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Productivity growth measurement and decomposition under a dynamic inefficiency specification: The case of German dairy farms

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ABSTRACT

Standard parametric models for efficiency and total factor productivity growth measurement either impose strict structures on the time-evolution of efficiency scores or no structure at all. When the data capture a sector in turbulent periods both specifications may be inappropriate. The dynamic stochastic frontier model takes a middle way in terms of the time-structure it imposes on efficiency scores. We apply the dynamic stochastic frontier model to the case of German dairy farms in a period that is characterized by high milk price volatility. The model is able to capture time-specific efficiency and total factor productivity growth shocks that may have been induced by this high volatility. Furthermore, the dynamic stochastic frontier model is favored by the data when compared to a model that imposes a very restrictive time structure on efficiency and two models that do not impose any time structure at all.

1. Introduction

The evaluation of the competitiveness of a sector has, traditionally, been based on the measurement of Total Factor Productivity (TFP) growth, defined as the ratio of output growth rate to input growth rate. In agriculture, TFP growth is used as an indicator of the ability of farms to generate high income and factor employment levels, while being exposed to both domestic and international competition (Newman & Matthews, 2007). High productivity growth is, therefore, essential to assure that a country's agricultural sector survives competitive pressures from abroad, but also from other sectors within the country. Assessing the critical role that TFP growth plays in determining whether a sector will survive or perish in a competitive environment requires that precise estimates are obtained. Given that TFP growth is a dynamic concept, the modeling approach should be able to capture potential shocks that may be due to bad weather conditions, pest outbreaks or high price volatility. For instance, in the specific context of dairy farms, Germany (as well as most of the European Union countries), has experienced large milk price changes towards the end of the first decade of the 21*st* century. More specifically, milk prices have steeply increased from 2007 to 2008, reaching a peak of 35.01€ /100 kilograms in 2008, while in 2009, they sunk to 25.25€ /100 kilograms (EUROSTAT, 2016). All the aforementioned price changes make German dairy farms an interesting case for measuring changes in farm efficiency and, more generally, TFP growth. This is because abrupt changes in output prices motivate farmers to rapidly alter their production levels, and potentially the efficiency of their resource utilization.

Detecting efficiency changes that can result in TFP growth volatility depends on the specification of inefficiency. In a parametric setting, measurement and decomposition of TFP growth relies on the estimation of the production frontier using the technique of Stochastic Frontier Analysis (SFA), introduced by Aigner, Lovel, and Schmidt (1977) and Meeusen and van den Broeck (1977). The most challenging task while measuring the efficiency of the decision making units concerns the assumptions made for the inefficiency component. In a cross-sectional setting, one should only be concerned with the distributional assumptions made. However, when panel data are available, the assumptions of time-invariant versus time-varying inefficiency become the focus of attention. Since the assumption of time-invariant inefficiency is very restrictive, several models have been developed that relax this assumption. For instance, Cornwel, Schmidt, and Sickles (1990) and Kumbhakar (1990) specified inefficiency as a quadratic function of time, while Battese and Coelli (1992) assumed that time-invariant inefficiency

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is scaled by a simple function of time. Specification of inefficiency as a quadratic function of time turns out to be more flexible than the Battese and Coelli model, which allows inefficiency to be either always increasing or decreasing with the passage of time. Furthermore, the Battese and Coelli model imposes uniform efficiency trends, while Cornwel et al. (1990) allow for heterogeneity between observations[1]. However, parametric efficiency studies that have attempted to measure and decompose TFP growth have mostly considered the Battese and Coelli (1992) approach. For instance, Newman and Matthews (2007), Emvalomatis (2012b) and Kellermann (2015) used the aforementioned inefficiency specification to measure and decompose the productivity growth of Irish agricultural enterprises and German dairy farms. This is primarily because the Battese and Coelli (1992) inefficiency specification usually produces smooth efficiency change results. Furthermore, the approach proposed by Cornwel et al. (1990) requires a large number of parameters to be estimated and consistency can only be met if the time dimension of the panel goes to infinity, while the model of Kumbhakar (1990) may be problematic as the identification of two parameters from a latent process is questionable. However, the major flaw of all the aforementioned specifications is that inefficiency is treated as a deterministic function of time and cannot capture abrupt shocks in the environment in which firms operate. This implies that these models may be unable to capture potential changes in efficiency and TFP growth that could result from the steep milk price changes mentioned above.

An alternative specification for time-varying inefficiency that does not impose any time structure on inefficiency assumes that, for each time period, inefficiency is a random draw from an one-sided distribution. This specification offers also the option to examine the potential drivers of inefficiency by allowing the mean of the distribution to be a function of firm-specific characteristics. For instance, Battese and Coelli (1995) assumed that for each time period, inefficiency is a random draw from a truncated normal distribution, while Koop, Osiewalski, and Steel (1997) use an exponential distribution, as it behaves better when Bayesian techniques are employed. In the efficiency and productivity measurement literature, this approach has been used by Brümmer, Glauben, and Thijssen (2002), Alvarez and del Corral (2010), and Sauer and Latacz-Lohmann (2015), who evaluated the productive performance of dairy farms. Meanwhile, Cechura, Grau, Hockmann, Levkovych, and Kroupova (2016) used it to perform TFP country comparisons for the European dairy sector. A similar (in the sense that inefficiency is a random draw from a one-sided distribution) but more recent model adds to the specification described above a one-sided non-negative time-invariant error component that aims to capture time-invariant (persistent) inefficiency and separate it from time-varying (transient) inefficiency. This model was introduced by Tsionas and Kumbhakar (2014) and is called the Generalized True Random Effects (GTRE) model. Recent applications of this model include Badunenko and Kumbhakar (2016) and Badunenko and Kumbhakar (2017). Irrespective of disentangling or not time-invariant from time-varying inefficiency, such specifications, in contrast to the Battese and Coelli (1992) model that imposes a very restrictive time structure on inefficiency, have the potential of capturing time-specific shocks in firm-level efficiency. However, they may also produce erratic results due to the complete absence of a time structure for inefficiency.

A more flexible specification for the inefficiency component that does not lie on the extremes of either imposing a very restrictive or a non-existing time structure on inefficiency, is one that allows for autocorrelation in firm-specific efficiency scores. The economic justification of this specification stems from the fact that firms' decisions have an intertemporal nature and concern an objective that extends in the long-run. Examples of such an objective is the maximization of discounted cash flows or the minimization of discounted costs. In such a dynamic setting, farmers face adjustment costs that make investing on a regular basis too costly (Stefanou, 2009). Therefore, if a firm is inefficient at a certain point in time, becoming fully efficient may not be optimal due of the existence of adjustment costs. This implies that it's optimal strategy may be to remain inefficient in the short-run, and therefore it's inefficiency will persist. The dynamic specification that is employed in the paper accounts for this persistence by assuming that inefficiency is autocorrelated. The first study that attempted to account for persistent shocks in firms' efficiency is the study of Ahn and Sickles (2000), who specified an autoregressive process on firm-specific efficiency scores. To overcome the complications that arise when specifying an autoregressive process on a non-negative variable, Tsionas (2006) specified an autoregressive process on transformed efficiency that can take any value on the real line. Subsequent studies on dynamic efficiency have followed the latter approach, with minor adjustments concerning the way that efficiency is transformed (Emvalomatis, 2012a; Emvalomatis, Stefanou, & Oude Lansink, 2011; Galán, Veiga, & Wiper, 2015). All studies find strong autocorrelation in efficiency scores, adding credibility to the adjustment cost theory. In contrast to the restrictive time structure for inefficiency that the Battese and Coelli (1992) model assumes, the dynamic efficiency specification offers a less restrictive time structure that can capture abrupt changes in firm-level efficiency and TFP growth. On the other hand, since it does not allow for the time evolution of efficiency scores to be completely arbitrary, the results should be more stable compared to models that do not impose any time structure on inefficiency scores.

The main objective of this paper is to measure and decompose TFP growth of German dairy farms for the period 2001–2009, using the dynamic (autoregressive) efficiency specification, which accounts for persistence of the effect of shocks on farm-level efficiency. The main contribution to the literature is that, to the best of our knowledge, this is the first study that uses this specification to calculate and decompose TFP growth. Furthermore, given that the time period under consideration is characterized by high price volatility, the dynamic efficiency specification could reveal abrupt changes in efficiency and TFP growth, as it can capture (persistent) time-specific efficiency shocks. The results from the dynamic efficiency specification are compared with those from a model that imposes the time structure of Battese and Coelli (1992), and two models that impose no time structure on efficiency. Additionally, formal model comparisons are performed to infer which of the models fit the data better. The remainder of the paper proceeds as follows: the next section describes the modeling approach, while Section 3 provides details on the estimation of the models. Section 4 describes the data, and Section 5 presents and discusses the results. Finally, Section 6 offers some concluding remarks.

2. Modeling approach

2.1. Distance functions and efficiency

We use an output distance function to measure efficiency in a multi-output production technology. Assuming that a vector of inputs $\tilde{\boldsymbol{x}} \in R_+^N$ is used to produce a vector of outputs $\tilde{\boldsymbol{y}} \in R_+^M$, the output distance function is defined as:

$$D_o(\tilde{\mathbf{x}}, \tilde{\mathbf{y}}, t) = \min\left\{\theta : \frac{\tilde{\mathbf{y}}}{\theta}\ \text{ can be produced by}\,\tilde{\mathbf{x}}\,\text{in period } t\right\} \quad (1)$$

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[1] Cuesta (2000) extended the Battese and Coelli model in a way that firm-specific efficiency scores are obtained.