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Total factor productivity of Korean manufacturing industries: Comparison of competing models with firm-level data

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ABSTRACT

This paper presents the parametric estimation of the rates of technical change and total factor productivity (TFP) growth of 7462 Korean manufacturing firms over the period 1987–2007. Two alternative formulations of technical change measured by the time trend and the general index approaches are estimated with panel data models assuming flexible functional forms. Several extensions of each approach are also considered and their benefits and limitations are discussed. In addition to making estimates of the TFP growth and its decomposition, the paper compares the parametric TFP growth measure with the non-parametric Solow residual serving as a benchmark. Several hypotheses related to technology level, firm sizes, industrial sectors, skill biased technological change and macroeconomic and industrial policies are tested to explain the growth patterns and heterogeneity in technical change, input biases and TFP growth rates. Using second regression analysis, the paper explores the determinants of TFP growth and their policy implications.

1. Introduction

Dynamic modeling of production functions has long been regarded as one of the interesting research topics by theoretical as well as applied researchers. The reason for its popularity is that finding appropriate production functions plays an important role in analyzing total factor productivity (TFP) growth and its decomposed sources. If a rich set of panel data is available, more sophisticated modeling can be conducted, enabling applied researchers to provide more reliable and practicable policy implications with respect to TFP growth. Considerable effort has been devoted to quantifying the rate of TFP growth and its components, and the following four main methodological strands have resulted: (a) econometric estimation of cost and production functions, (b) Divisia indexes, (c) exact index numbers and (d) nonparametric methods using linear programming (Diewert, 1981).

The econometric approach, which has dominated the applied research in the field of industrial economics, often assumes that technical change is generally represented by a simple time trend. It has a strong point in that it reveals long-run trends of technical change in an appropriate way when examining the behavior of manufacturing industries. This strong point comes from the fact that capital equipment, which rarely shows abrupt change over time, is the main determinant of long-run technical change and productivity growth. However, the use of the time trend model has been criticized for being merely the reflection of our ignorance about technical change. This weakness of the time trend model is overcome by the seminal work by Baltagi and Griffin (1988), in which the time trend is substituted by a general index in order to depict the *unknown* state of technology. The advantages of the general index model over the standard time trend model are summarized in Baltagi and Griffin (1988). The main advantage of the general index model is that it does not require any assumptions on the behavior of technical change.

We use parametric approaches to measuring TFP growth, technical change, returns to scale, biases in technical change and

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input elasticities of Korean manufacturing industries. The aforementioned two main strands of production functions, the time trend model (hereafter, TT1 model) and the general index model (hereafter, GI1 model), are used as a starting point of our model specifications in capturing the patterns of technical change. We also extend the TT1 and GI1 models since the basic models fail to provide firm-specific measures of technical change. The failure arises when: (a) the TT1 and GI1 models cease to provide firm-specific technical change if technical change is neutral, (b) firms confronting the same inputs and output prices yield the same measures of TFP growth, technical change, and returns to scale, for instance. In this sense, the TT1 and GI1 models play no role in measuring firm-specific TFP growth, technical change, returns to scale and biases insofar as one of the above conditions arises. Only intercepts are firm-specific with these specifications, which might not be sufficient to capture the economically meaningful firm-specific heterogeneity. Hence, it is necessary to alleviate the *implicitly restrictive* assumptions imposed on the conventional basic approaches. To consider this alleviation in our dynamic modeling, we allow flexibility by using *less* restrictive patterns in technical change.

In order to examine TFP growth and its relevant measures with these alleviated assumptions and to provide more economically meaningful concepts inherent in the measures, we have extended the two basic models. The first extension of the TT1 model incorporates firm-specific technical change, and is labeled as the TT2 model, which adopts the Cornwell et al. (1990) model, where the time-varying technical inefficiency of the Cornwell et al. (1990) model is interpreted as the firm-specific neutral rate of technical change. The second extension of the TT1 model, the TT3 model, removes inherited restrictions further, by making all components firm-specific. All the interaction terms of time and input factors are set to be firm-specific in the TT3 model. The corresponding two extensions of the GI1 models are as follows. The GI2 model interprets the time-varying firm-specific technical inefficiency of the Lee and Schmidt (1993) model as neutral firm- and time-specific technical change. The GI3 model generalizes the GI2 model by allowing both neutral and non-neutral components of technical change to be firm- and time-specific. The parametric TFP growth measures are also further compared with the non-parametric Solow residuals. The latter serves as a benchmark.

This paper employs the aforementioned six models to investigate the patterns in TFP growth of Korean manufacturing industries for the ‘roller-coaster period’ of 1987–2007. The following are the reasons for choosing the study period. After the Korean War in 1950, Korea showed a very rapid economic growth due to state-led economic planning during the 1960s and 1970s. The manufacturing industries have been chosen to be the main engines for developing the economy ever since this period. In the 1980s, most of the state-led economic planning was challenged. This challenge was regarded as an attempt to remove the old regime and to replace it with a new one, although the latter was autocratic from the political point of view. High-ranked bureaucrats attempted to transform the economy into a freer market system with export-driven and conglomerate-friendly policies (Park and Kim, 2008).

The Korean economy continued to grow until 1997, and reached per capita GDP of $10,000 in that year. However, the economy encountered the Monetary Crisis in November 1997. Macroeconomic statistics show that the economy was affected severely by the Crisis. GDP decreased by 6.7 percent in 1998 and fixed investment contracted by almost 40 percent. Average monthly bankruptcies surpassed 3000 in 1998. However, the economy recovered shortly after, and the government declared that the Crisis was formally ended in 2001. Despite this quick recovery from the 1997 crisis, another Crisis in 2003, the Credit Crunch Crisis, emerged and was overcome shortly after in the same year. The Credit Crunch Crisis was somewhat different from the Monetary Crisis in that the former was initiated by the high debts of households while the latter was initiated by the poor capital structure of enterprises.

Unlike previous studies, many of which employ macroeconomic tools to investigate the ‘roller-coaster period’, we examine this period from the microeconomic perspective. This attempt was justified for the following reasons. The microeconomic investigation, as a substitute of the macroeconomic approach, is likely to yield unexplored information about the crises. The rationale of this counterpart study is that the total sum of the behavior of micro agents is not necessarily the same as the aggregate macroeconomic output (Dopfer et al., 2004). We employ the aforementioned six econometric models in investigating firm-level TFP growth and its component during the roller-coaster period. We also use a large number of observations to guarantee robust and informative empirical investigation results.

The number of unique firms in our sample is 7462 and the total number of observations is 60,868. A comparison is made of the measures of TFP growth and rate of technical change in the manufacturing industry. We also compare the scale properties of the industry regarding input elasticities, returns to scale, and input and scale biases calculated from the competing models. The determinants of TFP growth and their impacts are also investigated.

The rest of the paper is organized as follows. Section 2 provides the theoretical framework of modeling TFP growth, technical change, input elasticities, returns to scale, and input and scale biases. Data on the Korean manufacturing industry is presented in Section 3. Section 4 discusses the model specifications, estimation methods, specification tests and empirical results. Finally, Section 5 briefly concludes this paper.

2. Models

2.1. Productivity and technical change

We assume that the firms' production function is best described as the following relationship between output, inputs and technology:

$$Y = f(X, t), \tag{1}$$

where Y is a scalar output, X is a vector of inputs ($j = 1, \ldots, J$), and t is the time trend variable representing technology. Taking total differential of Eq. (1) gives us the following equation:

$$\dot{Y} = \sum_j \frac{f_j X_j}{Y} \dot{X}_j + \frac{f_t}{Y} = \sum \epsilon_j \dot{X}_j + \frac{f_t}{Y}, \tag{2}$$

where the “dot” over a variable represents its growth rate. In Eq. (2), f_j is the marginal product of the jth input, and ε_j is the corresponding input elasticity.

We assume that the firms minimize cost and the input markets are competitive. Then, the relationship in Eq. (2) can be rewritten as:

$$\dot{Y} - \sum_j S_j \dot{X}_j = \frac{f_t}{Y} + (RTS - 1) \sum_j S_j \dot{X}_j, \tag{3}$$

where S_j is the cost share of jth input, and $RTS = \sum_j \epsilon_j$ denotes the returns to scale. The left-hand side of Eq. (3) is referred to as the Divisia index of TFP, expressed as:

$$TFP_{DIV} = \dot{Y} - \sum_j S_j \dot{X}_j \tag{4}$$

If price data is available to obtain the input cost shares, the above TFP growth measure can be calculated without an