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A new approach to estimating a profit frontier using the censored stochastic frontier model

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ABSTRACT

The translog profit functional form is widely used to study technical efficiency for banks. Although this functional form is known as being flexible, it is not applicable to those banks incurring economic losses. The recently developed approach, i.e., the censored stochastic frontier model (CSFM), by Tsay et al. (2013) appears to be superior to existing approaches, since CSFM does not need to transform negative profit into positive profit before taking the natural logarithm. The transformation with respect to the profit variable tends to bias the parameter estimates of the profit frontier and the subsequent profit efficiency measure. We show that the parameter estimates of CSFM have the desirable statistical properties. Moreover, empirical results reveal that the mean profit efficiency of CSFM is more robust than those models using transformed profits across the sub-periods 1991–1998 and 1999–2009.

1. Introduction

There have been many studies on the profit efficiencies (PE) of financial institutions over the past several decades that differ largely from the cost efficiency scores, implying the importance of the revenue side on the measurement of bank performance.[1] The study of profit frontiers for banks can provide more information for managers' references than cost frontiers that use information up to the expenditures of inputs hired and completely exclude the role of total revenue. This paper estimates the profit frontiers of Taiwan's banking industry, together with technical efficiency, under the assumption of perfect competition. Taiwan's banking sector consists of many small-sized banks and each of them takes a small market share. Therefore, perfect competition seems to be a valid assumption to characterize this condition of "over-banking".

Because banks in the sample may unfortunately incur losses during the period covered, the popular translog functional form is not specifically applicable for negative profits. One cannot take the natural logarithm with respect to a negative value. To date, three methods are suggested to deal with this problem. First, one simply dismisses those observations with negative profit values (henceforth, the dismissal approach). See, for example, Huang (2000). This approach obviously does

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[1] Existing research studies on the estimation of a profit function can be classified into the standard profit function and the alternative profit function. The former assumes that the input and output markets are perfect competition. Given the input and output price vectors, firms maximize their profits by adjusting the quantities of inputs and outputs. The latter allows for the possibility of imperfect competition in output markets so that output prices are replaced by output quantities. See, for example, Maudos, Pastor, Perez, and Quesada (2002), Maudos and Pastor (2003), Kasman and Yildirim (2006), Bos and Schmiedel (2007), Ariff and Can (2008), Berger, Hasan, and Zhou (2009), and Ray and Das (2010).

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not fully utilize the sample information, since these omitted observations contain useful information on a firm's input–output and exit decisions.

Second, one can inflate the profits (henceforth, the inflating approach) of all sample firms by adding the sum of the absolute value of the minimum (negative) profit in the sample and unity to each firm's observed profit, e.g., Maudos et al. (2002), Berger & di Patti (2006), and Fitzpatrick and McQuinn (2008). This second approach is the mainstream in the literature, but it distorts the original information embedded in the dependent (profit) variable due to an ad hoc amount being added. This causes the parameter estimates to be inconsistent. Even worse, the subsequent measures of technical efficiency and scale and scope economies, calculated by using these parameter estimates, are also misleading.[2]

Third and finally, an indicator approach, which Hasan, Koetter, and Wedow (2009) and Bos and Koetter (2011) propose, recommends that only profits of loss-incurring firms are altered into unity and an extra explanatory variable, say z, is created and takes the absolute value of the negative profit for the loss-incurring firm. The profits of profit-making firms remain intact, and the variable z takes a value of unity. Similar to the inflating approach, estimators from the indicator approach are devoid of desirable statistical properties.

This paper proposes a different approach from the above three methods, under the framework of a censored regression model with composed errors, i.e., the censored stochastic frontier model (CSFM). A bank incurring economic losses is treated as a censored sample whose (log)profit is set to equal an arbitrarily small value of $c > 0$, which is a threshold level of profit. In this manner, the dependent variable of profit is not continuous for loss-incurring banks and is set to equal c, but is continuous and recorded as the actual level if the bank makes a positive profit. The advantages of such a treatment for a loss-incurring bank are threefold. First, the censored sample remains in the data and can be used to estimate the parameter in the profit frontier – that is, CSFM allows one to fully utilize the entire sample. Second, no adjustment for profits is required, thus avoiding any potential distortion of the dependent variable. Amemiya (1973) proves that the maximum likelihood estimators of the Tobit model (Tobin, 1958) are consistent and asymptotically normal. Third, as can be seen in Section 3, CSFM is easily implemented and the resulting parameter estimates have the desirable properties.

This article introduces a new methodology to formally address the above issue by extending the conventional censored regression model (Tobit model) to the stochastic frontier context, characterized by composed errors. To our knowledge, it is the first work that applies CSFM to investigate profit efficiencies. The emergence of the composed errors in the profit frontier poses difficulty in deriving a closed-form cumulative distribution function (cdf) for the censored sample, as the probability density function (pdf) of the composed error cannot be directly integrated due to the fact that it has no closed form. This impedes the Tobit model with error components from being estimated by the maximum likelihood. Differing from Greene (2003,2010), who proposes the simulated maximum likelihood to approximate the integration, this paper derives a closed-form formula for the cdf of the profit frontier with censored observations, as first proposed by Tsay, Huang, Fu, and Ho (2013). Given the foregoing statements, the current paper contributes to the research on profit efficiency in the banking industry.

The remainder of the paper is organized as follows. Section 2 briefly reviews the literature mainly on the studies of bank efficiency scores. Section 3 introduces the methodology. Section 4 describes the data and variables employed. Section 5 delineates the empirical results, while Section 6 concludes the paper.

2. Literature review on bank efficiency

There are two definitions on Farrell's (1957) radial measure of technical efficiency: output-oriented and input-oriented measures. An output technically efficient firm can produce maximal output from a given input mix, and an input technically efficient firm is able to use a minimal input mix to produce a given set of outputs. Given an input mix, the output-oriented technical efficiency score of a firm measures how close the firm's actual output (cost or profit) level is to that of the best-practice firm on the efficient frontier. Given a set of outputs, the input-oriented technical efficiency score of a firm assesses deviations in its input mix from the predicted amounts of the best firms in the industry.

There are two popular approaches to measuring technical efficiency in the literature: the stochastic frontier approach (SFA) and data envelopment analysis (DEA). Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977) first introduce the former approach. Later, most existing works in the literature estimate either production or cost frontiers to measure technical efficiency. Profit frontiers are relatively less applied by empirical researchers. Huang (2000), Altunbas, Gardener, Moyneux, and Moore (2001), Kasman and Yildirim (2006), Fitzpatrick and McQuinn (2008), Berger et al. (2009), Koutsomanoli-Filippaki, Mamatzakis, and Staikouras (2009), and Akhigbe and Stevenson (2010), to name a few, employ SFA to estimate profit frontiers, as SFA allows for the presence of composite errors. One of them is a two-sided random disturbance, accounting for the random shocks uncontrollable by the bank under consideration, and the other is a one-sided non-negative random variable that represents production inefficiency. Bhaumik, Das, and Kumbhakar (2012) use SFA to model the financial constraints of firms. Kumbhakara, Parmeter, and Tsionas (2013) introduce the zero inefficiency stochastic frontier model to accommodate the presence of both efficient and inefficient firms in the sample.

[2] It is easy to show that the inflation approach leads to inconsistent parameter estimates in the context of a simple regression model.