TECHNICAL EFFICIENCY IN MANUFACTURING INDUSTRIES IN MALAWI USING DETERMINISTIC PRODUCTION FRONTIER

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Abstract

This paper uses the census of production data for large establishments in selected manufacturing industries in Malawi to estimate the level of technical efficiency between 1984 and 1988 using the deterministic production frontier approach. The study uses panel data for seven manufacturing sectors: tea; tobacco; wearing apparel; printing and publishing; soaps, perfumes and cosmetics; plastic products and fabricated metal products. We find that the mean overall technical efficiency ranges from 38 percent in the printing and publishing industry to 87 percent in fabricated metal products. However, the minimum technical efficiency scores range from as low as 16 percent in the tea industry to 55 percent in plastic products at firm level. The predicted firm level efficiencies are explained by firm specific and industry characteristics. The analysis reveals that the market share of the firm is positively associated with technical efficiency while monopoly power is negatively associated with technical efficiency.

1. Introduction

The manufacturing sector accounts for 12 percent of gross domestic product in Malawi. The bulk of industrial production is concentrated in five sub-sectors: food processing including sugar and tea; beverages; tobacco; textiles, netting and blankets; and pharmaceuticals, paints, soaps and cooking oils. These sectors accounted for about 71 percent of gross output and 78 percent of total employment in the manufacturing sector.[1] Most of these five sub-sectors have strong backward linkages with the agricultural sector as a source of raw materials but very few industrial linkages within the manufacturing sector. Overall the manufacturing sector in Malawi imports about two-thirds of their raw materials and sell their products to the final consumer (World Bank, 1989). The manufacturing sector is also highly concentrated and has enjoyed protection of various forms from several interventionist policies pursued by the government.

The structural adjustment programs that the Malawi government has been pursuing since 1981 have led to liberalisation of output and input markets and have opened the economy to international competition. These changes in output and input markets and the competitiveness of economic activities affect the environment in which firms operate and alters incentives for profit maximisation or cost minimisation. Arguably, since liberalisation of markets alters the incentive

[1] See Chirwa (1994) for a detailed analysis of the domestic market and market structure and prospects for industrial sector opportunities.

structure and the competitive environment, we would expect such changes to have influence on the input-output combination of manufacturing activities. Therefore, studying the efficiency of firms within the adjustment period over time is important in order to determine wether the incentives created by market reforms lead to improvements in the use of resources. Previous studies on the performance of firms in the Malawian manufacturing sector focus on profitability (Kaluwa, 1986; Kaluwa and Reid, 1991), total factor productivity (Mulaga and Weiss, 1996; Mulaga, 1995; World Bank, 1989) and export performance (Chirwa, 1998).

Technical efficiency is a form of productive efficiency and is concerned with the maximisation of output for a given set of resource inputs. Productive efficiency reflects the combination which minimizes the cost of producing a given level of output or equivalently the combination of inputs that for a given monetary outlay maximizes the level of production. We estimate technical efficiency using data envelopment analysis (DEA), a non-parametric and deterministic approach that uses the 'best practice' production function measures proposed by Farrell (1957). We organize the rest of paper as follows. Section 2 presents a brief overview of government policy towards the manufacturing sector in Malawi. In Section 3, we present the data envelopment analysis (DEA) technique of estimating technical efficiency. Section 4 presents a description of data and the methods of estimating technical efficiency. In Section 5, we present and discuss empirical results on the technical efficiency of firms and sources of technical efficiency. Finally, Section 6 provides concluding remarks for the paper.

2. Government Policy Towards the Manufacturing Sector in Malawi

Government policies towards industry from independence in 1964 until 1991 have been more protective and often conflicting with each other and economic objectives.[2] In the first two decades of independence the emphasis had been on the development of import substitution manufacturing industries. This resulted in some protectionist policies through tariff and non-tariff barriers and a tight regulatory regime for new entrants. Effectively, government intervention in

[2] See Kaluwa (1992) and Chirwa (1994, 1998) for cases of potential conflicts among objectives.

the manufacturing sector amounted to what we can characterize as anti-competition policy.[3] We can loosely divide the policy regime into three periods. The first period is a protective regime that covered the period between independence and the year before structural adjustment reforms (1964 - 1980). The second period is the intermediate or adjusting period in which the government pursued a phased approach to industrial sector reforms between 1981 and 1994. The third period is the post-adjustment era or less protective regime since 1995. This study focuses on part of the intermediate or adjusting period, particularly the 1984-1988 period.

Industrial policy in the protective regime was characterized by price controls that covered more than forty-two industrial products, regulation of entry into manufacturing activities through the licensing procedure that gave incumbent firm strategic advantages, provision for exclusive monopoly rights to large enterprises with the potential for the exploitation of economies of scale, presence of institutional barriers to entry and direct state investment in the manufacturing sector. Kaluwa (1986, 1992), Khan *et al*. (1992) and Chirwa (1994, 1998) provide extensive discussions of these issues. Kaluwa (1986) notes that these price controls had little incentives to efficiency (cost minimisation) and created equity problems and limited entry by restricting profitability that is the main source of investment financing. Direct state investment enhanced the protection of markets since most operated as statutory monopolies or oligopolies. Other protective policies included the allocation of foreign exchange and high tariffs. These policies contributed to the emergence of a highly monopolistic and oligopolistic market structure in Malawi manufacturing enterprises.

The intermediate or adjusting regime involves a phased reform of some policies that the government pursued in the protective regime. The industrial sector reforms were part of the overall economic reform program sponsored by the World Bank and International Monetary Fund (IMF) in a series of Structural Adjustment Programs (SAPs). Under structural adjustment programs various policy changes took place to correct the market distortions. Since 1981, the

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[3] Kirkpatrick *et al.* (1984) defines an effective competition policy as legislative or constitutional elements that essentially control the concentration of economic power, promote competition, encourage innovation, create conditions favourable to employment, strive to control inflation, encourage balanced economic development and promote social welfare.

government has tapped seven structural adjustment loans (SALs) and sectoral credits from the IMF and World Bank to support the implementation of a series of structural adjustment policies.[4]

Some structural adjustment measures directly aimed at stimulating growth in the manufacturing sector and are presented in Table 1. Policies towards the industrial sector clearly dominated the objectives of the first three programs, SAL I - SAL III. The program aimed at diversifying the export base, encouraging efficient import substitution and ensuring appropriate price and income policy. The policy actions taken to achieve these objectives centred on devaluation, agricultural prices and interest rate adjustments, reduction of products under price controls, privatization of state-owned enterprises.

[Table 1 goes here]

The fourth program, the Industrial and Trade Policy Adjustment Credit (ITPAC), was a special sectoral credit facility aimed at improving the policy environment for the manufacturing sector to increase the efficiency of resource use including imports and to expand exports. The policy of industrial price deregulation continued, and only the prices of fuel and motor vehicle parts were under price control. The government abolished exclusive monopoly rights in 1988, reduced the scope of export licensing and liberalized foreign exchange allocation.

The programs that followed ITPAC namely, Agricultural Sector Adjustment Credit (ASAC), Entrepreneurship Development and Drought Recovery Program (EDDRP) and Fiscal Restructuring and Deregulation Program (FRDP) reinforced the earlier adjustment policies. For instance, the government deregulated entry in manufacturing activities in 1992 and reduced tariffs with the consolidated tariff rates limited to a maximum of 75 percent.

It is evident from the above analysis that the industrial sector policies in particular and the economic policies overall have attempted to remove price distortions and adjustments to a market system are almost complete. The policy changes alter the incentive structure of the firms and their

[4] See Chirwa and Chilowa (1997) for the sectoral policy actions under each program and their effects on trade and industry development, and labour markets.

external environment and influence the input-output mix in production processes. We expect technical efficiency to improve in the manufacturing sectors during the adjustment period, for instance, due to increases in domestic and import competition, liberalisation of input and output prices and increases in trade openness.

3. Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a deterministic and nonparametric approach to efficiency measurement that has mostly been used in operational research and management science, following Charnes *et al.* (1978). This approach is an alternative measure of Farrell's original approach of computing the efficiency frontier as a convex hull in the input coefficient space by assuming strong disposability of inputs and constant returns to scale.[5] DEA is a linear programming approach for measuring the technical efficiency of a multiple input-multiple output individual decision making unit (DMU) that does not require any prior assumptions about the form of the production function. Fare and Lovell (1978), in related work, also provide an alternative measure of technical efficiency based on the axiomatic treatment of the production function. The DEA approach developed by Fare and others as presented in Byrnes *et al*. (1984) and Fare *et al.* (1985, 1994) allow further decomposition of technical efficiency into several mutually exclusive and exhaustive components, and where prices for inputs are available overall productive efficiency and allocative (factor price) efficiency are estimated by linear programs.[6]

The measures of technical efficiency are based on output and input sets.[7] Output-oriented measures of efficiency determine the extent to which output could be increased given inputs. On the other hand, input-oriented measures of efficiency identify the extent which inputs could be

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[5] See also Charnes *et al.* (1981) and Bjurek *et al.* (1990).

[6] Fare *et al*. (1983, 1985, 1994) generate six measures of efficiency by relaxing assumptions and use of input price data. These measures include overall productive efficiency, allocative (or factor price) efficiency, overall technical efficiency, pure technical efficiency, congestion efficiency and scale efficiency. A review of some developments in DEA is found in Seiford and Thrall (1990).

[7] See Fare *et al*. (1994) for the distinctions and linear programs for estimation of efficiency (inefficiency).

proportionally reduced to produce a given quantity of output. We follow the Fare tradition and focus on input-oriented measures of technical efficiency.

3.1 Constant Returns to Scale Model

The constant returns to scale model assumes strong disposability of inputs (S) and constant returns to scale (C). Strong or free disposability refers to the ability to stockpile or dispose of unwanted commodities. The linear program minimizes θ which determines the amount by which observed inputs can be proportionally decreased if they are utilized efficiently. We solve the following linear program:

$$OTE_{j_0}(y,x \mid C,S) = Min\ \theta \tag{1}$$

$$\text{s.t.} \quad \sum_{j=1}^{n} w_j x_{ij} \leq \theta x_{ij_0} \qquad i = 1,...,s$$

$$\sum_{j=1}^{n} w_j y_{rj} \geq y_{rj_0} \qquad r = 1,...,m$$

$$w_j \geq 0$$

where $OTE_{j_0}(y,x \mid C,S)$ is the overall technical efficiency of the firm j_0, θ is the measure of technical efficiency, y_{rj} denotes output *r* (*r* = 1, ..., *s*) for the *j* th firm, x_i denotes input *i* (*i* = 1, ...,*m*) and w_j are the weights used to construct hypothetical firms on the frontier. The relative efficiency here captures the percentage by which observed inputs can be proportionally decreased, given the output, if firms used them efficiently. This is equivalent to measuring the ratio of actual output to potential/efficient (frontier) output for output-oriented measures.

We illustrate the DEA technique in Figure 1 with one output and one input and four firms A, B, C and D. Under constant returns to scale and strong disposability, the frontier technology constructed by the observations is represented by the ray from the origin through point B. In the input-oriented measure of efficiency, only B is efficient since it is on the frontier and the input-saving measure is calculated by $x_b/x_b = 1$. Firm A is inefficient since output at point A can potentially be produced by a smaller quantity of input x_0 rather than x_a ($x_0 < x_a$) and its efficiency level is calculated as $x_0/x_a < 1$.

[Figure 1 goes here]

3.2 Variable Returns to Scale Model

We relax the assumption of constant returns to scale for estimating overall efficiency to obtain efficiency under variable returns to scale (V), while maintaining the assumption of strong disposability of inputs (S) following Banker *et al.* (1984). The reference technology in Figure 1 is bounded by $x_a ABC$ and the horizontal line to the right of C and the x-axis from x_a to infinity. This implies that firms A, B and C are fully efficient, while the efficiency of D is measured by x_1/x_d, which is less than one and below the frontier. Imposing a further restriction on the weights relaxes the assumption of constant returns to scale. The resulting linear program derives the input-oriented Weak Efficiency measure under variable returns to scale:

$$WTE_{j_0}(y,x \mid V,S) = Min\ \theta \tag{2}$$

subject to a further restriction in (1)

$$\sum_{j=1}^{n} w_j = 1$$

We calculate another input-oriented measure of technical efficiency under the assumption of nonincreasing returns to scale (N) and strong disposability of inputs (S) (Fare *et al.*, 1994; Bjurek *et al.*, 1990). We solve the linear program in (1) to obtain a Weak Efficiency measure under nonincreasing returns to scale by imposing a further constraint. Thus,

$$WTE_{j_0}(y,x \mid N,S) = Min\ \theta \tag{3}$$

subject to an additional constraint in equation (1)

$$\sum_{j=1}^{n} w_j \leq 1$$

The technology for $WTE_{j_0}(y,x \mid N,S)$ in Figure 1 is bounded by the x-axis and OBC and the horizontal line to the right of C. Thus, point A which is efficient under variable returns to scale and strong disposability, is inefficient under nonincreasing returns to scale and strong disposability of inputs. Points B and C are technically efficient both under variable returns to scale and nonincreasing returns to scale.

3.3. Scale Efficiency

Scale efficiency captures departure of a firm from optimal scale. The input-oriented scale efficiency measure is given as:

$$STE_{j_0}(y,x) = \frac{OTE_{j_0}(y,x \mid C,S)}{WTE_{j_0}(y,x \mid V,S)} \qquad \text{j = 1,2, ..., J} \qquad (4)$$

Thus, firm *j* is input scale efficient if $STE_{j_0}(y,x) = 1$, or if it is equally technically efficient relative to the (C,S) and (V,S) input set. Scale efficiency that measures input loss due to operating at an inefficient scale. In Figure 1, only point B is scale efficient. While points A, C, and D are scale inefficient since they could produce the same output with the less inputs if they operated on an efficient scale (the difference between nonconstant returns to scale technology and the constant returns to scale technology).

These four measures of efficiency enable the identification of the types of returns to scale in production for a particular firm. We have constant returns to scale if $OTE_{j_0}(y,x \mid C,S) = WTE_{j_0}(y,x \mid V,S)$. This is satisfied at point B. If $WTE_{j_0}(y,x \mid N,S) = WTE_{j_0}(y,x \mid V,S) \neq OTE_{j_0}(y,x \mid C,S)$, then the unit under consideration produces at decreasing returns to scale. The firm at point C produces at decreasing returns to scale. Finally, production takes place at increasing returns to scale if $WTE_{j_0}(y,x \mid V,S) \neq WTE_{j_0}(y,x \mid N,S)$, such as at points A and D.

In all the above types of technical efficiency, production is technically efficient if the measure of efficiency is equal to unity. If we have technical inefficiency, the corresponding measures will be less than one. The difference between unity and the observed measure yield the percentage of potential input savings that the firm could make due to the particular type of inefficiency.

3.4 DEA Approaches with Panel Data

The literature suggests at least four approaches of estimating technical efficiency in data envelopment analysis with panel data. These approaches are the window analysis, the contemporaneous frontier, sequential frontier and the intertemporal frontier.[8] In the present study we use the window analysis and the intertemporal frontier. The former ensures that technology is never forgotten while later increases the number of observations when the number of firms in the industry is small.

The window analysis technique involves partial pooling of panel data (k enterprises over T time periods). The panel is divided into a series of shorter overlapping panels, each having k enterprises and W time periods. The first pooled panel (window) consists of k enterprises and time periods $\{1,...,W\}$, the second consists of k enterprises and time periods $\{2,...,W+1\}$, and so on until the final window with k enterprises and time periods $\{T-W+1,...,T\}$. Thus, the window is shifted forward one period each time. The widths of each window (W) are equal and arbitrary. Each enterprise gets one efficiency score in the first period with a comparison set consisting all enterprises in time periods $\{1,...,W\}$; two efficiency scores in the second period, with the first comparison set consisting of all enterprises in time periods $\{1,...,W\}$ and the second comparison set consisting of all enterprises in time periods $\{2,...,W+1\}$; and so on. The window analysis technique increases the degrees of freedom and reveals the trends in efficiency scores.

Tulkens and Eeckaut (1995) propose the estimating efficiency from the 'intertemporal' frontier in which DEA is applied on the pooled cross-section and time-series sample. This assumes that the reference technology is time invariant. The pooling of cross-section and time-series data has

[8] See Lovell (1993), Charnes *et al.* (1995) and Tulkens and Eeckaut (1995).

the advantage of increases the number of observations especially in cases where the number of firms in the industry is small.

The major advantage of data envelopment analysis is that it does not require a specified production function or the weights for different inputs and outputs used (Seiford and Thrall, 1990). However, one disadvantage of the DEA approach is that it is sensitive to the number of observations, extreme observations and measurement errors.[9] The DEA approach is used extensively in measuring efficiency in various economic activities. Coelli (1995) provides a review of some studies in agriculture economics that have used DEA to estimate technical efficiency and Seiford (1996) gives a bibliography of theoretical and empirical work in data envelopment analysis. Other recent studies that apply the DEA technique include Cowie and Riddington (1996), Arnade (1998), Burki and Terrell (1998).

4. Data and Estimation

The study uses data from the census of production collected by the National Statistical Office (NSO) in the Annual Economic Survey. We estimate technical efficiency for large establishments in selected seven four-digit International Standard Industrial Classification (ISIC) industries between 1984 and 1988. The data set that includes medium and small scale enterprises does not contain values for capital and raw materials.[10] Only industries that have at least four firms were selected in this analysis. We use the concept of a firm producing one output and several inputs to compute input-oriented measures of technical efficiency.

DEA is performed using the window analysis technique and the intertemporal frontier. In the former we use the two-year windows for each respective sector leading to four windows in the five-year period. In the latter we pool cross-section and time-series and estimate one frontier for each sector. Output is measured by sales at 1980 prices. Inputs include number of workers

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9 See Zhang and Bartels (1998) on the implications for sample size in comparing efficiency across activities.

10 The National Statistical Office only publishes data for large establishments with a sales turnover of K100,000 at 1978 prices.

(labour), real capital (capital) estimated as real net book value of assets at end-of-year valued at 1980 prices, and real value of raw materials (materials) at 1980 prices. The technical efficiency scores are obtained from the DEAP 2.1, a data envelopment analysis computer program written by Coelli (1996). Table 2 presents descriptive statistics for the variables used in the estimation of production frontiers for various industries for the pooled sample. The statistics for the pooled sample mask the 'within the period' variations. However, the data show wide variations across observations. The standard deviation for most industry groups for output and inputs being greater than the average and the range suggests a wide gap between the largest and smallest firm based on the value of sales.

[Table 2 goes here]

5. Empirical Results

5.1 Efficiency Levels in Malawi Manufacturing Industries

Estimates of technical efficiency using panel data are computed using data envelopment analysis from both the window analysis technique and the intertemporal frontier approach. We report two types of efficiency - overall technical efficiency and scale efficiency. Table 3 presents the frequency distribution of technical efficiency scores by industry sector for the whole sample period. Overall, the mean technical efficiency scores obtained from the window analysis are higher than those obtained in the intertemporal frontier approach. We discuss results mainly based on the intertemporal frontier approach. In the tea industry, the mean technical efficiency is 41 percent and is as low as 16 percent. On average, firms in the tea industry could save 59 percent of inputs to produce existing output levels efficiently. The frequency distribution shows that 75.1 percent of observations have efficiency scores of less than 50 percent. Only 5 percent of the observations are technically efficient, thus four technically efficient observations from four firms.

With respect to the tobacco industry, the mean technical efficiency is 56 percent and is as low as 19 percent. Half of the observations have efficiency scores of less than 50 percent and only 15 percent of the observations are technically efficient (three technically efficient observations from two firms). The wearing apparel industry records a mean technical efficiency score of 69 percent and the minimum score in the sector is 31 percent. More than 80 percent of the observations have efficiency scores between 60 percent and 100 percent. Twenty percent of the observations, from six firms, are technically efficient.

[Table 3 goes here]

The technical efficiency scores in the printing and publishing industry are as low as 17 percent with a mean of 38 percent. About 75 percent of the observations have efficiency scores below 40 percent. Only 10 percent of the observations from two firms are technically efficient. With respect to the soaps and cosmetics industry, we observe a high mean efficiency of 79 percent with the lowest efficiency score of 38 percent. Of the total observations in the industry, 85 percent have efficiency scores between 60 percent and 100 percent. The soaps and cosmetics industry has four technically efficient observations from two firms.

The mean technical efficiency in the plastic products industry is 82 percent with a minimum efficiency score of 55 percent. The efficiency scores from the window analysis are similar. Most of the observations are close to the frontier, with 92 percent of efficiency scores falling between 60 percent and 100 percent. The industry also records six technically efficient observations but from only two enterprises. Similarly, most observations in the fabricated metal products industry are close to their frontier, with a mean efficiency of 87 percent and a minimum efficiency score of 49 percent. Most observations are technically efficient (40 percent), thus eight on the frontier spanning four firms. Thus, at least each firm is technically efficient for the pooled sample in the sector. We obtain similar results from the window analysis.

Overall, if we take technical efficiency scores above 80 percent, we find that proportionately most observations in the fabricated metal products industry (65 percent) are more efficient compared with 56 percent in plastic products, 55 percent in soaps and cosmetics, 35 percent in wearing apparel, 30 percent in tobacco industry, 10 percent in printing and publishing and 7.6 percent in the tea industry. This ordering is also apparent from the frequency distribution based on the window analysis efficiency scores.

Table 4 shows the mean annual technical efficiency levels by industry sector based on both the window analysis and intertemporal approach. We focus on the results from the intertemporal frontier approach. The mean overall technical efficiency ranges from 36 percent in 1986 to 49 percent in 1984 while the mean scale efficiency is stable ranging from 75 percent in 1988 to 78 percent in 1985 for the tea industry. In the tobacco industry, the mean overall technical efficiency ranges from 46 percent to 70 percent and the trend is a declining one over time. However, mean scale efficiency ranges from 70 percent in 1988 to 90 percent in 1985. The mean annual overall technical efficiencies in the wearing apparel industry are also stable but tend to increase over time. The trend in mean annual scale efficiency is similar ranging from 83 percent in 1984 to 90 percent in 1988.

[Table 4 goes here]

The mean annual overall technical efficiency in the printing and publishing industry shows a clear declining trend over time from 42 percent in 1984 to 32 percent in 1988. Similarly, the mean annual scale efficiency ranges from 63 percent in 1985 to 45 percent in 1988. With respect to the soaps and cosmetics industry, the mean annual overall technical efficiency ranges from 71 percent in 1984 to 87 percent in 1987, generally showing an increasing trend over time. Annual overall technical efficiencies are stable in the plastic products industry, 83 percent in the first four years and dropping to 77 percent in the fifth year, however scale efficiencies show a declining trend over the period of analysis. The trend in both overall and scale efficiency in fabricated metal products is mixed, but the efficiency levels are above 70 percent and 80 percent, respectively.

The annualized technical efficiency scores for respective industry frontiers show that mean scale efficiencies are much higher than overall technical efficiencies. Using the intertemporal frontier approach we observe that most firms operate at increasing returns to scale. Table 5 presents a summary of returns to scale by industry sector based on the intertemporal frontiers for respective industries. Overall, about 56 percent of the observations exhibit increasing returns to scale, while 28 percent exhibit decreasing returns and 15 percent exhibit constant returns to scale. Tea and wearing apparel industries dominate cases that exhibit increasing returns to scale (44.9% and 14.2%, respectively), plastic products (11.8%), soaps and cosmetics (10.2%).

[Table 5 goes here]

About 71 percent of observations in the tea industry, 65 percent in soaps and cosmetics, 60 percent in plastic products, 50 percent in tobacco, 45 percent in wearing apparel industry and 40 percent in printing and publishing industry exhibit increasing returns to scale. About 24 percent of observations in tea industry, 35 percent in tobacco, 43 percent in wearing apparel, 50 percent in printing and publishing, 30 percent in fabricated metal products exhibit decreasing returns to scale. Thus, in many industries inefficiency is partially due to firms operating at sub-optimal scale.

5.2 Determinants of Technical Efficiency

5.2.1 Specification of the Model

We also investigate the sources of the predicted inefficiencies using firm and industry attributes following Caves (1992a, 1992b), Mayes *et al.* (1994), Brada *et al.* (1997) and Burki and Terrell (1998). We use the efficiency scores and relate them to firm and industry characteristics and policy variables. We estimate the following relationship using pannel data regression:

$$TE_{it} = f(MS_{it}, \; HHI_{jt}, \; IMPS_{jt}, \; EXPS_{jt}, \; GROW_{jt}, \; TARF_{jt}, \; IND_{jt}) \qquad (6)$$

where for firm i and industry j at time t, TE is the measure of technical efficiency obtained from DEA (overall technical and scale efficiency), MS is the market share of the firm, HHI is the measure of domestic market power, IMPS is the measure of the import competition, EXPS is the measure of export-orientation, GROW is the market growth for the industry, TARF are nominal tariffs for imports of each industry and IND are industry dummies. Table 6 presents the variables included in the regression model. Although literature suggests several factors that influence firm efficiency, we focus on testing a few hypotheses.[11]

[Table 6 goes here]

[11] The available data does not have information of some variables such as the number of plants per enterprise, advertising expenses, R and D expenditures and multinationality of enterprises.

The market share of the firm (MS) is the firm characteristic variable under the hypothesis that large market shares reflect the relative efficiency of firms following Demsetz's (1973) efficient market hypothesis. The market share also reflects the relative size of the firm, and hence the importance of economies of scale. MS is calculated as the share of the firms output in the industry. We expect market share to be positively associated with technical efficiency. Due to endogeneity of market share, since firms get market shares partly because they are efficient, we use the lagged market share to instrument this variable in the regression analysis.

The structure of the industry plays a critical role in enhancing efficiency as far as competitive process is concerned. The nature of domestic competition is reflected by the Herfindahl-Hirschman index (HHI) which is calculated as sum of squared market shares (based on output) of all firms in the industry. We expect competition to have a positive relationship with the firm's efficiency, hence a negative relationship between technical efficiency and the Herfindahl-Hirschman index. To capture the role of international competition we use import shares (IMPS) and export shares (EXPS). IMPS is calculated as the ratio of imports of manufactured imports for the industry to total domestic supply. The inflows of imports exert some competitive pressure on domestic firms that in turn should encourage domestic firms to operate efficiently. EXPS represents the ratio of exports to total industry production. The desire for firms to become competitive in international markets should lead to higher technical efficiency. We expect EXPS to have a positive relationship with technical efficiency. GROW is the annual growth of the industry in real industrial output, which we include to capture demand effects on technical efficiency.

The role of trade policy is captured by the level of nominal tariffs (TARF) of imported finished goods in the relevant industries.[12] This measure captures the effect of trade protection on the technical efficiency of domestic firms. We expect a negative relationship between TARF and technical efficiency. We also include industry specific dummies representing the seven industries included in the study: TEA for tea, TOB for tobacco, WEA for wearing apparel, PRI for printing

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[12] The effective protection rate would be more appropriate to use in order to capture the real extent of a protective trade regime.

and publishing, SOA for soaps, perfumes and cosmetics, PLA for plastic products and FAB for fabricated metal products.

5.2.2 Empirical Results from Panel Regression Model

The regression results of the technical efficiency models using two measures of technical efficiency, based on the window and intertemporal efficiency scores are presented in Table 7. We carried out the estimations on TSP 4.4 using panel data methods to obtain the fixed effects and random effects models. The Hausman specification test is reported for the suitability of the random effects model and is only in favour of the random effect model in the overall technical efficiency model based on intertemporal frontier. Discussion of results focuses on our preferred fixed effect models in equations (1), (5) and (7) and the random effect model in equation (4). The explanatory power of these models ranges from 45 percent to 69 percent.

[Table 7 goes here]

The results show that the lagged market share of the firm (MS) is positively associated with technical efficiency in all preferred models. The coefficients are significantly significant at 1 percent level in equations (1), (2) and (7) and at 5 percent level in equation (5). The significance of the market share variable provides evidence in favour of the efficient market hypothesis that firms that secure larger market shares are more efficient. These results are also in favour of the argument that large firms, with economies of scale, are more efficient than small firms.

The level of domestic industrial concentration as indicated by HHI, is negatively associated with technical efficiency in all the preferred specifications, but the coefficients are only statistically significant at 10 percent level in equation (1) and at 5 percent level in equation (5). This relationship reflects the adverse impact of domestic monopoly power on firms' technical efficiency and renders some support for the competition hypothesis.

The demand variable (GROW) and the trade policy variable (TARF) are sensitive to the measure of technical efficiency and are weakly significant and negatively related to technical efficiency in equation (5) at 10 percent level for the former and in equation (4) at 5 percent level for the later.

Firms in the tea industry (TEA) have consistently lower efficiency levels in all the models and the coefficients are statistically significant. Other industry dummies are weakly significant.

6. Conclusions

This study has estimated the level of technical efficiency in Malawian manufacturing industries using the deterministic (nonparametric) data envelopment analysis approach. We have used panel data for seven manufacturing industries over the period 1984 to 1988. The results indicate high levels of technical inefficiency in most sectors. On average, for firms in Malawian manufacturing to produce existing levels of outputs, they can save inputs by 59 percent in the tea industry, 44 percent in the tobacco industry, 41 percent in the wearing apparel industry, 62 percent in the printing and publishing industry, 21 percent in the soaps and cosmetics industry, 18 percent in the plastic products industry and 13 percent in the fabricated metal products industry.

The results also show that 15 percent of observations exhibit constant returns to scale, while 28 percent and 56 percent exhibit decreasing and increasing returns to scale, respectively. This shows that inefficiency is partly a result of operating at sub-optimal scale of production. The average annual efficiency scores for most sectors also show a declining trend based on the intertemporal frontier approach although this varies from industry to industry. Decreasing trends are observed in tea, tobacco and printing and publishing industries, while clearly visible increasing trends are observed in wearing apparel and soaps and cosmetics. Average efficiency scores are more stable in plastic products and fabricated metal products industries. The trend in the efficiency of firms in the manufacturing sector during this adjustment period is rather mixed, with a positive effect in other sectors and negative effects on other sectors.

The second empirical part of the study attempts to identify sources of technical efficiency in the selected manufacturing industries using a censored regression model. The results show that the market share of the firm is positively associated with the level of technical efficiency reflecting the importance of economies of scale. Domestic monopoly power is negatively associated with the level of technical efficiency, suggesting that polices that aim at encouraging domestic competition are likely to have postive effects on the efficiency of manufacturing enterprises.

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Figure 1 Data Envelopment Analysis Efficiency Measures

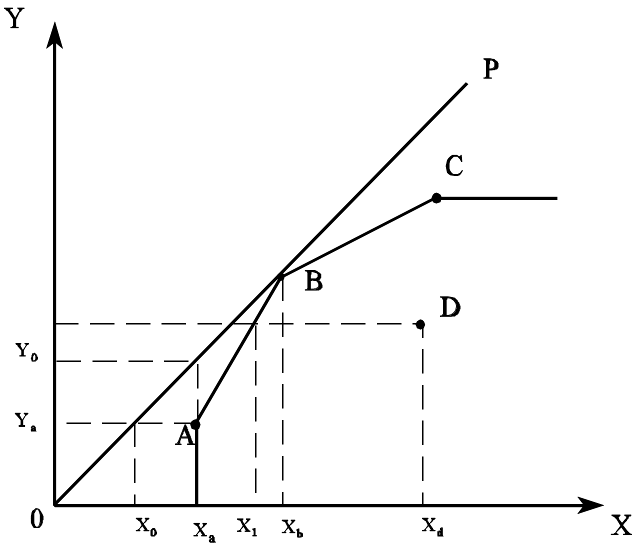

Table 1 Summary of Industrial Policy Actions under Structural Adjustment Programs

Program/Loan and Fiscal Years*		Main Policy Actions affecting the Manufacturing Sector
SAL I	!	Devaluation of Malawi Kwacha by 15% in April 1982, 12% in September 1983 and 3% in January 1984
1981-83	!	Annual increases in smallholder producer prices
	!	Periodic adjustments of interest rates
SAL II	!	Devaluation of Malawi Kwacha by 15% in April 1985 and 9.5% in January 1986
	!	Annual increases in smallholder producer prices
1984-85	!	Industry price decontrol - 41% of controlled products
	!	Periodic adjustments of interest rates
SAL III	!	Devaluation of Malawi Kwacha by 10% in August 1986, 20% in February 1987and 15% in January 1988
1986-87	!	Annual increases in smallholder producer prices
	!	Industrial price decontrol
	!	Privatization of state-owned enterprises
	!	Increases in taxes
	!	Establishment of an export financing facility
	!	Periodic adjustments of interest rates
ITPAC	!	Devaluation of Malawi Kwacha by 7% in March 1990
	!	Industrial price decontrol
1988-89	!	Abolition of exclusive product (monopoly) rights
	!	Revision of duty drawback system and introduction of surtax credit system
	!	Partial liberalization of foreign exchange rationing on 65% of imports
	!	Reduction in the scope of export licensing
ASAC	!	Annual increases in smallholder producer prices
	!	Periodic adjustments of interest rates
1990-91	!	Complete liberalization of foreign exchange allocation
EDDRP	!	Devaluation of Malawi Kwacha by 15% in June 1992, 22% in July 1992
	!	Floatation of the Malawi Kwacha in February 1994
1992-95	!	Establishment of Malawi Investment Promotion Agency
	!	Replacement of Industrial Development Act with Industrial Licensing Act
	!	Review of labour market imperfections and policy option including minimum wage policy
	!	Increase in surtax on electricity and telephone services
	!	Reduction in base surtax rate to 30 percent
	!	Reduction in tariffs and consolidated tariffs limited to a maximum of 75 percent
	!	Decreases in corporate and income tax rates
	!	Elimination of direct bank credit controls and liberalisation of interest rates
FRDP	!	Implementation of the Export Processing Zones Act
	!	Establishment of the Malawi Stock Exchange
1996-98	!	Privatization of state owned enterprises

Source: Chirwa and Chilowa (1997) and World Bank (1996).
Notes: * The fiscal year starts in April and ends in March the following year.

Table 2 Descriptive Statistics for Output and Inputs by Industry, 1984-88

Industry/(ISIC)	Statistic	Output	Labour	Capital	Materials	Firms (Obs)
Tea (3123)	Mean	2,981,689	371	139,665	2,213,193	16
	S. D	2,275,617	207	116,304	1,633,581	(80)
	Minimum	189,804	90	11,223	101,705	
	Maximum	9,384,339	1,011	451,306	6,992,388	
Tobacco (3140)	Mean	3,051,874	1,092	504,203	1,032,943	4
	S.D	2,878,014	1,462	323,190	771,148	(20)
	Minimum	239,539	29	88,454	7,864	
	Maximum	8,112,494	4,759	1,113,502	2,077,709	
Wearing Apparel excl Footwear (3220)	Mean	780,491	147	73,737	487,021	8
	S.D	748,594	135	77,152	491,165	(40)
	Minimum	160,581	12	12,606	55,412	
	Maximum	3,020,127	450	416,995	1,860,127	
Printing and Publishing (3420)	Mean	2,285,169	233	310,538	1,116,028	4
	S.D	2,994,054	252	403,636	1,437,778	(20)
	Minimum	176,517	4	15,290	10,392	
	Maximum	9,255,048	724	1,146,262	4,134,604	
Soaps, Perfumes and Cosmetics (3523)	Mean	7,217,284	161	499,090	3,359,467	4
	S.D	10,755,668	206	796,164	5,045,080	(20)
	Minimum	135,287	22	6,947	48,838	
	Maximum	26,713,917	591	3,055,805	13,980,121	
Plastic Products (3560)	Mean	1,421,126	97	140,331	725,475	5
	S.D	653,472	36	79,700	444,349	(25)
	Minimum	468,805	44	32,329	117,694	
	Maximum	2,633,984	189	277,923	1,675,030	
Fabricated Metal Products (3819)	Mean	2,190,234	194	206,323	1,193,566	4
	S.D	2,422,627	152	174,648	1,491,365	(20)
	Minimum	71,589	13	830	35,392	
	Maximum	8,865,572	421	520,100	5,337,567	

Note: All values for output, capital and materials are in Malawi Kwacha measured at 1980 prices using the consumer price index. The exchange rate in 1980: 1 US Dollar = MK 1.25.

Table 3 Distribution of Levels of Technical Efficiency by Industry Sector (percent) *

Level of Efficiency (OTE)	Tea		Tobacco		Wearing Apparel		Printing and Publishing		Soaps, Perfumes and Cosmetics		Plastic Products		Fabricated Metal Products	
0.1 - < 0.2	5.0	(1.3)	5.0	(-)	-	(-)	10.0	(10.0)	-	(-)	-	(-)	-	(-)
0.2 - < 0.3	31.3	(7.5)	5.0	(-)	-	(-)	45.0	(15.0)	-	(-)	-	(-)	-	(-)
0.3 - < 0.4	16.3	(8.8)	35.0	(15.0)	10.0	(7.5)	20.0	(20.0)	5.0	(-)	-	(-)	-	(-)
0.4 - < 0.5	22.5	(17.5)	10.0	(25.0)	10.0	(2.5)	-	(-)	5.0	(5.0)	-	(-)	5.0	(-)
0.5 - < 0.6	11.3	(16.3)	10.0	(10.0)	12.5	(7.5)	10.0	(-)	5.0	(-)	8.0	(-)	-	(-)
0.6 - < 0.7	3.8	(15.0)	5.0	(10.0)	15.0	(15.0)	-	(15.0)	10.0	(10.0)	20.0	(16.0)	5.0	(-)
0.7 - < 0.8	2.5	(8.8)	-	(10.0)	17.5	(20.0)	5.0	(5.0)	20.0	(10.0)	16.0	(28.0)	25.0	(25.0)
0.8 - < 0.9	1.3	(6.3)	-	(-)	20.0	(17.5)	-	(10.0)	25.0	(20.0)	20.0	(12.0)	5.0	(-)
0.9 - < 1.0	1.3	(7.5)	15.0	(10.0)	2.5	(12.5)	-	(5.0)	10.0	(20.0)	12.0	(16.0)	20.0	(20.0)
1.0	5.0	(11.3)	15.0	(20.0)	12.5	(20.0)	10.0	(20.0)	20.0	(35.0)	24.0	(28.0)	40.0	(55.0)
Cases	80	(80)	20	(20)	40	(40)	20	(20)	20	(20)	25	(25)	20	(20)
Mean OTE	0.41	(0.62)	0.56	(0.66)	0.69	(0.78)	0.38	(0.59)	0.79	(0.87)	0.82	(0.85)	0.87	(0.93)
SD	0.21	(0.23)	0.29	(0.25)	0.20	(0.19)	0.24	(0.31)	0.18	(0.16)	0.15	(0.13)	0.15	(0.10)
Minimum	0.16	(0.19)	0.19	(0.30)	0.31	(0.35)	0.17	(0.17)	0.38	(0.40)	0.55	(0.61)	0.49	(0.74)
Efficient Cases	4	(9)	3	(4)	5	(8)	2	(4)	4	(7)	6	(7)	8	(11)
Efficient Firms	4	(5)	2	(2)	4	(6)	2	(2)	2	(4)	2	(3)	4	(4)

* Frequency distributions based on intertemporal frontier (pooled sample) for respective sectors and the figures in parentheses are based on the window analysis.

Table 4 Summary of DEA Technical Efficiency Indices by Industry Sector, 1984-88

Industry	Year	Window Analysis [a]				Intertemporal Frontier [b]			
		Overall Technical Efficiency (OTE)		Scale Efficiency (STE)		Overall Technical Efficiency (OTE)		Scale Efficiency (STE)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Tea	1984	0.72	0.21	0.81	0.19	0.49	0.26	0.77	0.21
	1985	0.70	0.18	0.82	0.18	0.42	0.16	0.78	0.22
	1986	0.70	0.19	0.84	0.18	0.36	0.15	0.76	0.19
	1987	0.53	0.19	0.78	0.19	0.37	0.18	0.76	0.20
	1988	0.44	0.26	0.74	0.23	0.42	0.25	0.75	0.23
Tobacco	1984	0.61	0.29	0.77	0.23	0.61	0.29	0.77	0.23
	1985	0.70	0.35	0.90	0.14	0.70	0.35	0.90	0.14
	1986	0.70	0.24	0.82	0.14	0.57	0.28	0.74	0.25
	1987	0.61	0.29	0.83	0.16	0.46	0.32	0.73	0.19
	1988	0.66	0.26	0.83	0.16	0.46	0.32	0.70	0.21
Wearing Apparel	1984	0.73	0.22	0.84	0.15	0.67	0.17	0.83	0.14
	1985	0.78	0.23	0.86	0.18	0.71	0.22	0.83	0.16
	1986	0.76	0.21	0.87	0.17	0.64	0.19	0.85	0.13
	1987	0.81	0.14	0.87	0.14	0.68	0.20	0.86	0.12
	1988	0.80	0.19	0.84	0.18	0.75	0.25	0.90	0.16
Printing and Publishing	1984	0.42	0.39	0.53	0.32	0.42	0.39	0.54	0.31
	1985	0.46	0.36	0.59	0.30	0.46	0.37	0.63	0.29
	1986	0.46	0.26	0.59	0.24	0.37	0.23	0.53	0.22
	1987	0.71	0.13	0.81	0.15	0.33	0.12	0.52	0.18
	1988	0.91	0.12	0.93	0.08	0.32	0.13	0.45	0.08
Soaps, Perfumes and Cosmetics	1984	0.90	0.19	0.90	0.20	0.71	0.20	0.81	0.26
	1985	0.82	0.16	0.85	0.17	0.72	0.21	0.81	0.23
	1986	0.78	0.26	0.81	0.28	0.77	0.27	0.81	0.27
	1987	0.91	0.13	0.97	0.04	0.87	0.16	0.94	0.08
	1988	0.94	0.05	0.95	0.05	0.85	0.09	0.94	0.06
Plastic Products	1984	0.86	0.14	0.89	0.15	0.83	0.14	0.91	0.15
	1985	0.86	0.14	0.91	0.11	0.83	0.16	0.94	0.11
	1986	0.87	0.14	0.93	0.12	0.83	0.16	0.93	0.14
	1987	0.86	0.16	0.89	0.17	0.83	0.19	0.89	0.19
	1988	0.80	0.14	0.85	0.11	0.77	0.17	0.84	0.11
Fabricated Metals	1984	0.91	0.12	0.99	0.02	0.88	0.13	0.98	0.04
	1985	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
	1986	0.92	0.12	0.99	0.01	0.84	0.14	0.93	0.13
	1987	0.84	0.11	0.94	0.10	0.73	0.20	0.99	0.01
	1988	0.99	0.02	1.00	0.00	0.90	0.13	1.00	0.01

Notes:

[a] Window analysis based on two year windows.

[b] This is based on the pooled cross-section and time-series frontier.

Table 5 Summary of Returns to Scale by Industry Sector, 1984-88 [a]

Industry	CRS*	DRS*	IRS*	Cases
Tea	4	19	57	80
Tobacco	3	7	10	20
Wearing Apparel	5	17	18	40
Printing and Publishing	2	10	8	20
Soaps, Perfumes and Cosmetics	5	2	13	20
Plastic Products	7	3	15	25
Fabricated Metal Products	8	6	6	20
Total (Observations)	34	64	127	225
Percentage (Observations)	15.11	28.44	56.44	100.0

Notes:

[a] Based on the intertemporal frontier (pooled sample) for each respective sector.

* CRS = Constant Returns to Scale, DRS = Decreasing Returns to Scale, IRS = Increasing Returns to Scale

Table 6 Descriptive Statistics for Variables in the Panel Regression Model

Variable	Description	Mean	S.D	Min	Max
Firm Attributes					
MS	= market share of the firm	0.1556	0.2067	0.0048	0.9067
Industry Attributes					
HHI	= the Herfindahl-Hirschman Index.	0.2354	0.1489	0.0647	0.7506
IMPS	= import share.	0.1760	0.2426	0.0027	0.9581
EXPS	= export shares.	0.2502	0.2979	0.0000	1.0000
GROW	= annual growth rate of domestic production.	0.3069	0.7564	-0.866	3.4460
Public Policy					
TARF	= nominal tariff levels for manufactured imports.	0.3946	0.4404	0.0070	2.6180
Other Variables					
TEA	= 1 if Tea, and zero otherwise,	0.3556	0.4797	0.0000	1.0000
TOB	= 1 if Tobacco	0.0889	0.2852	0.0000	1.0000
WEA	= 1 if Wearing Apparel	0.1778	0.3832	0.0000	1.0000
PRI	= 1 if Printing and Publishing	0.0889	0.2852	0.0000	1.0000
SOA	= 1 if Soaps, Perfumes and Cosmetics	0.0889	0.2852	0.0000	1.0000
PLA	= 1 if Plastic Products	0.1111	0.3150	0.0000	1.0000
FAB	= 1 if Fabricated Metal Products	0.0889	0.2852	0.0000	1.0000

Table 7 Sources of Technical Efficiency: Panel Regression Models

Variables	Overall Technical Efficiency (OTE)				Scale Efficiency (STE)			
	Window Analysis		Intertemporal Frontier		Window Analysis		Intertemporal Frontier	
	(1) FE	(2) RE	(3) FE	(4) RE	(5) FE	(6) RE	(7) FE	(8) RE
Constant	-	0.8252	-	0.7569	-	0.9815	-	0.8482
		(7.64)[a]		(6.61)[a]		(9.97)[a]		(8.24)[a]
MS(-1)	0.2229	0.1467	0.2995	0.2235	0.1412	0.0705	0.1790	0.0988
	(3.31)[a]	(1.91)[c]	(3.82)[a]	(3.25)[a]	(2.57)[b]	(1.16)	(2.87)[a]	(1.55)
HHI	-0.5131	-0.3563	-0.3754	-0.1649	-0.462	-0.3537	-0.2983	-0.0401
	(-1.69)[c]	(-1.66)[c]	(-1.17)	(-0.73)	(-2.00)[b]	(-1.82)[c]	(-1.40)	(-0.20)
IMPS	0.3654	0.2740	0.1031	0.0549	0.1293	0.1353	-0.2613	-0.0990
	(1.37)	(2.10)[b]	(0.34)	(0.17)	(0.61)	(1.08)	(-1.26)	(-0.76)
EXPS	-0.0810	0.1956	0.1609	0.0186	-0.1230	0.0154	0.0787	0.0642
	(-0.48)	(1.82)[c]	(0.96)	(0.113)	(-1.12)	(0.16)	(0.71)	(0.63)
GROW	-0.0482	0.0104	0.0413	0.0076	-0.0807	-0.0277	-0.0015	0.0033
	(-0.86)	(0.45)	(0.71)	(0.29)	(-1.85)[c]	(-1.26)	(-0.04)	(0.14)
TARF	0.0174	-0.4833	-0.1178	-0.1041	0.0565	0.0073	0.0181	-0.0325
	(0.23)	(-1.22)	(-1.67)[c]	(-2.36)[b]	(1.00)	(0.19)	(0.40)	(-0.83)
TEA	-0.3256	-0.2883	-0.4964	-0.3349	-0.4339	-0.1637	-0.4574	-0.1242
	(-2.36)[b]	(-4.35)[a]	(-3.19)[a]	(4.61)[a]	(-5.33)[a]	(-2.64)[a]	(-4.42)[a]	(-1.91)[c]
WEA	0.2060	-0.0241	0.2676	0.0019	0.2742	-0.0535	0.3800	0.0540
	(1.20)	(-0.29)	(1.38)	(0.02)	(1.95)[c]	(-0.69)	(2.68)[a]	(0.67)
PRI	-0.1804	-0.2126	-0.2626	-0.4154	-0.0990	-0.2168	-0.1330	-0.3176
	(-1.34)	(-2.59)[a]	(-1.81)[c]	(-5.16)[a]	(-0.96)	(-3.09)[a]	(-1.28)	(-4.33)[a]
PLA	-0.3321	-0.1087	-0.0898	0.0256	-0.1831	-0.0936	0.0575	0.1235
	(-2.38)[b]	(-0.97)	(-0.57)	(0.22)	(-1.68)[c]	(-0.92)	(1.51)	(1.17)
FAB	-0.1245	0.1236	0.0078	0.1174	-0.1119	0.0557	0.1022	0.1570
	(-1.46)	(1.54)	(0.07)	(1.35)	(-1.70)[c]	(0.75)	(1.70)[c]	(2.02)[b]
R^2	0.5025	0.3505	0.5940	0.4964	0.4555	0.1686	0.5338	0.2901
F	1.1594	-	0.8840	-	1.9138[a]	-	1.8987[a]	-
Hausman	-	51.518[a]	-	7.9353	-	59.514[a]	-	114.89[a]
se	0.1973	0.2006	0.2041	0.2023	0.1550	0.1707	0.1624	0.1786
Nobs	180	180	180	180	180	180	180	180

Notes: MS(-1) is the lagged market share, and the excluded industry dummies are TOB and SOA. The figures in parenthesis are t-statistics (based on heteroskedastic-consistent standard errors for the fixed effects model). The superscripts *a*, *b* and *c* are levels of significance at 1%, 5% and 10%, respectively. FE = fixed effects model and RE = random effects model. F is the F-test of A,B=Ai,A and Hausman is the Hausman $\chi^2(7)$ specification test.