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Abstract

An empirical model determining the relationship between changes in firm-level productivity and changes in firm value is estimated using an unbalanced panel of 706 public limited companies observed over the period 1996-2002. The main findings are: (1) changes in technical efficiency and labour productivity are reflected in changes in the value of manufacturing firms, and (2) changes in earnings per share and return on capital employed explain changes in the value of service sector firms but technical efficiency and labour productivity do not. For manufacturing firms, the evidence is consistent with the stock market valuing the adoption of better management practices that lead to better resource utilisation.

Key words: Firm value; resource utilisation

JEL Classification: G12, D21

1. Introduction

Wealth maximising shareholders are concerned with the value of the firm (or firms) in which they hold equity. Research examining the factors that affect the value of the firm has examined a variety of *financial factors* (e.g. capital structure (Bradley *et al.*, 1984), beta and the cost of equity capital (Yagill, 1982), and dividend policy (Brennan, 1971)); *business factors* (e.g. investment (Morgado and Pindado, 2003) and innovation (Toivanen *et al.*, 2002)); and *governance factors* (e.g. mergers and takeovers (Shleifer and Vishny, 1988), and incumbent management equity holdings (Morck *et al*. 1988)). There is, however, a paucity of research examining the relationship between economic based measures of performance and the value of the firm. Riahi-Belkaoui (1999) is a notable exception in that he examines whether value-added can be used to predict the future value of the firm using US data and finds that it explains cross-sectional differences in market value incremental to that explained by the book value of the firm.

This paper seeks to contribute to the literature on the value of the firm by determining and quantifying the effect of *changes* in firm-level technical efficiency on *changes* in firm value. Technical efficiency is a relative measure of firms' ability to utilise resources with higher technical efficiency indicating superior performance. Consequently, firms with higher technical efficiency are extracting greater output from a given set of factor inputs than less technically efficient firms. Indeed, firms with higher technical efficiency are doing so because they adopt better management practices than firms with lower technical efficiency. Efficient equity markets should reflect such technical efficiency capabilities in their valuation of equity because technical efficiency reflects the ability of firms management to extract value from resources on shareholders behalf.

We estimate technical efficiency using the stochastic production frontier proposed by Battese and Coelli (1992). There are two principal motivations for adopting this estimation approach and measure of performance. First, factors under management control and random factors are decomposed. Most productivity measures (e.g. total factor productivity and financial ratios) lump these two factors together and typically label them productivity. Second, unlike financial and accounting ratios, technical efficiency is not a partial measure of performance because it accounts for both capital and labour inputs in the production process and not just one of these factors of production. Given these two motivations, we contend that technical efficiency estimated by a stochastic frontier is superior in identifying 'best practice' and well-managed firms than other measures of performance.

This paper is organised in the following way. Section 2 describes the estimating equation through which the effect of changes in technical efficiency on changes in firm value is determined and quantified. A description of the data is in Section 3. The results are presented in Section 4 and conclusions are drawn in Section 5.

2. Estimating Equation

Hirsch and Seaks (1993) suggest there are no strong theoretical predictions regarding the functional form of market value models. The same might also be said with respect to the independent variables employed in valuation models. We adopt a modelling approach similar to that employed by Hall (1993) and Toivanen *et al.* (2002) in their innovation studies. In, addition, we assume a semi-logarithmic functional form, Hirsch and Seak's (1993) preferred specification. Thus, the basic valuation model for firm i (i = 1, 2, ..., N) in year t (t = 1, 2, ..., T) is expressed as:

$$\frac{MV_{it}}{BV_{it}} = \exp.(\boldsymbol{\beta x_{it}} + f_i + t_{ind} + \varepsilon_{it}) \tag{1}$$

where MV is the market value of the firm, BV is the book value of total assets, $\boldsymbol{x}$ is a vector of parameters that determines the market value of the firm, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, f_i are firm-specific fixed effects, t_{ind} are industry specific time trends, and ε is an error term. Note that MV/BV is analogous to Tobin's q. Multiplying equation (1) by BV we obtain:

$$MV_{it} = BV_{it} \exp.(\boldsymbol{\beta x_{it}} + f_i + t_{ind} + \varepsilon_{it}) \tag{2}$$

Taking natural logarithms of equation (2) yields:

$$\ln MV_{it} = \ln BV_{it} + \boldsymbol{\beta x_{it}} + f_i + t_{ind} + \varepsilon_{it} \tag{3}$$

We follow previous empirical studies and incorporate a variety of business and financial variables as our explanatory variables, $\boldsymbol{x}$, to obtain the following empirical model:

$$\begin{aligned} \ln MV_{it} &= \beta_1 \ln BV_{it} + \beta_2 Leverage_{it} + \beta_3 Eff_{it} + \beta_4 Earn_{it} + \beta_5 ROCE_{it} \\ &+ \beta_6 Invest_{it} + \beta_7 t_{ind} + f_i + \varepsilon_{it} \end{aligned} \tag{4}$$

where MV, BV, f_i, t_{ind}, and ε are the same as previously defined, *Leverage* is the debt to equity ratio, *Eff* is output oriented technical efficiency (or average labour productivity), *Earn* is earnings per share, *ROCE* is the return on capital employed, and *Invest* is capital and financial investment.[1]

There are two competing theories on the effect of capital structure (*Leverage*) on firms performance. First, higher levels of debt in the capital structure acts as a discipline on managerial behaviour. This discipline involves reducing sub-optimal investments in order to service debt (Jensen, 1986). In addition, the fixed interest obligation associated with debt provides managers with the incentive to generate cash flows in order to service the debt otherwise they will lose control of the firm via liquidation (Thompson *et al.*, 1992). Second, high levels of leverage reduce the market value of the firm because high leverage increases equity holders financial risk because of the fixed interest obligation associated with debt. Moreover, it also increases the likelihood of liquidation and the expected future costs of liquidation are reflected in the current market value of the firm (Myers, 1984). We include *Leverage* as a control variable in our study in order to capture the effects of capital structure on the market value of the firm. Note that a positive sign on this variable would be consistent with debt acting as a disciplinary device while a negative sign would be consistent with equity holders lowering the value of their holdings due to the future costs of financial distress.

Capital and financial investment (*Invest*) is also included as a control variable. Following Morgado and Pindado (2003) *Invest* is included in the empirical model in order to determine whether it adds to the value of firms. A positive sign on parameter estimates

[1] Average labour productivity is employed as an alternative productivity measure to technical efficiency in order to explore the robustness of any findings with respect to the technical efficiency measure. A useful feature of labour productivity is that it can be easily constructed using accounting data.

for this variable indicates that equity holders value the investments that arise from such expenditures. Equity holders will assess whether such investments will lead to firms success, the present value of such future success will be reflected in the contemporaneous market value of the firm. If equity holders believe that firms investments will yield a negative net present value, then a negative sign on the coefficient estimate for *Invest* will be obtained.

In the accounting and finance literature the ‘fundamentals’ of the firm are important factors in determining the market value of the firm. A variety of financial/profitability ratios have been employed as performance indicators in order to aid the determination of the intrinsic value of the firm (e.g. see Quirin *et al.,* 2000). We use Earnings per share (*Earn*) and return on capital employed (*ROCE*) in the spirit of this type of finance and accounting research. We also propose a new performance indicator as a determinant of firm value i.e. output oriented technical efficiency (*Eff*). In contrast to *Earn* and *ROCE*, *Eff* is not reported in firms accounts. Thus, it is not directly observable. Instead, *Eff* is derived from the estimation of a stochastic frontier production function using the technique proposed by Battese and Coelli (1992), which allows technical efficiency to vary over time. A two-input (labour and capital) translog production function is employed to this end. Sales proxies output, labour input is taken to be the total number of employees and capital is measured by the book value of fixed assets.

Technical efficiency measures resource utilisation within a firm with respect to an estimated best practice frontier that defines the maximal possible output for a given set of inputs. A firm is perfectly output-oriented technically efficient if it produces the maximal possible output (Farrell, 1957; Lovell, 1993). A firm's deviation from this maximal possible output is a measure of its technical inefficiency. Technical efficiency scores are bounded between zero and one, where one defines a best practice frontier and if a firm lies on the frontier it is described as perfectly technically efficient.[2]

We use technical efficiency estimated by a stochastic production frontier as an additional measure of firm-level performance to those typically employed for four reasons. In the introduction to this paper we outline two principal motivations: random factors and factors under management control are decomposed rather than lumped together and labelled efficiency/productivity, and that technical efficiency is not a partial measure of performance. Indeed, *Earn* measures performance relative to the value of outstanding equity and *ROCE* measures performance relative to the book value of capital employed. Notice that neither of these measures take into consideration the labour input cf. *Eff*, which takes into consideration both capital and labour inputs in the production process. It will, therefore, be interesting to note the relative impact of these performance indicators on firms market value given that we are proposing a new (in this context) measure of performance for consideration. The two additional motivations for employing technical efficiency are: first, it is a measure of resource utilisation that identifies well-managed best practice firms; and second, it is easy to interpret. A score of, say, 0.75 indicates that a firm is producing 75% of its potential output.

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[2] Greene (1993) and Lovell (1993) provide good reviews of the stochastic production frontier and the measurement of technical efficiency. A detailed description of parametric estimation of technical efficiency is beyond the scope of this study.

The main concern of this study is whether changes in the technical efficiency of firms is reflected in changes in their market value. We are concerned with changes because we suggest that holders of firms securities value organisational improvements and the adoption of better management practices that lead to better resource utilisation (measured by technical efficiency) rather than security holders simply being concerned with the level of technical efficiency. Consequently, equation (4) is first differenced to yield:

$$\begin{aligned}\Delta \ln MV_{it} &= \beta_1 \Delta \ln BV_{it} + \beta_2 \Delta Leverage_{it} + \beta_3 \Delta Eff_{it} + \beta_4 \Delta Earn_{it} + \beta_5 \Delta ROCE_{it} \\ &+ \beta_6 \Delta Invest_{it} + \beta_7 \Delta t_{ind} + \Delta \varepsilon_{it}\end{aligned} \tag{5}$$

where Δ is the first-difference operator and all other variables have been previously defined. Note, that as a consequence of first-differencing the firm-specific fixed effects are removed.

4. Data

Both the financial and accounting data used in this study are obtained from FAME (Financial Analysis Made Easy). An unbalanced panel of 706 public limited companies over the 1996-2002 period are obtained, with 440 firms operating in the service sector and the remainder being in the manufacturing sector. Manufacturing (service) sector firms are defined as those with one-digit SIC 2003 code less (greater) than 4. Sample characteristics are reported in Table 1. Note that financial data are deflated using the consumer price index: 1996=100.

Pairwise correlations are reported in Table 2 and indicate a stronger relationship between our performance indicators and the market value of the firm for firms in the manufacturing sector than for firms operating in the service sector. The results of further analysis of these empirical relationships are explored in the next section.

5. Results

We employ three alternative techniques to estimate Equation (5) in order to explore the robustness of our findings, particularly the statistical relationship between efficiency and the market value of the firm. First, we use OLS with standard errors that are robust to general forms of heteroskedasticity and within-firm serial correlation. This is essentially a conditional mean regression. Second, we use outlier robust regression (see Rousseeuw and Leroy, 1987). Outliers are a problem frequently encountered in empirical work. If useful generalisations are to be drawn, it is important to ensure that the results reflect what is going on in the majority of the sample rather than being driven by a few outlying observations. The version of outlier robust regression we use is a three-step procedure. The first step involves estimating the regression via OLS and calculating Cook's Distance measure of influence.[3] High values of Cook's D indicates the observations that have significant influence on estimation results, therefore, they can be deemed outliers. The second step in robust regressions is to screen data points in search of such outliers and eliminates observations for which Cook's distance exceeds 1, which are the gross outliers. Thereafter, robust regression involves an iterative weighted least squares method

[3] Cook's D for the ith observation is a measure of the distance between the coefficient estimates when observation i is included and when it is not, and it is defined as: $D_i = \frac{\hat{e}_{si}^2 (s_{pi} / s_{ri})^2}{k}$

where $\hat{e}_{si}$ refers to standardized residuals, s_{ri} to standard error of the residuals and s_{pi} to standard error of prediction, and *k* represents the number of independent variables including the intercept term.

whereby weights are assigned to the observations in inverse proportion to their Cook's D values.

The third technique employed is a median regression technique that is a special case of the semi-parametric method of quantile regressions (see Buchinski, 1998, for an excellent review of the literature). We use this estimation technique because standard techniques concentrate on the conditional mean function of the dependent variable and as a consequence are unlikely to be adequate analytical tools in the presence of heterogeneous processes. The median regression addresses these concerns. Subsuming all regressors in a matrix Z, the median regression estimator solves the following minimisation problem:

$$\min_{\beta} \frac{1}{n} \left\{ \sum_{i,t:} \left| \Delta Y_{it} - Z'_{it} \beta \right| \right\} \quad (6)$$

Thus, in contrast to OLS, the sum of the absolute values of the residuals is minimised, and for this reason this method is also known as the Least Absolute Deviations regression.

Results employing the three techniques described above are reported in Tables 3 and 4. Results are presented for both the service and manufacturing sectors separately as it allows us to examine the differences in factors that affect the valuation of these two types of firms.

Table 3 presents results of models where the performance measure employed is output-oriented technical efficiency is included. With respect to this performance indicator there are clear differences between service sector firms and manufacturing firms. There is no evidence of a statistically significant relationship at the usual probability levels between technical efficiency and the market value of service sector firms from the results of any of the three estimation techniques employed. In contrast, estimates using the OLS with robust standard errors and the median regression indicate a statistically significant relationship (at the 1% level) between technical efficiency and the market value of manufacturing firms. Indeed, the coefficient estimates have a positive sign, as expected, with the OLS estimates indicating a 10% increase in technical efficiency leads to 0.984% increase in the value of the average firm. The median regression indicates that a 10% increase in technical efficiency leads to a 0.760% increase in the value of the median firm.

The elasticity of market value with respect to each performance indicator is calculated in order to determine the relative impact of each performance indicator on market value When we compare technical efficiency to our other performance indicators, earnings per share and return on capital employed, the OLS results indicate technical efficiency is a superior performance indicator for manufacturing firm because the other performance indicators are not significant at the 10% level. At the mean, the elasticity of market value with respect to labour is 0.05. The results of the outlier robust regression indicate that, at conventional probability levels, only earnings per share has a statistically significant impact. At the mean, the elasticity of market value with respect to earnings per share is 0.03.

The median regression results indicate that all three performance indicators reported in Table 3 are significant at conventional probability levels. At the median, the elasticity of market value with respect to technical efficiency, earnings per share, and return on capital employed is 0.04, 0.01, and 0.004, respectively. This suggests a stronger relationship between technical efficiency and market value than such a relationship for earnings per share and the return on capital employed. Thus, it appears that technical efficiency is a superior performance indicator than those typically used by investors and analysts. Note that all three estimation techniques find a statistically significant relationship between earnings per share and the return on capital employed and the market value of service sector firms, however, no such statistical relationship is found between market value and technical efficiency.

Turning to the remaining control variables, for both manufacturing and service sector firms, there is strong evidence of a relationship between the book value of total assets and the market value of the firm. The outlier robust regression and median regression indicate a negative relationship between gearing and the market value of the firm, however, no such relationship is found for service sector firms. No evidence is found to suggest that the capital expenditure of manufacturing firms impacts on their market value in contrast to the OLS and median regressions for service sector firms.

As mentioned in Section 3, we examine the robustness of our findings with respect to technical efficiency using average labour productivity as an alternative performance indicator. The pairwise correlation matrix, Table 2, indicates a strong relationship between technical efficiency and labour productivity, though it is strongest for manufacturing firms. Results using the labour productivity indicator are reported in Table 4. The results are generally consistent with those reported in Table 3, where technical efficiency is used as an explanatory variable, in that no statistical relationship (at conventional probability levels) is found between the labour productivity of service sector firms but such a relationship is found for manufacturing firms using all three estimation techniques. Indeed, the parameter estimates on the labour productivity variable (which are elasticities) indicate that it has a larger effect on firm market value than technical efficiency.

For manufacturing firms, OLS estimates indicate that labour productivity is significant at the 5% level. At the mean, the OLS results indicate the elasticity of market value with respect to labour productivity is 0.33. OLS estimates indicate that the other performance indicators are not statistically significant at conventional probability levels. The outlier robust regression indicates that labour productivity and earnings per share are significant at the 1% level, while the return on capital is not statistically significant. At the mean, the elasticity of market value with respect to labour productivity and earnings per share is 0.20 and 0.03, respectively.

The median regression in table 4 indicates that both labour productivity and earnings per share are significant at the 1% level. At the median, the elasticity of market value with respect to labour productivity and earnings per share is 0.24 and 0.01, respectively. Considering the regressions overall for the manufacturing sample the preferred performance indicator is labour productivity. Note that labour productivity is not statistically significant at conventional probability levels for any of the regressions using service sector data.

Briefly, we now discuss the other control variables in the estimated models. The book value of total assets is statistically significant at the 1% level for both service and manufacturing firms. Earnings per share and return on capital employed are both statistically significant at conventional probability levels and changes in these variables appear to explain changes in the market value service sector firms better than labour productivity. OLS and median regressions indicate that capital expenditure has a negative and statistically significant impact on changes in the market value service sector firms, which is consistent with the management of the mean and median service sector firm making sub-optimal investments. The capital expenditure variable is not statistically significant at conventional probability levels for manufacturing firms.

6. Conclusions

We find robust evidence that changes in technical efficiency and average labour productivity impact on changes in the market value of manufacturing firm. Of the performance indicators employed, labour productivity has the strongest relationship with market value. There are two possible explanations for this. First, in contrast to technical efficiency, labour productivity is easily observed from firms' accounts and so investors and market analysts can easily acquire this information. Second, investors and analysts have generally given more attention to labour productivity as a measure of firm performance than technical efficiency.

By contrast, we find no evidence to support the hypothesis that changes in labour productivity and technical efficiency are reflected in changes in the market value of service sector firms. Indeed, a stronger statistical relationship is found between firm value and earnings per share and return on capital employed for service sector firms. A possible explanation for this finding is that investors and analysts apply different performance criteria to firms operating in the service sector than those operating in manufacturing sectors.

Our study, by proposing additional firm characteristics not considered in previous studies, provides further insight into the determinants of the value of the firm. We believe, therefore, that our findings will aid investors and managers decision-making with respect to maximising the value of the firm on shareholders behalf. Indeed, our results indicate that, for manufacturing firms, the stock market values the adoption of management practices that lead to better resource utilisation. Given that the statistical relationship between technical efficiency and firm value is confined to firms in the manufacturing sector, however, further research is required to better understand such empirical findings.

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Table 1
Summary statistics

Variable	**Service sector**			**Manufacturing sector**		
	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median
ln (*Market value*)	10.98	2.17	10.91	10.648	2.265	10.26
ln (*Labour productivity*)	4.70	0.96	4.64	4.392	0.748	4.39
Technical efficiency	0.54	0.123	0.54	0.51	0.094	0.52
ln (*Total assets*)	11.55	2.07	11.33	11.24	1.95	10.92
Gearing	84.56	245.02	52.97	90.90	176.21	50.83
Earnings per share	-0.30	2.17	0.07	0.08	0.28	0.05
Return on capital employed	-6.23	65.61	8.58	-2.26	58.71	8.33
Investment	56050.19	558047.40	2714.23	57920.75	398046.20	8.33
Observations	1124			830		
Number of firms	440			266		

Notes: market value, total assets, and investment are expressed in thousands of pounds; labour productivity, gearing, earnings per share, and return on capital employed are ratios; technical efficiency is expressed as a per cent.

Table 2
Pairwise correlation matrix

	Service sector		**Manufacturing sector**	
	Market value	*Labour productivity*	*Market value*	*Labour productivity*
Market value				
Labour productivity	0.1504		0.3434	
Technical efficiency	0.1138	0.8456	0.2314	0.9019

Table 3
The relationship between changes in firm value and changes in technical efficiency

Explanatory variables	**Service sector**			**Manufacturing sector**		
	OLS with robust s.e	Outlier robust regression	Median regression	OLS with robust s.e	Outlier robust regression	Median regression
Total assets	0.3832 (0.1072)***	0.4432 (0.0567)***	0.3752 (0.0552)***	0.4734 (0.1195)***	0.2799 (0.0599)***	0.2755 (0.0444)***
Gearing	-0.0001 (0.0001)	-0.0000 (0.0001)	-0.0000 (0.0000)	-0.0001 (0.0001)	-0.0002 (0.0001)**	-0.0001 (0.0000)***
Technical efficiency	**-0.0166 (0.1260)**	**0.0096 (0.0869)**	**0.0176 (0.0808)**	**0.0984 (0.0349)*** **	**0.0197 (0.1800)**	**0.0760 (0.0113)*** **
Earnings per share	0.0186 (0.0018)***	0.0498 (0.0239)**	0.0170 (0.0007)***	0.1947 (0.2075)	0.3392 (0.0771)***	0.2021 (0.0570)***
Return on capital employed	0.0021 (0.0005)***	0.0024 (0.0003)***	0.0027 (0.0003)***	0.0005 (0.0006)	0.0002 (0.0003)	0.0005 (0.0002)**
Investment	-0.0243 (0.0075)***	-0.0308 (0.0390)	-0.0294 (0.0065)***	0.0066 (0.0807)	0.0787 (0.1596)	0.0357 (0.1090)
Observations	1124	1123	1124	830	829	830
R-squared	0.14	0.21	Not applicable	0.10	0.10	Not applicable

Notes:

(i) Robust standard errors in parentheses
(ii) * significant at 10%; ** significant at 5%; *** significant at 1%
(iii) All regressions contain industry and time dummies

Table 4
The relationship between changes in firm value and changes in labour productivity

Explanatory variables	**Service sector**			**Manufacturing sector**		
	OLS with robust s.e	Outlier robust regression	Median regression	OLS with robust s.e	Outlier robust regression	Median regression
Total assets	0.3846 (0.1057)***	0.4399 (0.0557)***	0.3784 (0.0546)***	0.4436 (0.1158)***	0.2553 (0.0596)***	0.2546 (0.0536)***
Gearing	-0.0001 (0.0001)	-0.0000 (0.0001)	-0.0000 (0.0000)	-0.0001 (0.0001)	-0.0002 (0.0001)**	-0.0001 (0.0000)***
Labour productivity	**-0.0127** **(0.0784)**	**0.0149** **(0.0562)**	**0.0195** **(0.0537)**	**0.3250** **(0.1296)****	**0.2027** **(0.0722)*****	**0.2373** **(0.0567)*****
Earnings per share	0.0186 (0.0017)***	0.0490 (0.0239)**	0.0170 (0.0007)***	0.1626 (0.2010)	0.3253 (0.0771)***	0.2159 (0.0690)***
Return on capital employed	0.0021 (0.0005)***	0.0024 (0.0003)***	0.0027 (0.0003)***	0.0006 (0.0005)	0.0002 (0.0003)	0.0004 (0.0003)
Investment	-0.0244 (0.0076)***	-0.0308 (0.0389)	-0.0292 (0.0064)***	-0.0030 (0.0841)	0.0686 (0.1588)	0.0011 (0.1368)
Observations	1125	1124	1125	830	830	830
R-squared	0.14	0.21	Not applicable	0.11	0.11	Not applicable

Notes:

(i) Robust standard errors in parentheses
(ii) * significant at 10%; ** significant at 5%; *** significant at 1%
(iii) All regressions contain industry and time dummies