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Efficiency and profitability: a panel data analysis of UK manufacturing firms, 1993-2007

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Abstract:

This paper examines the impact of efficiency on profitability using a panel of 11728 UK manufacturing firms for the period 1993-2007. A key contribution is estimation of the relationship between firm efficiency and profitability in a new way. Part of this novelty involves direct estimation of firm efficiency using a stochastic frontier method rather than inferences being made about the impact of efficiency based on anticipated firm and market behaviour. Two key aspects of the discussion are (1) the shape of the relationship between efficiency and profitability and (2) the way in which this changes in the short and long runs. A simple theoretical model is developed that predicts a 4^{th} order polynomial for efficiency on the right hand side of a profit equation in levels. This model also predicts short-run and long-run impacts that can involve a switching in the sign of the impact of efficiency. Estimation of this model suggests a threshold effect of efficiency on profitability. Below the threshold efficiency has effectively no effect on profitability, but above the threshold the impact is positive in the short-run but negative in the long-run. This switching is consistent with theoretical expectations.

Key words: Firm efficiency, firm profitability, stochastic frontier analysis, UK manufacturing firms.

JEL: C23, D21, L60

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1. Introduction

A well established industrial organisation tradition involves estimation of profit functions with various right hand side explanatory variables. Of particular significance for the current paper is the long traditional that identifies the importance of efficiency, frequently as an alternative to market power, as a determinant of profitability that follows the original contribution by Demsetz (1973). This paper contributes to this literature by specifying and then estimating, using UK manufacturing firm data, the efficiency-profitability relationship in a new way. Among other things, the novelty of the approach used here involves direct estimation of firm efficiency, using a stochastic frontier method, rather than inferences being made about the impact of efficiency based on anticipated firm and market behaviour (for example Clarke et al, 1984). The intention here is not to revisit the existence of any efficiency – monopoly power relative impact on profitability, but rather a more limited objective of how the impact of efficiency might be understood and modelled.

Recent contributions (Caves, 2007; Lee and Mahmood, 2009) emphasise the ambiguity of many of the findings with this established industrial organisation tradition. A number of reasons can be cited to account for this ambiguity that provide a rationale for the current study. Traditionally investigation was based on industry based studies that were originally cross-sectional in nature. Obviously these can generate different results compared to panel based analyses that include firm data. This was originally identified by Rumelt (1991) and more recently Hawawini et al (2003) emphasise this point. The reasoning for the divergence is now well established: firm based characteristics are at least as important in explaining profit variation as industry characteristics. This importance of firm based characteristics is carried forward into the current study. Industries are obviously weighted averages of firms that populate them. Given characteristic skewed firm size distributions, large firms are therefore given greater weight than small firms. It is shown below that firms with different characteristics and different sizes have apparently different linkages between efficiency and profitability. In addition it is shown below that short-run linkages may be different from those that exist in the long-run and that these interact with firm characteristics. It follows that industry level analysis may not be able to track the subtleties of the efficiency-profitability relationship.

These aspects of the efficiency-profitability relationship are explored here. While “traditional” efficiency effects can be derived particularly for large firms, it is shown that this is not a general result. This is explored using a panel of UK manufacturing firms for the period 1993-2007. Two key issues are emphasised in the discussion: (1) the “shape” of any relationship between efficiency and profitability; and (2) the extent to which this relationship is different in the short and long runs. It is shown here, using GMM estimation that allows effective tracking of short-run and long-run effects, that there appears to be a “threshold” effect of efficiency on profitability. Below this threshold efficiency appears to have no influence on profitability but above the threshold there appears to be a strong positive effect in the short-run. In the long-run this effect, for the most efficient firms, becomes negative. Furthermore, it is shown that with standard panel fixed effects estimation the nature of this threshold relationship between efficiency and profitability cannot be identified empirically, even if the endogeneity of efficiency is accounted for. Instead something like the traditional impact of efficiency is estimated.

There are two aspects to the reasoning used here that can account for this threshold relationship that switches between the short and long runs. First, is the threshold relationship itself. A simple model of firm adjustment to changed efficiency is developed below. Although the constituent parts of this model are simple, they imply a 4^{th} order polynomial for efficiency on the right hand side (RHS) of a profit equation that is in levels. Without this high order polynomial in efficiency the threshold effect cannot be identified. The threshold effect can therefore be explained in terms of adjustment to, and the effects of, changing efficiency. Secondly, given the identification of this threshold based model the differing short and long-run effects can be identified.

Many variants of economic theory can be used to predict that increased efficiency increases profitability (ceteris paribus). For example, standard Cournot oligopoly has this characteristic (Hay and Liu, 1997). Different variants of more process based theory have the characteristic that to manage necessary adjustment in a changing environment firms require a degree of slack resources. So, at least locally, increasing slack and so decreasing efficiency may increase long-run profitability. This claimed (locally) negative relationship between efficiency and profitability can be found in at least three different approaches to the firm. Traditional behavioural theory (March and Simon 1958; Cyert and March 1963) suggests that firms react to a changing environment using standard operating procedures. Fundamental change requires adjustment of these standard procedures and such adjustment is costly in terms of organisational effort. It follows that organisational slack is required to manage change. This slack is identified as inefficiency for the production of existing goods and services. Penrose (1959) used different, but related reasoning that is relevant here. She suggested that firms require a degree of managerial excess capacity to effectively plan and enact firm growth. This excess capacity is, once again, inefficiency in terms of the production of existing goods. The so-called Penrose effect emerges when growth is not based on managerial excess capacity, in which case it involves a shift of managerial effort away from current activity with a resulting reduction in the efficiency of current activity with negative effects on profitability. Finally there is the more recently developed idea of dynamic transaction costs (Langlois 1992; Langlois and Robertson 1995). These dynamic transaction costs are zero if firms do not change; in which case there is a positive relationship between transaction cost efficiency and profitability as suggested by Williamson (1985, 1991). But as with behavioural and Penrosian theory, the management of change requires organisational efforts over and above those needed for existing activity. Once again, these dynamic costs imply inefficiency for current activity but greater long-run profitability.

Obviously both positive and negative effects of efficiency on profitability may occur in the short and long-runs. In addition, both short and long run effects may differ by specific firm and market characteristics e.g. monopoly power and firm size. The rest of the paper is organised as follows. In the next section it is shown how efficiency can be estimated using a stochastic frontier method and the data to be used here is introduced. In section three a model of efficiency and profitability at the firm level is developed. It is shown that simple adjustment equations for how efficiency might affect profitability imply a 4th order polynomial in a profit levels equation. In addition it is shown that we might expect a switching of coefficient signs in the levels equation when the short and long-runs are compared. Following this, in section four, there is a first discussion of how efficiency affects profitability initially using a standard panel analysis and following this using GMM estimation. Section five introduces complexities to the identified relationships in terms of specific firm and market characteristics. This leads on to empirical investigation of these complexities where estimated marginal effects of efficiency on profitability in different contexts are reported. These marginal effects are logical given expectations. Finally conclusions are drawn.

2. Estimating Firm Efficiency

This section presents a background discussion of how stochastic frontier analysis can be used to generate measures of firm efficiency. No claim of originality is being made here as the discussion relies on standard presentations of the method (for example, Khumbaker and Lovell, 2000; Greene, 2007). In addition this section introduces the data to be used: a population of UK manufacturing firms allocated to two digit industries extracted from the FAME database of UK companies. Stochastic frontier modelling is now arguably the standard econometric method of efficiency analysis, and is in a number of respects superior to alternative parametric and non-parametric methods (Greene, 2007; Van Biesebroeck, 2007). This is the case for two broad reasons. First, the inclusion of standard residuals during estimation allows for data noise in a way that cannot be accommodated with non-parametric methods. Secondly, the explicit modelling of firm efficiency allows efficiency to impact on all estimated coefficients, which is not the case with other parametric methods.

Stochastic frontier estimation is carried out here using a series of data panels at the two digit industry level. This covers all UK manufacturing industries SIC10-SIC37 i.e. 27 industries (SIC12 is excluded because of insufficient complete observations). Following this the data is combined, with estimated firm efficiencies, into a single panel for the second stage analysis. The usable panel is for the period 1993-2007 and covers 11728 firms with 89942 usable observations. It is somewhat obvious to state that a panel based approach to efficiency analysis is superior to estimation based on cross-section data. Firms clearly have non-observable characteristics that influence input use and that are correlated with efficiency levels. Hence a non-panel analysis is econometrically unreliable. With a panel based analysis two possible stochastic frontier models can be estimated: a time-invariant efficiency model [1], i.e. the equivalent of fixed effects estimation, and a time varying efficiency model [2], i.e. the equivalent of random effects estimation

$$\ln(R_{it}) = \ln[f(L_{it}, K_{it})] - u_i + v_{it} \qquad [1]$$

$$\ln(R_{it}) = \ln[f(L_{it}, K_{it})] - u_{it} + v_{it} \qquad [2]$$

R_{it} is firm turnover, L_{it} and K_{it} labour and capital inputs. As with all stochastic frontier models, v_{it} are the standard residuals and u_i and u_{it} estimate firm efficiency levels, i.e. the distance from the estimated frontier that can be either time invariant (u_i) or time varying (u_{it}).

All stochastic frontier regressions used here are based on a trans-log form. For brevity the full results are not shown but are available from the author. For reasons set out below, both formulations [1] and [2] are estimated for the 27 two digit industries used here, this implies 54 regressions. These are all well specified in terms of overall explanation and significance of regressors. Labour input (L_{it}) is number of employees and capital (K_{it}) is total assets. The monetary measures are transformed from current to constant prices using the GDP deflator. Firm revenue (R_{it}) is used here as the dependent variable, rather than for example value added, for two reasons. First, this facilitates the collection of a large, firm based data panel that covers the full firm size range which would not be possible using value added. The reason why the full firm size range, i.e. a large panel, is important is considered at the end of this section. Estimation within each two digit industry provides a minimum degree of homogeneity of technical and market characteristics; hence the non-use of value added is not considered a significant technical problem. Secondly, in the next section a simple model of the relationship between firm efficiency and profitability is developed. This requires defining efficiency in terms of revenue not value added. Hence the estimation method used here is consistent with this later model.

With the time invariant model [1] the estimated firm efficiencies are assumed to follow a truncated normal distribution, $u_i \sim N^+(\mu, \sigma^2)$. To estimate time varying efficiencies the Battese-Coelli (1992) parameterisation of time efficiency is used. This now appears to be the commonly accepted approach to time variation (Greene, 2007):

$$u_{it} = \exp[-\eta(t - T_i)]u_i \qquad [3]$$

T_i = the last time period in the i'th panel

η = decay parameter; with $\eta>0$ the degree of inefficiency decreases over time.

Note that η is constant over i and t. In the current context η is common for all firms within a 2 digit industry. Also note that with $t = T_i$ (i.e. last period of the i'th panel) $u_{it} = u_i$.

In the current context we require efficiencies that vary over time, i.e. [2] is the relevant model. In the second stage analysis we use the efficiencies for all firms to examine the dynamics of the efficiency – profitability relationship for which a panel is needed. But only the time invariant model can be effectively estimated as there is no requirement that u_i are uncorrelated with the regressors (Khumbhaker and Lovell, 2000). For this reason the u_i estimates defined in [1] can be considered reliable. With the time varying model it is necessary to assume the u_{it} are uncorrelated with the regressors and v_{it}. Post estimation prediction of both u_i and u_{it} indicates that with the current data the extent of bias with the estimated u_{it} is not insignificant. To control for this bias in u_{it} we can use the fact that with $t = T_i$ in [3] (i.e. the last period of the i'th panel) $u_{it} = u_i$. This allows a rescaling of u_{it} to ensure this equivalence in the final period but maintaining the same growth rate of u_{it} over the panel. After rescaling we can predict the degree of efficiency (e_{it}) for all firms and its variation over time

$$e_{it}\ [0, 1) = R_{it}/R^*_{it} \qquad [4]$$

R^* is estimated frontier revenue i.e. with zero u_{it}. It is important to point out that e_{it} is not an absolute measure of firm efficiency but rather is scaled from zero to unity. This allows its effective use in a second stage profit function with firms of differing sizes.

Tables 1a and 1b here, see end.

The basic distribution of efficiency estimates is shown in tables 1a and 1b. Note that these estimated firm efficiencies are the rescaled time varying coefficients e_{it}. The overall distribution is indicated in table 1a. These estimates are of the same order as stochastic frontier manufacturing studies reported by Wadud (2004) for Australia and Sheehan (1997) for Northern Ireland. In addition the results are of the same order as an earlier study of efficiency in UK manufacturing conducted at the industry not firm level (Green and Mayes, 1991). Many stochastic frontier studies report estimated efficiencies larger than the average scores reported in table 1a. A possible reason for this is indicated in table 1b. It is apparent that with the current data set increasing firm size is positively correlated with estimated efficiencies. The largest one per cent of firms in the current sample covers 917 observations. This would appear to be consistent with Wang's (2000) study of 163 large US law firms that reports an average estimated efficiency of 82 per cent. The study by Diaz and Sanchez (2008) of Spanish manufacturing covers 1898 firms over six years i.e. is smaller than the current data set. Correspondingly it reports higher efficiency levels and that small and medium sized firms tend to be more efficient i.e. the opposite of the current study. On the other hand the study by Lundvall and Battese (2000) suggests that technical efficiency is positively related to firm size i.e. the same finding as that reported in table 1b. Two possible reasons might be cited for the greater efficiency of larger firms. Contra to Diaz and Sanchez (2008) the greater formality of management in large firms may be necessary to exploit efficiency gains. Secondly, it is generally recognised that small firms have the highest failure rates. The current data set does not exclude failing or exiting firms hence the greater inefficiency of smaller firms may not be surprising. But, to state an obvious point: even though larger firms have greater relative efficiency scores they have larger absolute inefficiency levels.

3. Firm Efficiency and Profitability: a simple model

In this section a model of firm efficiency and profitability will be presented that will be used to guide empirical investigation. The objective here is to analyse the relationship between efficiency and profitability. It is shown that when a simple set of processes are defined for how a firm adjusts to changing efficiency the formulation results in a levels equation for profitability and efficiency that is a 4^{th} order polynomial. In later discussion it is shown that this 4^{th} order equation can be effectively estimated. The estimated coefficients define a short-run relationship between efficiency and profitability based on a threshold level of efficiency. Below this threshold increasing efficiency appears to have no effect on profitability but above the threshold there is a positive relationship. This threshold effect is produced by the simple adjustment processes defined in this section.

It is useful, for later discussion, if the model developed here uses time subscripts that are unnecessary for current discussion. For expositional convenience firm subscripts are omitted. Firm profitability in period t can be defined as the difference between revenue and labour plus capital costs:

$$\pi_t = R_t - p_L L_t - p_K K_t \qquad [5]$$

Dividing through by K_t and expanding terms:

$$\frac{\pi_t}{K_t} = \frac{L_t}{K_t}\left(e_t \frac{R^*_t}{L_t} - p_L\right) - p_K \qquad [6]$$

where e_t defines the level of firm efficiency, as specified in [4] above, and R^*_t is firm revenue if there is zero inefficiency i.e. a firm is operating on the efficiency frontier. Assuming that factor prices are unchanged as efficiency changes, it follows from [6] that

$$\frac{\partial(\pi_t/K_t)}{\partial e_t} = \frac{\partial(L_t/K_t)}{\partial e_t}\left(e_t \frac{R^*_t}{L_t} - p_L\right) + \frac{L_t}{K_t}\left(\frac{R^*_t}{L_t} + e_t \frac{\partial(R^*_t/L_t)}{\partial e_t}\right) \qquad [7]$$

To use formulation [7] we can specify simple adjustment processes that define terms for the derivatives on the RHS of the equation.

An initial point concerns interpretation of the efficiency parameter e_t. If, for example, a firm is on the efficiency frontier and maintains this position on the frontier this implies not only that operations are as efficient as possible but also adjustment is as effective as possible to maintain this efficiency. It follows that e_t can be used as a measure of adjustment effectiveness as well as relative efficiency. With this background we can now specify how labour intensity might adjust to efficiency. By expansion:

$$\frac{L_t}{K_t} = e_t \frac{R^*_t}{K_t}\frac{L_t}{R_t} \qquad [8]$$

Using [8] the general evolution and adjustment of L_t/K_t can be specified:

$$\frac{\partial(L_t/K_t)}{\partial t} = \frac{\partial e_t}{\partial t}\frac{R^*_t}{K_t}\frac{L_t}{R_t} + \frac{\partial(R^*_t/K_t)}{\partial t} e_t \frac{L_t}{R_t} + \frac{\partial(L_t/R_t)}{\partial t}\frac{R_t}{K_t} \qquad [9]$$

We can specify simple forms for the derivatives on the right hand side of [9] that are either linear or simple partial adjustment formulations. Note the use of e_t as a partial adjustment coefficient for reasons just set out:

$$\frac{\partial e_t}{\partial t} = ae_t, \qquad 0 < e_t \leq 1 \qquad [9a]$$

$$\frac{\partial \left(R_t^*/K_t\right)}{\partial t} = e_t\left(\frac{R_t^*}{K_t^*} - \frac{R_t^*}{K_t}\right) \qquad [9b]$$

$$\frac{\partial \left(L_t/R_t\right)}{\partial t} = e_t\left(\frac{L}{R} - \frac{L_t^*}{R_t^*}\right) \qquad [9c]$$

Substituting [9a]-[9c] into [9] and simplifying:

$$\frac{\partial \left(L_t/K_t\right)}{\partial t} = a\frac{L_t}{K_t} + e_t\frac{L_t}{K_t^*} - e_t^2\frac{L_t^*}{K_t} \qquad [10]$$

Integrating [10] and assuming the arbitrary constant is zero:

$$\frac{L_t}{K_t} = at\frac{L_t}{K_t} + e_t t\frac{L_t}{K_t^*} - e_t^2 t\frac{L_t^*}{K_t} \qquad [11]$$

Hence with given t, L_t and K_t:

$$\frac{L_t}{K_t} = e_t\frac{t}{1-ta}\frac{L_t}{K_t^*} - e_t^2\frac{t}{1-ta}\frac{L_t^*}{K_t} \qquad [11a]$$

Formulation [11a] produces the following reduced form equation:

$$\frac{L_t}{K_t} = \alpha e_t - \beta e_t^2 \qquad [12]$$

$$\alpha = \frac{t}{1-at}\frac{L_t}{K_t^*}; \quad \beta = \frac{t}{1-at}\frac{L_t^*}{K_t}$$

Hence using [12]:

$$\frac{\partial \left(L_t/K_t\right)}{\partial e_t} = \alpha - 2\beta e_t \qquad [12a]$$

With any inefficiency caused by excess labour, the derivative in [12a] is negative hence $e_t > \alpha/2\beta$ implies a constrained lower bound on efficiency. From [11a], with small "a" and in the short-run (i.e. small t) the ratio t/(1-ta) can be positive. But in the long-run, i.e. with larger t, this ratio can switch sign. This suggests possible time period dependent signs for α and β in [12] and [12a], and also suggest a complexity consistent with the literature cited above that efficiency can have differing effects on profitability in the short and long runs.

We can specify an equivalent short-run adjustment process for R_t/L_t in [9]. By expansion firm labour efficiency is:

$$\frac{R_t}{L_t} = e_t \frac{R_t^*}{L_t} \qquad [13]$$

Hence the general adjustment and evolution of labour efficiency is:

$$\frac{\partial(R_t/L_t)}{\partial t} = \frac{\partial e_t}{\partial t}\frac{R_t^*}{L_t} + e_t \frac{\partial(R_t^*/L_t)}{\partial t} \qquad [14]$$

Using equivalent formulations as that just used for labour intensity:

$$\frac{\partial e_t}{\partial t} = ae_t, \qquad 0 < e_t \leq 1 \qquad [14a]$$

$$\frac{\partial(R_t^*/L_t)}{\partial t} = e_t\left(\frac{R_t^*}{L_t^*} - \frac{R_t^*}{L_t}\right) \qquad [14b]$$

Substituting [14a] and [14b] into [14]

$$\frac{\partial(R_t/L_t)}{\partial t} = ae_t \frac{R_t^*}{L_t} + e_t^2\left(\frac{R_t^*}{L_t^*} - \frac{R_t^*}{L_t}\right) \qquad [15]$$

Integrating [15] and assuming the arbitrary constant is zero:

$$\frac{R_t}{L_t} = tae_t \frac{R_t^*}{L_t} + te_t^2\left(\frac{R_t^*}{L_t^*} - \frac{R_t^*}{L_t}\right) \qquad [16]$$

With given t and L_t [16] implies the following reduced form:

$$\frac{R_t}{L_t} = \delta e_t + \varepsilon e_t^2 \qquad [17]$$

$$\delta = ta\frac{R^*}{L_t} > 0; \quad \varepsilon = t\left(\frac{R^*}{L^*} - \frac{R^*}{L_t}\right) >< 0$$

Hence using [17]:

$$\frac{\partial (R_t / L_t)}{\partial e_t} = \delta + 2\varepsilon e_t \qquad [17a]$$

With $R_t^*/L_t^* > R_t^*/L_t$ a firm has excess labour, so ε is positive and labour efficiency increases with e_t. With labour shortages, in principle ε can be negative. If we wish to restrict the derivative [17a] to be positive, with negative ε, this implies a constraint on parameter values: $e_t < \delta/2\varepsilon$. As e_t has an upper bound of one this suggests $\delta > 2\varepsilon$. Assuming positive δ and ε an increase in t increases the value of these coefficients. An obvious interpretation here is that in the long-run labour productivity adjustment to efficiency change is greater than in the short-run. This possibility requires dynamic estimation techniques.

As $R^*_t = R_t/e_t$ it follows from [17] that

$$\frac{R_t^*}{L_t} = \delta + \varepsilon e_t \qquad [17b]$$

Using [17b]:

$$\frac{\partial (R_t^* / L_t)}{\partial e_t} = \varepsilon \qquad [17c]$$

Substituting the relevant formulations into [7] and simplifying:

$$\frac{\partial(\pi_t / K_t)}{\partial e_t} = -(4\beta\varepsilon)e_t^3 + 3(\alpha\varepsilon - \beta\delta)e_t^2 + 2(\alpha\delta + \beta p_L)e_t - \alpha p_L \qquad [18]$$

For reasons just set out, the signs of α and β in [18] can switch between the short-run and the long-run. It follows that the sign of the overall derivative can similarly switch. This conclusion suggests a requirement for dynamic estimation and is also consistent with the earlier cited literature. Integrating [18] to obtain a profit equation in levels that incorporates adjustment processes:

$$\frac{\pi_t}{K_t} = b_0 + b_1 e_t + b_2 e_t^2 + b_3 e_t^3 + b_4 e_t^4 \qquad [19]$$

b_0 = an arbitrary constant; $b_1 = -\alpha p_L$; $b_2 = \alpha\delta + \beta p_L$; $b_3 = \alpha\varepsilon - \beta\delta$; $b_4 = -\beta\varepsilon$. The rest of the discussion uses formulation [19] as the basis for a regression model, along with control variables, to estimate efficiency based profit equations. This empirical analysis uses models of the form specified in [19'] and [19'']:

$$\frac{\pi_{it}}{K_{it}} = \varphi_0 + \varphi_1 e_{it} + \varphi_2 e_{it}^2 + \varphi_3 e_{it}^3 + \varphi_4 e_{it}^4 + \gamma X_{it} + \omega_i + \xi_{it} \qquad [19']$$

$$\frac{\pi_{it}}{K_{it}} = \eta \frac{\pi_{it-1}}{K_{it-1}} + \varphi_0 + \varphi_1 e_{it} + \varphi_2 e_{it}^2 + \varphi_3 e_{it}^3 + \varphi_4 e_{it}^4 + \gamma X_{it} + \omega_i + \xi_{it} \qquad [19'']$$

X_{it} is a vector of control variables that is specified shortly. Equation [19'] is a standard fixed effects model. A fixed effects formulation is used here to control for unobservable firm specific characteristics. Equation [19''] is a dynamic model that is estimated using GMM. The implied long-run coefficients are found in the standard manner by dividing each estimated short-run coefficient by 1/(1-η).

4. Firm efficiency and profitability: UK evidence

This section will report panel based profit function estimates with firm efficiency (e_{it}) as an explanatory variable. Firm profitability is measured as return on capital i.e. π_{it}/K_{it} (as used in the previous section) with π_{it} measured as profit before tax. Initially a standard, static fixed effects panel model is estimated. Fixed effects estimation is used to control for non-observable firm specific determinants of profitability. This initial set of results should be viewed as background. To some extent they show what might be viewed as a standard result that efficiency increases profitability particularly when the endogeneity of efficiency is recognised; the latter is an obvious characteristic of efficiency (Hay and Liu, 1997). But equally problems with the results are emphasised. Following this initial set of results a dynamic model is estimated, as defined in formulation [19] above i.e. with polynomials up to power four being used. For reasons set out in the previous section, this relatively high order polynomial is appropriate as it can effectively track adjustment to efficiency changes. In addition we cannot assume firm efficiency is exogenous of, for example, general market and firm characteristics. Hence different estimates are presented here with exogenous and endogenous e_{it}. To track short and long-run effects lagged dependent variables are used on the right hand side of all regressions. Lags of different length are used to track these dynamic effects. This modelling implies a requirement to use GMM estimation.

Control variables are included to track the effects on profitability of market conditions and firm characteristics. These variables are: firm market share (S), the change in market share (ΔS); firm growth (G) and firm size. Market share is measured as firm turnover as a proportion of total firm turnover at the two digit level defined for each year of the panel. The change in firm market share is measured over a one year interval. Firm growth is measured as annual growth in firm turnover: R_{it}/R_{it-1}. Finally, size is measured by the log of firm employment (ln(L)) with L measured (as above) by the number of employees. Quadratic forms are included to track non-linearities for control variables where this is significant and appropriate, as indicated by overall model efficiency and t or z statistics (as relevant).

Table 2 here, see end.

For purposes of comparison table 2 presents basic panel regression results with and without instruments to account for the endogeneity of efficiency. For the control variables all results appear logical. Growth indicates a monotonic positive but diminishing effect over the relevant data range. Market share has an inverted U relationship with maxima ranging from 45-48 percent depending on specification. The 99^{th} centile for market share is 0.06. Hence apart from the extreme upper tail of the distribution the market share effects are monotonic positive but with diminishing effect. The change in market share has a logical positive effect on profitability. Finally increasing firm size reduces profitability (when this is significant) a result that is different from similar recent evidence from the USA (Lee, 2009). But note that this size effect occurs after controlling for market share.

With efficiency defined as an exogenous variable in table 2 it has a positive impact on profitability that is not significant with fixed effects estimation. Experiments with higher order terms on efficiency generated inferior results. In addition we can note that the presence of efficiency adds little to overall explanatory power when the first two regressions are compared. When the endogeneity of efficiency is modelled it has a positive impact on profitability that is significant at the 10 per cent level. But the Hausman test for this third regression, that compares this formulation with an equivalent fixed effects model, is insignificant. The final column indicates a significant quadratic effect for the impact of efficiency on profitability; higher order efficiency effects are not significant. In addition the Hausman test for this specification is significant at the 10% level. This quadratic has a minimum with an efficiency score of approximately 0.4 which is internal to the current data (see table 1). This therefore indicates the rather counter-intuitive effect that for very inefficient firms increasing efficiency is counterproductive in terms of any profit gain. This finding perhaps suggests that standard panel analysis cannot effectively analyse the relationship between efficiency and profitability. But it also suggests that if empirical work is restricted to the top end of the firm size distribution we might expect a positive relationship between efficiency and profitability using static regression methods.

Table 3 here, see end.

Table 3 shows GMM estimates of profitability functions with only the control variables (i.e. excluding efficiency effects). The Wald statistics indicate that a two period lag is the best specification. The implication here for steady state profitability is that as the significant lagged coefficient is larger than one, with this two period lag specification the long-run determinants of profitability are opposite in sign to the short-run effects. This short-run to long-run switching is consistent with the theoretical framework developed above. The estimated effects of firm growth (G), market share (S), the change in market share (ΔS) and firm size (lnL) on profitability are broadly the same as reported in table 2.

Table 4 here, see end

Table 4 shows GMM estimation results with efficiency included in the profit equation. In this table efficiency is considered an exogenous determinant of profitability. As with table 3, the lag structure can be chosen to maximise the Wald statistic. The results here show the same general short-run control variable coefficients and lag structure effects as in table 2. The estimated coefficient on $(\pi/K)_{t-1}$ with the two period lag (i.e. 1.1088) is larger than the equivalent estimated coefficient in table 2. This suggests that the short-run to long-run switching in table 3 is greater when efficiency effects are recognised than was found above. Exogenous efficiency clearly has an insignificant impact on profitability. Over the relevant range for e, which is bounded by zero and unity, the estimated (insignificant) coefficients indicate an impact on profitability with an approximately zero slope for e from zero to (approximately) 0.7 followed by a clear positive impact on profitability. The nature of this relationship is shown in the penultimate section when marginal effects are reported. Hence the results do not indicate a monotonic effect of efficiency on profitability. In addition they qualify significantly the standard panel estimates reported earlier. Using the simple theoretical model set out above in section 3, this threshold effect can be explained in terms of adjustment to changing efficiency.

Table 5 here, see end.

Table 5 reports results when the endogeneity of efficiency is recognised. An initial point is that the Wald statistic is greatest with a two period lag, as in table 4, and this is increased compared to the earlier regression. The short-run impact of the control variables is unchanged. But the impact of efficiency on profitability and the dynamic structure are somewhat different. The efficiency variables are now highly significant. The estimated coefficients here indicate the same general relationship between efficiency and profitability as that just identified. In the short-run efficiency appears to not affect profitability until e is approximately 0.8 following which there is a positive impact. Hence the insignificance of the efficiency variables in table 4 appears to result from endogeneity issues rather than no effective impact of efficiency on profitability. In the long-run allowing for the endogeneity of efficiency changes the results significantly. The estimated coefficients on lagged π/K indicate that long-run efficiency effects require multiplying the short-run coefficients by a negative number. In addition this short-run to long-run switching is greater than that found in table 4. This conclusion is consistent with improved efficiency increasing profitability in the short-run (subject to a threshold effect) but reducing long-run profitability. This result is therefore consistent with theoretical expectations cited earlier.

5. Efficiency and profitability: further analysis

This section incorporates complexities and qualifications to the general analysis of the relationship between efficiency and profitability reported above. These developments are primarily robustness checks for the results reported in the previous section. A first observation is that in both the short and long runs the effects of efficiency on profitability might depend on the market position and size of a firm. This position and size will be proxied here by sales growth, market share and ln(L) i.e. three of the control variables used above. Hence these control variables will be assumed to have direct impacts on profitability and indirect impacts that operate via efficiency. These indirect impacts will be tracked using interaction terms between the variables and firm efficiency.

To explore the possible issues here in more detail the simple model developed earlier can be further developed. Expanding [4] and, as above, omitting firm specific subscripts:

$$e_t = \frac{R_t}{R_{t-1}} \cdot \frac{R_{t-1}}{R^*_{t-1}} \cdot \frac{R^*_{t-1}}{R^*_t}$$

It follows that

$$e_t = \frac{G_t}{G^*_t} e_{t-1} \qquad [20]$$

where $G_t = R_t/R_{t-1}$ i.e. actual firm sales growth; $e_{t-1} = R_{t-1}/R^*_{t-1}$ i.e. lagged efficiency; $G^*_t = R^*_t/R^*_{t-1}$ i.e. growth potential, that is assumed exogenous. Formulation [20] is an accounting relationship that is consistent with causation running in both directions. G_t can affect e_t by, for example experience effects. Alternatively e_t can affect G_t, and hence profitability, because of competitive advantage. This second effect is relevant here. To control for the first effect the interaction term e_t*G_t will be considered endogenous in later GMM estimation.

Using [7] and [20]

$$\frac{\partial(\pi_t/K_t)}{\partial e_t}=\frac{\partial(L_t/K_t)}{\partial e_t}\left(\frac{R*_t}{L_t}\frac{G_t}{G*_{t-1}}e_{t-1}-p_L\right)+\frac{L_t}{K_t}\left(\frac{R*_t}{L_t}+\frac{\partial(R*_t/L_t)}{\partial e_t}\frac{G_t}{G*_{t-1}}e_{t-1}\right)$$

[20']

It is clear from [20'] that the size of the impact of efficiency (e_{t-1}) on $\partial(\pi_t/K_t)/\partial e_t$ depends on G_t. This impact of growth on the extent to which efficiency improves profitability will be measured below by the marginal effect on profitability of a one per cent increase in efficiency. Based on [20'] we can expect that this marginal effect will increase with G_t with efficiency held constant. It therefore follows from [20'] that we might expect the following:

> Proposition one:
>
> In the short-run, faster sales growth will generate greater marginal effects of efficiency on profitability with efficiency held constant.

Defining total market size in period t for any firm as M_t, expression [20] can be further expanded as follows:

$$e_t=\frac{S_t}{S_{t-1}}\frac{G^M_t}{G*_t}e_{t-1} \qquad [21]$$

where $S_t = R_t/M_t$ i.e. market share; $G^M{}_t = M_t/M_{t-1}$ i.e. market growth, that is assumed exogenous. As with formulation [20], [21] is an accounting relationship that is consistent with causation running from e_t to S_t and the reverse. Here we are interested in the effect of e_t on S_t and hence (indirectly) on profitability. To control for the reverse effect the interaction term e_t*S_t will be considered endogenous in later GMM estimation. Using similar logic as that for equation [20] it follows from formulation [21] that the extent to which the level of efficiency (e_{t-1}) results in a profit gain $[\partial(\pi_t/K_t)/\partial e_t]$ is positively influenced by market share. Also comparing [20] and [21] it follows that

$$\frac{G_t^M e_{t-1}}{S_{t-1} G*_t} >< \frac{e_{t-1}}{G*_t} \qquad \text{as } G^M{}_t >< S_{t-1}.$$

Hence apart from highly concentrated and declining markets we can expect the impact of market share on the impact of efficiency on profitability to be greater than that of firm growth. It follows that we can conclude:

Proposition two:

In the short-run, greater market share will generate greater marginal effects of efficiency on profitability with efficiency held constant. In addition these short-run marginal effects of markets share will be larger than in proposition one.

Finally we can turn to the impact of firm size on the ability to exploit efficiency gains. Two effects are evident here: (1) a direct effect of firm size on the exploitation of efficiency; and (2) indirect effects that operate via firm size on sales growth and market share. With respect to the direct effect the approach used below is equivalent to that used for growth and market share. Initially we can define:

$$e_t = \frac{R_t}{L_t} \cdot \frac{L_t}{R_t^*} \qquad [22]$$

Substituting [22] into [7] and simplifying:

$$\frac{\partial(\pi_t/K_t)}{\partial e_t} = \frac{\partial(L_t/K_t)}{\partial e_t}\left(\frac{R_t}{L_t} - p_L\right) + \frac{R*_t}{K_t} + e_t \frac{L_t}{K_t}\frac{\partial(R*_t/L_t)}{\partial e_t} \qquad [22']$$

It follows from [22'] that the short-run impact of an increase in L_t is ambiguous. We might expect higher L_t to reduce R_t/L_t (in the short run) and increase L_t/K_t (in the short-run). To explore this empirically interaction terms involving efficiency and ln(L) are defined. This allows the marginal effect of a one per cent change in efficiency on profitability to be defined with different ln(L), but holding efficiency constant. We can expect the short-run marginal effects to be positive, but the change in the marginal effects with different employment levels will indicate the extent to which changing firm size promotes or impedes efficiency gains as defined in [22']. This can be interpreted as the direct impact of organisational size on the ability to exploit efficiency gains. We refer to this impact as organisational effectiveness.

Proposition three:

Holding efficiency constant, the marginal effects of efficiency on profitability as ln(L) increases indicate how organisational effectiveness changes as firm size changes. The marginal effects will be positive but may increase or decrease with ln(L).

With respect to the indirect effects of firm size on efficiency gains, these are investigated below by (a) holding efficiency and growth constant and defining marginal effects for differing ln(L) and (b) holding efficiency and market share constant and defining marginal effects for differing ln(L). With respect to the firm size – growth interaction, a given rate of sales growth implies a larger absolute sales change as firm size increases. Hence even though efficiency is size neutral, in that it is measured on the interval [0, 1), the effect of this on profitability for different growth rates should be increasing in firm size.

> Proposition four:
>
> Holding efficiency and firm growth constant, the marginal effects of efficiency on profitability as ln(L) increases should be increasing because a given growth rate will have greater absolute impact on profitability with greater firm size.

For the market share – firm size interaction we can expect the opposite result. The greater a firm's market share the more difficult we can expect it to be to increase it further, ceteris paribus. The reasoning here is an upper bound of market share of one combined with a diminishing marginal returns to marketing effort. Hence given the positive correlation of firm size and market share, ceteris paribus, we can expect the following:

> Proposition five:
>
> Holding efficiency and market share constant, the marginal effects of efficiency on profitability as ln(L) increases will fall if diminishing marginal returns to marketing effort are experienced in the presence of the inevitable upper bound of pure monopoly.

These various effects are explored here by interacting efficiency with the relevant control variables as well as the control variables having independent and exogenous effects. These effects will be summarised below in terms of marginal impacts on profitability of a one per cent efficiency gain at 25^{th}, 50^{th}, 75^{th} and 95^{th} centiles for the variable e. At each of these efficiency levels the same centiles will be identified for G, S, and ln(L). This allows conclusions to be drawn that vary by efficiency gain and interacting factor. In addition the GMM estimation will allow further investigation of the possible long-run (negative) implications of greater efficiency.

6. Efficiency and profitability: further empirical analysis

For reasons already set out we can expect the impact of efficiency on profitability to be endogenous to firm and market factors. For the same reasons we must allow for the endogeneity of any efficiency interaction terms. This requirement to allow for the endogeneity of efficiency places a technical constraint on the estimation procedure. GMM estimation requires a limit to be placed on the maximum lags that can be used as instruments (Greene, 1993). With the earlier estimates, this maximum lag length was set at six. But the more endogenous variables that are introduced during estimation, the more binding this lag constraint becomes. In principle, all the interaction terms could be introduced in a single regression in which case this would require a lower limit than six on the maximum allowable lags particularly in the context of the polynomial efficiency effects that are interacted. This adjustment to instrument use is, in principle, undesirable. To overcome this constraint, the interaction terms are introduced in two stages. First three separate regressions are reported for each of the interaction terms G, S and ln(L).

Secondly, employment effects are further examined with two regressions that include G with ln(L) and S with ln(L). This procedure allows estimation with maximum lags of six that can be used as instruments in all cases.

Tables 6-8 here, see end.

The results of the first stage of this further analysis are presented in tables 6, 7 and 8. In each case, the interaction terms are included if they add to model specification. In addition all included efficiency effects are considered endogenous including the interaction terms for the reasons set out above. It is clear that a two period lag is best in all three cases, replicating earlier results. We can therefore restrict further analysis to the case of this lag structure. For all of tables 6, 7 and 8 the estimated coefficients on the lagged variables are (as above) greater than one, indicating that the long-run and short-run effects are of opposite signs. With respect to the short-run effects of efficiency on profitability in tables 6, 7 and 8, the non-linearity of the forms used here suggests the use of marginal impacts. The marginal effects for the results in tables 6, 7 and 8 are reported in table 9. In all cases, the two period lag model is used.

Table 9 here, see end.

With respect to the results in table 9, if the rows are examined, in all cases at efficiency levels of 25^{th}, 50^{th} and 75^{th} centiles the marginal effects are effectively flat. But with efficiency at the 95^{th} centile there is a clear positive impact on profitability. This conclusion is consistent with the earlier reported threshold effect of efficiency on profitability. This threshold appears to occur at an efficiency level between the 75th and 95th centiles. Comparing the marginal effects for growth and market share, in all cases the growth effects are smaller. This finding is consistent with proposition two set out in the previous section. At the 95th efficiency centile it is apparent that the marginal effects for growth and market share increase as growth and market share increase. This finding is consistent with propositions one and two set out above. Finally, at the 95th efficiency centile the marginal effects for ln(L) decline as employment increases but in all cases they are positive. As highlighted in proposition three above, this is consistent with declining organisational effectiveness with increasing firm size.

Table 10 here, see end.

Table 11 here, see end.

Turning to the second stage of the analysis in this section, the effects of firm size are further examined with two regressions that include G with ln(L) and S with ln(L). The basic results are reported in table 10 and the corresponding marginal effects in table 11. Table 10 only presents two period lag regressions, that are, as above, superior to alternative specifications. A preliminary point is that the estimated coefficients on the lagged dependent variable are still greater than one but smaller than the equivalent specification in table 8. This implies that increasing efficiency still undermines long-run performance but to a lesser extent than earlier results. The combined interaction terms can therefore, in this respect, be considered important.

With respect to the marginal effects in table 11, a threshold impact of efficiency on profitability is still evident in all rows, apart from the bottom four rows that are commented on below. For the 95th efficiency centile, increasing growth and market share increases the marginal effects on profitability, if firm employment is held constant. This is the case for all the marginal effects in the final column. The greater detail shown here is consistent with the more aggregate results in table 9 and earlier propositions. With respect to the market share marginal effects these decline as firm size increases. This result shows that the effect identified in proposition five, stated above, is important. This effect is so strong that for the largest firms shown in the bottom four rows there is no obvious impact of efficiency on profitability, even with a threshold effect. With respect to the growth marginal effects in table 11, it is apparent that these increase as firm size increases. This shows that the effect identified in proposition four above is important. It is perhaps pertinent to emphasise that earlier it was concluded that the direct impact of firm size on a firm's ability to exploit efficiency gains was declining. This was interpreted as declining organisational effectiveness. But the indirect impact here is increasing when the effect of firm size on growth benefits is recognised because of the increasing absolute impact of larger firm size with a given rate of growth.

7. Conclusion

This paper has explored the relationship between efficiency and profitability using a panel of UK manufacturing firms. An over-riding theme has been that any relationship will potentially differ in the short and long-runs. While we might expect efficiency to increase profitability in the short-run, in the long-run firm adjustment to a changing environment requires a degree of slack resources. This required organisational slack will generate inefficiencies. In this paper estimates of firm efficiency are generated using a stochastic frontier methodology.

With standard panel analysis this short-run/long-run distinction cannot be identified. After allowing for the endogeneity of efficiency this standard analysis suggests a positive or a counter-intuitive U shaped relationship between efficiency and profitability. As there appears to be a positive relationship between efficiency and firm size it follows from these findings that if empirical work concentrates on the top end of the firm size distribution a positive relationship between efficiency and profitability can be expected. But with GMM estimation, and allowing for the endogeneity of efficiency, the short and long-run effects can be identified. The estimated model is based on a 4^{th} order relationship between efficiency and profitability. This 4^{th} order model is predicted here using a theoretical framework that incorporates simple efficiency adjustment processes. It is somewhat obvious that with more sophisticated adjustment processes a higher order levels equation might result. In the short-run the 4^{th} order relationship indicates a threshold effect of efficiency on profitability. After allowing for the endogeneity of efficiency, below efficiency scores of approximately 0.8 increases in efficiency have no significant impact on profitability. Above the threshold there is a positive relationship between efficiency and profitability. Solving the GMM regression for the implicit long-run relationship suggests that increasing efficiency reduces long-run profitability, but only above the estimated threshold.

The final two substantive sections of the paper introduce complexities involving the ways in which the impact of efficiency on profitability can interact with firm growth, market share and firm size. These effects are investigated using interaction terms between efficiency and these other variables. Specific propositions are presented for the effects involved. The calculated marginal effects on profitability of a one per cent increase in efficiency generate results consistent with the propositions. In particular increasing firm growth and market share increase the marginal effects but increased firm size reduces the marginal effects. The more complex interaction between firm size and (1) growth and efficiency and (2) market share and efficiency generates results consistent with expectations.

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Tables

Table 1a
Distribution of estimated firm efficiencies (e_{it})

Percentile	Efficiency
25	0.2747
50	0.3693
75	0.5090
95	0.7617
99	0.9202
Mean	0.4067
Obs	89942

Table 1b
Distribution of estimated firm efficiencies by firm revenue

Revenue centile	Obs	Efficiency 50^{th} centile	Efficiency 75^{th} centile	Efficiency 95^{th} centile	Efficiency 99^{th} centile
50	46097	0.3612	0.4951	0.7630	0.9276
75	23049	0.3753	0.5195	0.8003	0.9483
95	4591	0.4720	0.6380	0.9166	0.9690
99	917	0.6468	0.7969	0.9320	0.9612

Table 2
Fixed effects profit equations: dependent variable π/K

G	0.0122 (6.13)	0.0122 (6.13)	0.0122 (6.14)	0.01210 (6.01)
G^2	-1.03e-06 (-5.64)	-1.03e-06 (-5.64)	-1.03e-06 (-5.64)	-1.03e-06 (-5.56)
S	35.0935 (4.32)	35.2603 (4.34)	35.9186 (4.42)	35.5596 (4.32)
S^2	-39.1727 (-3.89)	-39.3127 (-3.91)	-39.8616 (-3.96)	-37.9198 (-3.71)
ΔS	22.1691 (3.89)	22.0068 (3.86)	21.3543 (3.74)	22.6045 (3.89)
$(\Delta S)^2$	26.3915 (3.03)	26.1941 (3.00)	25.4013 (2.91)	27.4538 (3.09)
ln(L)	-0.2378 (-2.06)	-0.2329 (-2.02)	-0.2130 (-1.84)	-0.3331 (-2.60)
e		1.9302 (0.59)	9.6906 (1.86)	-287.9418 (-2.28)
e^2				345.9728 (2.36)
Cons	1.1677 (2.09)	0.3647 (0.25)	-2.8661 (-1.28)	50.5333 (2.22)
F stat	10.54	9.26		
Wald χ^2			85.00	88.59
R^2 within	0.0011	0.0011	0.0010	.
R^2 between	0.0067	0.0055	0.0023	0.0028
Hausman χ^2	18.94	20.77	3.71	10.41
Obs	77471	77456	77456	77456
Firms	11675	11674	11674	11674
Instrument list			G G^2 S S^2 ΔS ΔS^2 ln(L) year dummies	G G^2 S S^2 ΔS ΔS^2 ln(L) year dummies

Notes:
1. t or z scores in parentheses
2. Hausman tests compare the fixed effects with the equivalent random effects model in the first two columns, and the instrumental variables specification with the equivalent fixed effects model in the final two columns.

Table 3
Profitability Equation (excluding efficiency effects): dependent variable π/K

$(\pi/K)_{t-1}$	0.9051 (4.65)	1.0436 (3.53)	1.3240 (3.44)
$(\pi/K)_{t-2}$		0.1700 (0.82)	0.3048 (1.00)
$(\pi/K)_{t-3}$			0.0124 (0.15)
G	0.0132 (6.70)	0.1032 (15.60)	0.0683 (8.46)
G^2	-1.13e-06 (-6.11)	-0.00002 (-14.55)	-0.00002 (-8.10)
S	58.1581 (6.25)	107.6497 (7.39)	84.9614 (3.41)
S^2	-62.3283 (-5.56)	-115.3456 (-6.39)	-101.2864 (-3.08)
ΔS	15.4035 (2.74)	21.1708 (2.58)	12.0255 (0.94)
$(\Delta S)^2$	18.1425 (2.16)	25.2065 (2.12)	18.2262 (0.77)
ln(L)	-0.3709 (-2.42)	-0.6754 (-3.71)	-0.6075 (-2.73)
Cons	1.7065 (2.30)	2.9527 (3.35)	2.7378 (2.54)
Wald χ^2	112.04	350.25	108.14
Sargan χ^2	92.8006	85.4425	57.0616
Additional instruments	Year dummies	Year dummies	Year dummies
Obs	64946	54441	44357
Firms	11449	10807	10099

Note: z statistics in parentheses.

Table 4
Profitability Equations (exogenous efficiency effects): dependent variable π/K

$(\pi/K)_{t-1}$	0.9437 (4.85)	1.1088 (3.75)	1.3887 (3.61)
$(\pi/K)_{t-2}$		0.2006 (0.97)	0.3392 (1.11)
$(\pi/K)_{t-3}$			0.0153 (0.18)
G	0.0133 (6.76)	0.1032 (15.60)	0.0683 (8.46)
G^2	-1.13e-06 (-6.15)	-0.00002 (-14.55)	-0.00002 (-8.09)
S	58.6340 (6.30)	107.7483 (7.39)	84.9482 (3.41)
S^2	-62.7659 (-5.59)	-115.5654 (-6.40)	-101.4459 (-3.09)
ΔS	15.1196 (2.69)	21.1181 (2.58)	12.0337 (0.94)
$(\Delta S)^2$	17.7850 (2.11)	25.1402 (2.11)	17.9561 (0.75)
ln(L)	-0.3483 (-2.25)	-0.6597 (-3.58)	-0.5988 (-2.66)
e	-76.4264 (-1.09)	-113.9848 (-1.29)	-129.7267 (-1.15)
e^2	306.1354 (1.32)	421.9008 (1.44)	460.0189 (1.23)
e^3	-476.6551 (-1.47)	-641.7694 (-1.56)	-679.6347 (-1.31)
e^4	258.195 (1.62)	344.2986 (1.70)	356.8352 (1.40)
Cons	7.0536 (0.94)	13.0377 (1.37)	15.0617 (1.22)
Wald χ^2	120.64	357.96	113.06
Sargan χ^2	96.8372	92.1957	61.4410
Additional instruments	Year dummies	Year dummies	Year dummies
Obs	64935	54432	44349
Firms	11447	10805	10097

Note: z statistics in parentheses.

Table 5
Profitability Equations (endogenous efficiency effects): dependent variable π/K

$(\pi/K)_{t-1}$	1.0432 (5.37)	1.2547 (4.26)	1.4440 (3.78)
$(\pi/K)_{t-2}$		0.2480 (1.20)	0.3538 (1.17)
$(\pi/K)_{t-3}$			0.0193 (0.23)
G	0.0137 (6.93)	0.1035 (15.67)	0.0678 (8.41)
G^2	-1.16e-06 (-6.28)	-0.00002 (-14.61)	-0.00002 (-8.04)
S	54.1986 (6.26)	97.9343 (7.11)	79.4481 (3.27)
S^2	-57.3569 (-5.41)	-106.4922 (-6.05)	-94.1933 (-2.89)
ΔS	13.6701 (2.50)	20.1154 (2.52)	10.3472 (0.82)
$(\Delta S)^2$	16.9492 (2.08)	24.1932 (2.13)	16.2143 (0.69)
ln(L)	-0.2287 (-1.48)	-0.4926 (-2.67)	-0.4366 (-1.93)
e	-788.5573 (-7.90)	-759.3231 (-6.21)	-447.6784 (-2.84)
e^2	2982.869 (8.42)	2831.124 (6.57)	1627.114 (2.96)
e^3	-4509.885 (-8.79)	-4256.382 (-6.85)	-2413.702 (-3.05)
e^4	2363.909 (9.21)	2233.557 (7.19)	1275.625 (3.23)
Cons	67.7362 (6.88)	67.8811 (5.56)	41.3705 (2.59)
Wald χ^2	268.38	455.87	144.84
Sargan χ^2	2366.254	1962.125	1325.491
Additional instruments	year dummies	year dummies	year dummies
Obs	64935	54432	44349
Firms	11447	10805	10097

Note: z statistics in parentheses.

Table 6: Profitability equations (with endogenous efficiency effects and growth interaction terms): dependent variable π/K

$(\pi/K)_{t-1}$	1.2324 (4.85)	1.1530 (4.04)	1.3256 (3.54)
$(\pi/K)_{t-2}$		0.2265 (1.11)	0.2759 (0.92)
$(\pi/K)_{t-3}$			0.0062 (0.07)
e	-617.6536 (-6.19)	-577.720 (-4.73)	-450.5396 (-2.86)
e^2	2341.454 (6.60)	2146.46 (4.99)	1673.043 (3.04)
e^3	-3539.814 (-6.88)	-3210.825 (-5.17)	-2549.89 (-3.24)
e^4	1857.272 (7.20)	1681.187 (5.42)	1393.509 (3.56)
$e*G$		2.1655 (2.89)	17.6253 (4.18)
e^2*G	2.3276 (3.31)	-7.4579 (-3.45)	-95.6949 (-4.50)
e^3*G	-8.2283 (-3.35)	6.7048 (4.30)	202.5766 (4.83)
e^4*G	7.2505 (3.88)		-144.572 (-5.09)
Wald χ^2	400.22	612.56	183.43
Sargan χ^2	2419.049	1932.543	1376.228
Additional instruments	year dummies	year dummies	year dummies
Obs	64935	54432	44349
Firms	11447	10805	10097

Note:
Control variables included in regressions: G, G^2, S, S^2, ΔS, $(\Delta S)^2$, ln(L) but not reported.
Constant term not reported.

Table 7: Profitability equations (with endogenous efficiency effects and market share interaction terms): dependent variable π/K

$(\pi/K)_{t-1}$	1.0548 (5.44)	1.2759 (4.34)	1.4669 (3.84)
$(\pi/K)_{t-2}$		0.2582 (1.25)	0.3642 (1.20)
$(\pi/K)_{t-3}$			0.0205 (0.24)
e	-789.2845 (-7.92)	-756.0443 (-6.23)	-451.3324 (-2.91)
e^2	2984.697 (8.45)	2821.484 (6.61)	1655.065 (3.06)
e^3	-4509.513 (-8.82)	-4242.205 (-6.90)	-2465.978 (-3.17)
e^4	2361.523 (9.23)	2223.272 (7.24)	1303.465 (3.37)
e*S		-405.1182 (-1.39)	-2435.488 (-1.68)
e^2*S	-26.8105 (-1.23)	486.4621 (1.90)	4835.139 (1.76)
e^3*S			-2800.621 (-1.74)
e^4*S			
Wald χ^2	269.50	459.89	148.48
Sargan χ^2	2423.614	2052.238	1397.021
Additional instruments	year dummies	year dummies	year dummies
Obs	64935	54432	44349
Firms	11447	10805	10097

Note:
Control variables included in regressions: G, G^2, S, S^2, ΔS, $(\Delta S)^2$, ln(L) but not reported.
Constant term not reported.

Table 8: Profitability equation (with endogenous efficiency effects and employment interaction terms): dependent variable π/K

$(\pi/K)_{t-1}$	1.0741 (5.51)	1.2802 (4.33)	1.5838 (4.10)
$(\pi/K)_{t-2}$		0.2912 (1.40)	0.4073 (1.34)
$(\pi/K)_{t-3}$			0.0188 (0.22)
e	-2345.554 (-5.78)	-2628.195 (-5.57)	-870.2786 (-4.29)
e^2	8244.434 (5.73)	9114.061 (5.45)	1556.642 (3.80)
e^3	-11710.3 (-5.73)	-12846.21 (-5.43)	-815.4983 (-3.15)
e^4	5792.364 (5.83)	6342.794 (5.54)	
e*ln(L)	307.4864 (3.81)	371.9903 (4.03)	
e^2*ln(L)	-1042.411 (-3.60)	-1258.061 (-3.81)	290.1271 (4.80)
e^3*ln(L)	1433.747 (3.46)	1736.8 (3.69)	-690.1746 (-4.77)
e^4*ln(L)	-685.5239 (-3.39)	-838.464 (-3.66)	430.2483 (4.68)
Wald χ^2	324.99	508.32	157.83
Sargan χ^2	2814.271	2386.58	1482.904
Additional instruments	year dummies	year dummies	year dummies
Obs	64935	54432	44349
Firms	11447	10805	10097

Note:
Control variables included in regressions: G, G^2, S, S^2, ΔS, $(\Delta S)^2$, ln(L) but not reported.
Constant term not reported.

Table 9: Short-run marginal effects on profitability of a 1 per cent increase in efficiency

	e 25th centile	e 50th centile	e 75th centile	e 95th centile
G 25th centile	0.0396	0.1180	-0.0118	0.6310
G 50th centile	0.0395	0.1178	-0.0119	0.6329
G 75th centile	0.0394	0.1176	-0.0120	0.6352
G 95th centile	0.0388	0.1165	-0.0125	0.6445
S 25th centile	0.0521	0.1473	-0.0470	0.7254
S 50th centile	0.0520	0.1473	-0.0469	0.7261
S 75th centile	0.0517	0.1471	-0.0465	0.7284
S 95th centile	0.0483	0.1456	-0.0422	0.7522
ln(L) 25th centile	0.0441	0.2371	0.0273	0.7781
ln(L) 50th centile	0.0525	0.1918	0.0248	0.7463
ln(L) 75th centile	0.0621	0.1401	0.0219	0.7099
ln(L) 95th centile	0.0804	0.0416	0.0165	0.6406

Note:

Calculations based on results reported in tables 6, 7 and 8.

Table 10: Profitability equations (with endogenous efficiency effects and general interaction terms): dependent variable π/K

$(\pi/K)_{t-1}$	1.1562 (4.03)	1.1814 (4.00)
$(\pi/K)_{t-2}$	0.2099 (1.03)	0.2234 (1.08)
e	-546.9072 (-2.64)	288.6112 (1.38)
e^2	1081.09 (2.47)	-894.5333 (-2.05)
e^3	-631.3167 (-2.28)	775.6631 (2.86)
e*ln(L)	-68.1847 (-2.01)	-169.1826 (-4.94)
e^2*ln(L)	427.9769 (4.68)	592.3443 (6.49)
e^3*ln(L)	-818.3927 (-6.62)	-776.1124 (-6.33)
e^4*ln(L)	484.23 (7.06)	327.9214 (4.87)
e*G	1.3134 (1.99)	
e^2*G	-5.4782 (-2.81)	
e^3*G	5.7188 (4.02)	
e^2*S		132.2347 (2.23)
Wald χ^2	734.59	498.73
Sargan χ^2	2253.566	2555.175
Additional instruments	year dummies	year dummies
Obs	54432	54432
Firms	10805	10805

Notes:
Control variables included in regressions: G, G^2, S, S^2, ΔS, $(\Delta S)^2$, ln(L) but not reported.
Constant term not reported.

Table 11: Short-run marginal effects on profitability by firm size of a 1 per cent increase in efficiency

		ln(L) 25th centile		
	e 25th centile	e 50th centile	e 75th centile	e 95th centile
G 25th centile	-0.0251	0.1289	0.0539	0.5235
G 50th centile	-0.0252	0.1288	0.0540	0.5257
G 75th centile	-0.0254	0.1286	0.0541	0.5284
G 95th centile	-0.0259	0.1279	0.0546	0.5394
S 25th centile	0.0099	0.0420	-0.0268	1.0063
S 50th centile	0.0099	0.0421	-0.0266	1.0067
S 75th centile	0.0101	0.0425	-0.0260	1.0081
S 95th centile	0.0119	0.0458	-0.0197	1.0223
		ln(L) 50th centile		
G 25th centile	0.0219	0.1589	-0.0002	0.6265
G 50th centile	0.0218	0.1588	-0.0001	0.6287
G 75th centile	0.0216	0.1586	-2.2E-05	0.6314
G 95th centile	0.0211	0.1579	0.0005	0.6424
S 25th centile	0.0273	0.0910	-0.0142	0.7769
S 50th centile	0.0273	0.0911	-0.0140	0.7773
S 75th centile	0.0275	0.0914	-0.0134	0.7786
S 95th centile	0.0293	0.0947	-0.0071	0.7928
		ln(L) 75th centile		
G 25th centile	0.0755	0.1932	-0.0620	0.7441
G 50th centile	0.0754	0.1931	-0.0619	0.7463
G 75th centile	0.0753	0.1929	-0.0618	0.7489
G 95th centile	0.0748	0.1922	-0.0613	0.7599
S 25th centile	0.0471	0.1468	0.0002	0.5149
S 50th centile	0.0471	0.1469	0.0004	0.5153
S 75th centile	0.0473	0.1472	0.0010	0.5166
S 95th centile	0.0492	0.1506	0.0073	0.5308
		ln(L) 95th centile		
G 25th centile	0.1778	0.2585	-0.1797	0.9681
G 50th centile	0.1777	0.2584	-0.1796	0.9704
G 75th centile	0.1775	0.2582	-0.1795	0.9730
G 95th centile	0.1770	0.2575	-0.1790	0.9840
S 25th centile	0.0848	0.2532	0.0276	0.0159
S 50th centile	0.0849	0.2533	0.0278	0.0162
S 75th centile	0.0850	0.2537	0.0284	0.0176
S 95th centile	0.0869	0.2570	0.0348	0.0318

Note:
Calculations based on results reported in table 10.