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Productivity with general indices of management and technical change

T.P. Triebs [a,*], S.C. Kumbhakar [b]

[a] Ifo Institute - Leibniz Institute for Economic Research at the University of Munich, Poschingerstrasse 5, 81679 Munich, Germany

[b] Department of Economics, State University of New York, Binghamton, NY 13902, United States

HIGHLIGHTS

- We contribute to the nascent literature on the inclusion of observed management into models of production.
- Our general indices models allow technical change to be induced by time and management.
- Time-induced technical change varies with the level of management but the variance over time dominates.
- Management-induced technical change is higher for lower levels of management.

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ABSTRACT

We propose a model of production where technical change is both time and management induced. We define a general management index in addition to the general time index of Baltagi and Griffin (1988) and use them as arguments in the translog production function. Time and management induced technical change are then defined in terms of these general indices. For comparison, we also consider models in which time and management are specified as continuous variables. We report empirical results for a sample of manufacturing firms in the US, UK, Germany and France.

1. Introduction

Business scholars have long maintained that management is an important factor in production. And it is often perceived to be qualitatively different from conventional input factors and attracts special attention. Yet, there is little empirical evidence on how management contributes to production and productivity. To better understand how management affects production we let technical change vary with the level of managerial capability of the firm. That is, we do not only associate technical change with time but also with management.

Empirical modeling of technical change (i.e., the shift in the production function over time) faces a challenge in terms of a trade-off between the flexibility of the production technology and the flexibility with which technical change is characterized (Baltagi and Griffin, 1988; Kumbhakar and Heshmati, 1996; Kumbhakar and Sun, 2012). Index number models (Solow, 1957; Diewert, 1976) allow a fully flexible representation of technical change at the cost of a very restricted model of production (e.g.: constant returns to scale, competitive input and output markets, neutral technical change). Alternatively, econometric models (Tinbergen, 1942; Gollop and Roberts, 1983) offer flexibility for the production technology but require technical change to be a function of time only. In their seminal paper Baltagi and Griffin (1988) overcame this trade-off and introduced an econometric model in which technical change is represented by a general index of time. We generalize their model further by including a management index in addition to the general time index. Just like a general time index model can free technical change from the straitjacket of the time trend, our management index model can free an ordinal variable from the straitjacket of modeling it as a continuous variable. Our

* Corresponding author. Tel.: +49 8992241258.
E-mail addresses: triebs@ifo.de (T.P. Triebs), kkar@binghamton.edu (S.C. Kumbhakar).

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model allows us to define technical change in terms of a time trend (the traditional one) as well as management (which we call management-induced technical change). This is because the technology (production function in our case) shifts over time as well as with the level of management which is observed in our data.

Our results show that the higher the level of management practice the lower the time-induced technical change. This might seem surprising but we believe there are good (competing) explanations. It is possible that a lower quality of management correlates with more organizational flexibility which in turn makes it easier to exploit opportunities for technical change. Alternatively, well managed firms might already have exploited their potential and therefore have lower technical change. For management-induced technical change we also find evidence (albeit less robust) that technical change is higher for lower levels of management. Again, this might suggest that there are decreasing returns to management.

2. Model

We start from the following specification of the production function

$$y = f(x, z, t), \tag{1}$$

where y is output, x is a vector of conventional inputs, z is a management variable and t is time trend. Since the management variable is reported on a 1–5 scale we can specify it as either continuous or an index defined from different discrete levels of management. Similarly, time can be treated as a continuous variable or specified as an index from time dummies. These models are known as the time trend and general index models. Since we view management as a shift variable like a time trend, technical change (a measure of the shift in the production function) can be driven by time and/or induced by management. Parametric versions of (1) can be specified in several ways depending on how time and management variables are treated. We alternatively treat technical change and/or management as either continuous or as a general index. That is, the management variable is treated either as continuous (1–5), or we define 5 management dummies $D_m,\ m = 1, \ldots, 5$.

Model 1 (the baseline model): here both management z and time t are treated as continuous variables. The resulting translog form of (1) is

$$\begin{aligned}\ln y_{it} = {} & \beta_c + \sum_j \beta_j \ln x_{jit} + \frac{1}{2}\sum_j\sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} \\ & + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_j \beta_{jt} \ln x_{jit} t + \beta_z z_i + \frac{1}{2}\beta_{zz} z_i^2 \\ & + \sum_j \gamma_{jz} \ln x_{jit} z_i + \delta z_i t,\end{aligned} \tag{2}$$

where the subscripts i, t and c represent firm, time and country. The intercept is country specific. Since the management variable in our data is time invariant it does not have a time subscript. However, in general, the z variable is likely to vary in both i and t dimensions.

In Model 1 (time-induced) technical change (TC), which is the derivative of $\ln y_{it}$ with respect to time, is

$$\mathrm{TC}_{1it} = \beta_t + \beta_{tt} t + \sum_j \beta_{jt} \ln x_{jit} + \delta z_i. \tag{3}$$

In a similar fashion, management-induced technical change (MTC) can be defined as the percentage change in output with respect to a change in management, *ceteris paribus*,

$$\mathrm{MTC}_{1it} = \beta_z + \beta_{zz} z_i + \sum_j \gamma_{jz} \ln x_{jit} + \delta t. \tag{4}$$

Model 2: time is continuous but the management variable is an index, defined as $M(z_i) = \sum_{m=1}^{5} \theta_m D_{mi}$ where θ_m are unknown parameters. The translog form of it is

$$\begin{aligned}\ln y_{it} = {} & \beta_c + \sum_j \beta_j \ln x_{jit} + \frac{1}{2}\sum_j\sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} \\ & + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_j \beta_{jt} \ln x_{jit} t + M(z_i) \\ & + \sum_j \gamma_j \ln x_{jit} M(z_i) + \delta M(z_i)\, t.\end{aligned} \tag{5}$$

Unlike in (2), the management index model in (5) is non-linear because of the interaction terms between inputs and the management index function. Note the difference between this model and a model in which the management dummies appear additively as well as interactively with all other regressors. The latter model is more general and is equivalent to running separate regressions for each level of management which assumes that the production technology differs with the level of management. In the general index model management is treated like any other covariate. The model in (5) is more parsimonious than a dummy model specification, especially when management is constructed from Likert scale variables containing a fairly large number of groups. Technical change in this model is

$$\mathrm{TC}_{2it} = \beta_t + \beta_{tt} t + \sum_j \beta_{jt} \ln x_{jit} + \delta M(z_i). \tag{6}$$

And management-induced technical change is

$$\mathrm{MTC}_{2it} = (M(z) - M(z-1))\left(1 + \sum_j \gamma_j \ln x_{jit} + \delta t\right). \tag{7}$$

Compared to (4) this allows the effect of management to be more "erratic" (not smooth). Also factor inputs and the time trend have no impact on management-induced technical change in the absence of pure management-induced technical change. That is there can be no factor bias or scale augmentation in the absence of pure management-induced technical change which is represented by $M(z) - M(z-1)$.

Model 3: management is continuous but the time trend in Model 1 is replaced by a time index $A(t) = \sum_{t=1}^{T} \lambda_t D_t$ à la Baltagi and Griffin (1988)

$$\begin{aligned}\ln y_{it} = {} & \beta_c + \sum_j \beta_j \ln x_{jit} + \frac{1}{2}\sum_j\sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} \\ & + A(t) + \sum_j \beta_{jt} \ln x_{jit} A(t) + \beta_z z_i + \frac{1}{2}\beta_{zz} z_i^2 \\ & + \sum_j \gamma_{jz} \ln x_{jit} z_i + \delta z_i A(t).\end{aligned} \tag{8}$$

The original motivation for this model stems from Solow (1957) who replaced the time trend in a parametric model by an index $A(t)$. Baltagi and Griffin (1988) specified $A(t)$ as time-specific dummies. Again, the model in (8) is more parsimonious than a dummy model, especially when T is large (see Baltagi and Griffin, 1988, p. 27, for more on this point).

Technical change in Model 3 is

$$\mathrm{TC}_{3it} = (A(t) - A(t-1))\left(1 + \sum_j \beta_{jt} \ln x_{jit} + \delta z_i\right), \tag{9}$$

and management-induced technical change is

$$\mathrm{MTC}_{3it} = \beta_z + \beta_{zz} z_i + \sum_j \gamma_{jz} \ln x_{jit} + \delta A(t). \tag{10}$$