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On Study of the Relationship between TCRI and Technical Inefficiency

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***Abstract*—In this paper, a stochastic frontier model with firm-specific technical inefficiency effects in a panel framework (Battese and Coelli, 1995) is used to examine whether a firm with better Taiwan Corporate Credit Risk Index (TCRI) provided by Taiwan Economic Journal attains higher technical efficiency. A special design matrix of discrete ordinal variables is used to study the effects of TCRI on technical inefficiency for firms in Taiwan under the two control variables, firm's age and size. Our empirical result shows that a firm with better TCRI generally has higher technical efficiency. Combining the result with the fact that economic-based efficiency measures are reasonable indicators of the long-term health and prospects of firms (Baek and Pagán, 2002), we conclude that TCRI is a good credit risk proxy for firms in Taiwan.**

Discrete ordinal variable; issuer credit rating; panel data; stochastic frontier model; technical efficiency

I. Introduction

Credit ratings have been extensively used by practitioners and regulators as a surrogate measure for the creditworthiness of bonds and companies. Under the New Basel Capital Accord (Basel II), credit ratings will play an even more important role in capital markets than they have so far. Currently, Taiwan Ratings Corporation and Taiwan Economic Journal (TEJ) are two popular credit rating agencies for companies in Taiwan. They routinely provide the issuer credit rating. The issuer credit rating is an overall assessment of the creditworthiness of a company.

The purpose of this paper is to examine whether the firm with better Taiwan Corporate Credit Risk Index (TCRI) provided by TEJ attains higher technical efficiency. A firm is characterized as technically inefficient if it is not able to reach maximum output given its available resources and technology. Analyzing the relationship between credit rating and economic efficiency is particularly important because economic-based efficiency measures are reasonable indicators of the long-term health and prospects of firms [1].

Stochastic frontier analysis is a method of economic modeling; see for example [9] and [14]. It has been widely used to estimate technical inefficiencies of production of firms; see for example the monographs [5] and [12]. It also has been used in studies of corporate financial decision and bank efficiency; see for example [2], [6], [7], [10], [11], and [13]. There are many software packages having capabilities to estimate the stochastic frontier model, for example, FRONTIER, LIMDEP, and STATA, etc.

In this paper, the linkages between TCRI and technical inefficiency are analyzed using a stochastic frontier model with firm-specific technical inefficiency effects in a panel framework [4]. The parameters of the production function are estimated simultaneously with those of technical inefficiency effects in the stochastic frontier model. We use discrete ordinal variables to express the categories of TCRI. A special design matrix of discrete ordinal variables is used to study the effects of TCRI on technical inefficiency for firms in Taiwan under two control variables, firm's age[1] and size. TEJ began to provide TCRI from 1995. Hence, we collect a panel dataset for firms having TCRIs during the years 1995-2008 in this paper. Using the panel dataset, the relationship between TCRI and technical inefficiency is studied. Our empirical result shows that a firm with better TCRI generally has higher technical efficiency. Combining the result with the fact that economic-based efficiency measures are reasonable indicators of the long-term health and prospects of firms [1], we conclude that TCRI is a good credit risk proxy for Taiwan firms.

[1] The variable Age denotes a firm's age which is defined as the number of calendar years it has been listed on the TAIWAN STOCK EXCHANGE (TWSE) or Over-the-counter Market (OTC) [6]. See [4] for the improvement of technical efficiency of firms over time.

II. METHODOLOGY

To examine the relationship between TCRI and technical inefficiency for firms in Taiwan, the stochastic frontier model proposed by [4] for panel data is considered. The advantage of using this model is that it permits the estimation of both technical change in the stochastic frontier and time-varying technical inefficiency. We use discrete ordinal variables to express the categories of TCRI. There are 9 categories in TCRI. Here $Y_{i,t} = k$ indicates that the value of TCRI of the i-th company in year t belongs to the category k, where $k \in \{1, \cdots, 9\}$. By the definition of TCRI, the smaller the value of $Y_{i,t}$, the better the TCRI category of the i-th company in year t.

Using a translog specification, the stochastic frontier production function for panel data in [8] is given by:

$$\ln(Q_{i,t}) = \gamma_0 + \gamma_1\, w_{i,t} + (\eta_0 + \eta_1 w_{i,t}) SIC_i + V_{i,t} - U_{i,t}, \quad (1)$$

for $t = 1, \cdots, t_i$ and $i = 1, \cdots, n.$ Here $\ln(Q_{i,t})$ is the natural logarithm of the dollar value of production $Q_{i,t}$ for the i-th firm at time t, and $Q_{i,t}$ is estimated as the sum of sales and inventory increase during the period from the time point $t-1$ to t;

$w_{i,t} = \{\ln(L_{i,t}),\ \ln(K_{i,t}),\ \ln(L_{i,t})^2,\ \ln(K_{i,t})^2,\ \ln(L_{i,t})\ln(K_{i,t})\}'$ is a 5×1 vector of explanatory variables related to the stochastic frontier production function for the i-th firm at time t;

$\ln(L_{i,t})$ is the natural logarithm of the total number of employees for the i-th firm at time t;

$\ln(K_{i,t})$ is the natural logarithm of the value of fixed assets for the i-th firm at time t;

SIC_i is an industry dummy variable for capturing differences in the production technology across two industry categories, electronic and non-electronic[2], for the i-th firm;

$V_{i,t}$s are independent and identically distributed $N(0, \sigma_v^2)$ random errors and independently distributed of $U_{i,t}$s;

$U_{i,t}$s are nonnegative random variables, associated with technical inefficiency effects, which are assumed to be independently distributed, such that $U_{i,t}$ is obtained by truncation (at zero) of the normal distribution with mean $\delta_0 + \delta_1 R_{i,t} + \delta_2 z_{i,t}$ and variance σ_u^2;

$R_{i,t}$ is an 8×1 vector with elements 0 or 1, and $z_{i,t}$ is a 2×1 vector of two control variables, Age and firm size, related to technical inefficiency effect $U_{i,t}$ for the i-th firm at time t;

γ_0, γ_1, η_0, η_1, δ_0, $\delta_1 = (\delta_{1,1}, \cdots, \delta_{1,8})$, and $\delta_2 = (\delta_{2,1}, \delta_{2,2})$ are unknown 1×1, 1×5, 1×1, 1×5, 1×1, 1×8, and 1×2 vectors of parameters to be estimated, respectively.

[2] $\text{SIC}_i = 1$ denotes electronic industry; $\text{SIC}_i = 0$ denotes non-electronic industry.

Let $\theta = (\gamma_0, \gamma_1, \eta_0, \eta_1, \delta_0, \delta_1, \delta_2)$, σ^2, and ζ be the unknown parameters in (1), where the variance parameters σ^2 and ζ are defined by $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\zeta = \sigma_u^2 / \sigma^2$. The values of θ, σ^2, and ζ can be estimated by maximizing the log-likelihood function of the panel data [3]. Their maximum likelihood estimates $\hat{\theta} = (\hat{\gamma}_0, \hat{\gamma}_1, \hat{\eta}_0, \hat{\eta}_1, \hat{\delta}_0, \hat{\delta}_1, \hat{\delta}_2)$, $\hat{\sigma}^2$, and $\hat{\zeta}$ can be simply computed using the free software FRONTIER Version 4.1 written by Professor Tim Coelli. That software is available at http://www.uq.edu.au/economics/cepa/frontier.htm.

Because economic-based efficiency measures are reasonable indicators of the long-term health and prospects of firms, it is important to observe the relationship between TCRI and technical inefficiency. In this paper, we use a special design matrix to study the effects of TCRI on firm's technical inefficiency. The special design matrix [15] is defined as follow:

δ_1 / Y_{it}	**Design matrix**				
	$\delta_{1,1}$	$\delta_{1,2}$	$\delta_{1,3}$	$\cdots$	$\delta_{1,8}$
1	0	0	0	$\cdots$	0
2	1	0	0	$\cdots$	0
3	1	1	0	$\cdots$	0
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\ddots$	0
9	1	1	1	$\cdots$	1

Using the design matrix, set $R_{i,t} = (R_{i,t,1}, \cdots, R_{i,t,8})^T$, where $R_{i,t,j} = I(Y_{i,t} > j),\ j = 1, \cdots, 8.$ Specifically, if $Y_{i,t} = k$, then $R_{i,t}$ is an 8×1 vector with the first $k-1$ components as 1 and all other components as 0, for each $k = 2, \cdots, 9.$ Further, if $Y_{i,t} = 1$, then $R_{i,t}$ is an 8×1 vector with all components as 0. Using the estimate $\hat{\delta}_1 = (\hat{\delta}_{1,1}, \cdots, \hat{\delta}_{1,8})$, we can examine whether a firm having better TCRI attains higher technical efficiency. If each element of $\hat{\delta}_1$ is positive, then it shows that a firm with better TCRI is generally more technically efficient than that with worse TCRI.

The technical efficiency of production for the i-th firm at time t is defined by $TE_{i,t} = \exp(-U_{i,t})$, which can be estimated by

$$\hat{E}[\exp(-U_{i,t}) \mid \varepsilon_{i,t} = \hat{e}_{i,t}] = \exp(-\mu_{i,t} + 0.5\phi^2) \times \frac{\Phi[(\mu_{i,t}/\phi) - \phi]}{\Phi(\mu_{i,t}/\phi)}, \quad (2)$$

where

$$\varepsilon_{i,t} = V_{i,t} - U_{i,t},$$

$$\hat{e}_{i,t} = \ln(Q_{i,t}) - \{\hat{\gamma}_0 + \hat{\gamma}_1 w_{i,t} + (\hat{\eta}_0 + \hat{\eta}_1 w_{i,t})SIC_i\},$$

$$\mu_{i,t} = (1-\hat{\zeta})(\hat{\delta}_0 + \hat{\delta}_1 R_{i,t} + \hat{\delta}_2 z_{i,t}) - \hat{\zeta}\hat{e}_{i,t},\ \phi^2 = \hat{\zeta}(1-\hat{\zeta})\hat{\sigma}^2,$$

and $\Phi(\bullet)$ represents the standard normal distribution function.

III. DATA

To study the relationship between TCRI and technical inefficiency for firms in Taiwan, a panel dataset for building the stochastic frontier model was collected from TEJ database. Since TEJ began to provide TCRI from 1995, our sample period is from 1995 to 2008. Because of regulations and adopting different accounting conventions, the financial services companies are excluded from the sample. Our panel dataset consists of the complete values of the explanatory variables in the production function and the two control variables, Age and firm's size, of companies having TCRIs during sample period. After deleting observations with missing values, our final sample for estimating the stochastic frontier model consists of 1,712 firms with 12,518 firm-year observations.

Table I shows the frequency distributions of industry categories and TCRI categories. Table II reports summary statistics for the other predictor values employed in estimating the stochastic frontier model.

IV. EMPIRICAL RESULTS

The empirical results based on the stochastic frontier models without and with TCRI in the inefficiency effect equation are given in Tables III and IV, respectively. Panel A in each of Tables III and IV shows that most of parameters of the production function are statistically significant at 5% level. The result of statistical significance for most of industry dummy variables indicates that the production technology indeed varies across industries.

Panel B in each of Tables III and IV shows that the estimated coefficient of control variable Age is positive and statistically significant at 1% level, which indicates that the old firms are less technically efficient than the young ones. It also shows that the estimated coefficient of control variable firm's size is negative and statistically significant at 1% level, which indicates that the large firms are more technically efficient than the small ones.

Panel C in Table III presents that the estimated variance parameter ζ is 0.999, and is statistically significant at 1% level. The result indicates that the inefficiency effect is likely to be important because most of the composite error variance σ^2 is accounted for by the variance of the inefficiency effect. Further, by performing a likelihood-ratio test, the null hypothesis that the values of parameters in inefficiency effect equation and ζ are all equal to zero is rejected at 1% level of significance. The test result is given in Panel D of Table III. The same remarks made for the variance parameter ζ using results in Panels C and D of Table III can also be obtained for that using results in Panels C and D of Table IV.

After controlling for firm's age and size in Table IV, most of the estimated coefficients for elements in $\hat{\delta}_1$ are positively correlated with technical inefficiency except $\hat{\delta}_{1,4}$ which is not statistically significant at 10% level. The result indicates that if a firm has a worse TCRI, then it is generally less technically efficient. Also, Table IV shows a larger log-likelihood statistic than Table III. The result indicates that the stochastic frontier model with TCRI indeed provides more information about firm's technical inefficiency than that without TCRI. Further, by comparing the values of $\hat{\sigma}^2$ and $\hat{\zeta}$ given in each of Tables III and IV, the corresponding estimated value for σ_u^2 in Table III is much larger than that

TABLE I. THE FREQUENCY DISTRIBUTIONS OF INDUSTRY CATEGORIES AND TCRI CATEGORIES FOR THE SAMPLED COMPANIES

Categories	Frequency
Panel A: industry categories	
Electronic	1,039
Non-electronic	673
Total firms	1,712
Panel B: TCRI categories	
1	190
2	343
3	558
4	1,580
5	2,656
6	3,501
7	1,933
8	1,113
9	644
Total firm-year obervations	12,518

TABLE II. SUMMARY STATISTICS OF THE PANEL DATASET USED TO ESTIMATE THE STOCHASTIC FRONTIER MODEL

Variable	Mean	Median	Standard deviation	Minimum	Maximum
$\ln(Q)$	14.685	14.563	1.384	6.229	21.120
$\ln(L)$	5.783	5.700	1.189	1.609	10.455
$\ln(K)$	13.327	13.329	1.771	2.639	19.872
Age	7.806	5.000	7.903	1.000	47.000
$\ln(A)$	15.051	14.913	1.313	11.143	20.290

TABLE III. MAXIMUM LIKELIHOOD ESTIMATES OF PARAMETERS IN THE STOCHASTIC FRONTIER MODEL WITHOUT TCRI IN THE INEFFICIENCY EFFECT EQUATION

Variable	Coefficient	Standard error
Panel A: Production function		
Intercept	19.214**	0.273
$\ln(L)$	0.092	0.094
$\ln(K)$	0.380**	0.065
$\ln(L)^2$	-0.089**	0.007
$\ln(K)^2$	-0.041**	0.004
$\ln(L)\ln(K)$	0.091**	0.009
SIC	0.672	0.405
$\ln(L)$ SIC	-0.686**	0.144
$\ln(K)$ SIC	0.332**	0.087
$\ln(L)^2$ SIC	0.103**	0.018
$\ln(K)^2$ SIC	-0.013	0.007

$\ln(L)\ln(K)$ SIC	-0.031	0.020
Panel B: Inefficiency effect equation		
Intercept	22.027**	0.158
Age	0.018**	0.001
$\ln(A)$	-1.011**	0.008
Panel C: Variance parameter		
σ^2	0.384**	0.005
ζ	0.999**	0.006
Panel D: Model fit test		
Log-likelihood	-11770.618	
Likelihood-ratio	9244.442**	

The notations ** and * indicate the significance of test at 1% and 5% levels, respectively.

in Table IV. The result indicates that the firm's technical inefficiency effects can be effectively explained by TCRI. Combining the empirical results with the fact that economic-based efficiency measures are reasonable indicators of the long-term health and prospects of firms, it is reasonable to conclude that TCRI is a good credit risk proxy of firms.

V. CONCLUDING REMARKS

Credit ratings have been extensively used by practitioners and regulators as a surrogate measure for the creditworthiness of bonds and companies. Under the New Basel Capital Accord (Basel II), credit ratings will play an even more important role in capital markets than they have so far. The purpose of this paper is to examine whether a firm with better TCRI provided by TEJ attains higher technical efficiency. Analyzing the relationship between credit rating and economic efficiency is particularly important because economic-based efficiency measures are reasonable indicators of the long-term health and prospects of firms.

TABLE IV. MAXIMUM LIKELIHOOD ESTIMATES OF PARAMETERS IN THE STOCHASTIC FRONTIER MODEL WITH TCRI IN THE INEFFICIENCY EFFECT EQUATION

Variable	Coefficient	Standard error
Panel A: Production function		
Intercept	20.008**	3.759
$\ln(L)$	0.109	0.095
$\ln(K)$	0.317**	0.070
$\ln(L)^2$	-0.093**	0.008
$\ln(K)^2$	-0.037**	0.004
$\ln(L)\ln(K)$	0.090**	0.011
SIC	0.573	0.401
$\ln(L)$ SIC	-0.641**	0.118
$\ln(K)$ SIC	0.321**	0.082
$\ln(L)^2$ SIC	0.107**	0.014
$\ln(K)^2$ SIC	-0.011*	0.006
$\ln(L)\ln(K)$ SIC	-0.037**	0.016
Panel B: Inefficiency effect equation		
Intercept	21.638**	3.756
$I(Y>1)$	0.049	0.060
$I(Y>2)$	0.072	0.042
$I(Y>3)$	0.097**	0.031
$I(Y>4)$	-0.004	0.021
$I(Y>5)$	0.089**	0.016
$I(Y>6)$	0.086**	0.018
$I(Y>7)$	0.105**	0.023
$I(Y>8)$	0.150**	0.030
Age	0.015**	0.001
$\ln(A)$	-0.976**	0.009
Panel C: Variance parameter		
σ^2	0.370**	0.005
ζ	0.673**	0.148
Panel D: Model fit test		
Log-likelihood	-11546.794	
Likelihood-ratio	9692.091**	

The notations ** and * indicate the significance of test at 1% and 5% levels, respectively.

To study the relationship between TCRI and technical inefficiency for firms in Taiwan, a panel dataset with 1,712 firms and 12,518 firm-year observations from 1995 to 2008 for building the stochastic frontier model was collected from the TEJ database. After controlling for firm's age and size, the estimated result indicates that if a firm has worse TCRI, then it is generally less technically efficient. Combining our empirical results with the fact that economic-based efficiency measures are reasonable indicators of the long-term health and prospects of firms, it is reasonable to conclude that the TCRI is a good credit risk proxy for firms in Taiwan.

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