{it} is i^{th} input; and u is a half-normally distributed random variable with a positive mean. The inclusion of t in F allows for the production function to shift over time due to technical progress. The last term e^{-u_t} measures technical inefficiency. Taking logarithm transformation yields

$$\log Y_t = \log F(X_{1t}, X_{2t}, \cdots, X_{nt}, t) - u_t. \tag{2}$$

Technical inefficiency occurs when $u_t>0$ and the level of log Y_t is less than the level of log F. Differentiating Eq. (2) with respect to time yields the following output growth equation:

$$\dot{Y}_t = \sum_i \frac{\partial F}{\partial X_{it}} \frac{X_{it}}{F} \dot{X}_{it} + \frac{\partial F / \partial t}{F} - \frac{\partial u_t}{\partial t}, \tag{3}$$

where $\dot{Y}_t = \frac{\partial Y_t / \partial t}{Y_t}$ is the growth of output and $\dot{X}_{it} = \frac{\partial X_{it} / \partial t}{X_{it}}$ is the growth of input X_{it}. Define $e_{it} = \frac{\partial F}{\partial X_{it}} \frac{X_{it}}{F}$ as the output elasticity for input X_{it}. Let $e_t = \sum_i e_{it}$ (the sum of the elasticity to each input). It can be shown that e_t is a measure of returns to scale. Suppose changes in all inputs have the same scale, $\Delta X_{it} = aX_{it}$. Consider the changes in output ΔF by taking the total derivative of $F(X_1, X_2, \cdots, X_n, t)$ and substituting $\Delta X_{it} = aX_{it}$ into ΔF, we have the following:

$$\Delta F = \sum_i \frac{\partial F}{\partial X_{it}} \Delta X_{it} + \frac{\partial F}{\partial t} \Delta t = F \sum_i \frac{\partial F}{\partial X_{it}} \frac{aX_{it}}{F} + F\dot{A}_t = Fa \sum_i e_{it} + F\dot{A}_t$$
$$= aFe_t + F\dot{A}_t, \tag{4}$$

where $\dot{A}_t = \frac{\partial F / \partial t}{F}$ is technical progress. The production shows increasing (constant, decreasing) returns to scale when $e_t>1$ $(=1, <1)$.

Define the technical efficiency (TE) as the ratio of the actual output and the potential output, $TE_t = \frac{Y}{F} = e^{-u_t}$. Then, the growth of the technical efficiency $T\dot{E}_t$ is

$$T\dot{E}_t = -\frac{\partial u_t}{\partial t}. \tag{5}$$

The output growth can be represented as

$$\dot{Y}_t = \sum_i e_{it} \dot{X}_{it} + \dot{A}_t + T\dot{E}_t. \tag{6}$$

Consider the following cost minimization problem under perfect competition in the factors markets, but not necessary in the product market.

$$\min_{X_{it}} C_t = \sum_i w_{it} X_{it} \text{ subject to } Y_t = F(X_{1t}, X_{2t}, \cdots, X_{nt}, t)e^{-u_t}. \tag{7}$$

We express the objective function and the constraint in the Lagrangian form.

$$L(X_{it}, \lambda) = \sum_i w_{it} X_{it} + \lambda(Y_t - Fe^{-u_t}), \tag{8}$$

where λ is the Lagrange multiplier. The first-order condition for minimization is the following:

$$w_{it} = \lambda \frac{\partial F}{\partial X_{it}} e^{-u_t}. \tag{9}$$

Or,

$$w_{it} = \lambda \frac{\partial F}{\partial X_{it}} e^{-u_t} = \lambda \frac{\partial F}{\partial X_{it}} \frac{X_{it}}{F} \frac{F}{X_{it}} e^{-u_t} = \lambda e_{it} \frac{Y_t}{X_{it}}. \tag{10}$$

Multiplying both sides by X_{it},

$$w_{it} X_{it} = \lambda e_{it} Y_t. \tag{11}$$

Taking the sum of all inputs, the total cost is the following:

$$\sum_i w_{it} X_{it} = \sum_i \lambda e_{it} Y_t. \tag{12}$$

Or,

$$C_t = \lambda e_t Y_t. \tag{13}$$

Denote the cost share of input X_{it} as s_{it}. Dividing Eq. (11) by Eq. (13), the cost share is the following:

$$s_{it} = \frac{w_{it} X_{it}}{C_t} = \frac{e_{it}}{e_t}. \tag{14}$$