HAS KOREAN MANUFACTURING PRODUCTION REACHED ITS FULL POTENTIAL?

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This paper sheds some light on the relevance of the assimilation view for South Korea, whereby successful mastering of foreign technology in its adoption and use would lead to firms producing at their full potential output. This is investigated by studying the technical efficiency performance of firms in four manufacturing industries using firm-level data from 1980-94 and applying the random coefficient frontier model. Empirical results show that the assimilation view holds true in the heavy industries but not in the light industries. Although the rate of technical efficiency varied within the two industries, the variation was statistically significant only for firms in the heavy industries since the late 1980s.

1. INTRODUCTION

Before the 1997 financial crisis, South Korea was one of the newly industrialising economies (NIEs), which grew at a very rapid rate of 7 per cent or more for all but a few years in the 1969-1996 period. Along with the other three NIEs, South Korea's miraculous growth has been widely researched with many views as to what caused it. In this study, we examine the assimilation view (Pack 1993, Nelson and Pack 1999) that South Korea successfully mastered foreign technology by developing new skills and learning how to use imported technology efficiently. Appropriate technology adoption/use and learning-by-doing would lead to increased technical efficiency such that maximum output from a given combination of inputs and technology can be obtained. Thus, studying the technical efficiency performance of firms would provide an indication of the relevance of the assimilation view for South Korea.

Technical efficiency is defined as the ratio of a firm's actual output level to its maximum feasible output level. The concept of potential or maximum output is often associated with the ability of the firm to operate on its production frontier by using the best-practice techniques. However, due to various non-price and organisational factors, a firm may be operating below the frontier and thus is said to be technically inefficient. To date, Kim (2001) is the only study on Korea which attempted to estimate technical efficiency using the stochastic frontier cost model.[1]

[1] Park and Kwon (1993) also estimate technical inefficiency or what they call capacity utilisation rate but they used a Leontief cost function.

However, there are three major drawbacks in the model used by Kim (2001). First, technical efficiency was assumed (in an ad hoc way) to follow a truncated normal distribution based purely on the attractiveness of the statistical properties without any theoretical reasoning. Second, is the rigid assumption of the adopted frontier model in Kim (2001) whereby the technical efficiency effect either increases or decreases at the same rate for all firms in the sample. Thus, the model does not account for situations in which some firms may be relatively inefficient initially but become relatively more efficient in subsequent periods. The third drawback is that the frontier in Kim's (2001) model shifts neutrally over time, implying that the marginal rate of technical substitution at any input combination does not change over time.

The random coefficient frontier model used in this study overcomes these shortcomings in the following ways. As this model is estimated using the generalised least squares (GLS) technique, it does not rely on any distributional assumptions about the error term and thus technical inefficiency is not specified to take on any rigidities. Also, here, the more realistic non-neutral shifting production frontier is estimated.[2] This follows from Kalirajan and Shand's (1994) argument that with the same level of inputs, different levels of output are obtained by following different methods of applications.

The main aim of this paper is to examine and compare the technical efficiency performance of firms across time in light industries such as the food, beverage, and tobacco industry and the textile, wearing apparel, and leather products industry as well as heavy industries such as the chemicals, petroleum and coal products industry and the fabricated metal products, machinery, and equipment industry. How quickly firms realise their potential output has important policy implications related to the assimilation view. The plan of the paper is as follows. The next section sets out the theoretical framework of the random coefficient frontier model to measure technical efficiency of the firms in the industry. Section 3 outlines the data sources and variables used while section 4 presents the empirical results and analysis. Section 5 concludes.

2. THE RANDOM COEFFICIENT FRONTIER MODEL

The concept underlying the stochastic frontier approach was initiated by Farrell (1957) and emphasizes the idea of maximality. A production function methodology based on Farrell's method to measure firm performance is appealing as the frontier functions can indicate the maximum possible output from a combination of inputs and technology.

The generalized version of the model adopted from Kalirajan and Shand (1994) can be written as:

$$\ln Y_{it} = \gamma_{1i} + \sum_{j=1}^{n} \gamma_{ij} \ln X_{ijt} \qquad (1)$$

[2] See Kalirajan and Shand (1994) for details.

where i represents number of firms;
j represents number of inputs used;
t represents time period;
Y = output;
X = inputs used;
γ_{1i} = intercept term of the i th firm; and
γ_{ij} = actual response of output to the method of application of the j th input used by the i th firm.

Since intercepts and slope coefficients can vary across firms, we can write:

$$\gamma_{ijt} = \overline{\gamma}_j + u_{ij}$$
$$\gamma_{Ii} = \overline{\gamma}_1 + v_{1i} \tag{2}$$

where $\overline{\gamma}_j$ is the mean response coefficient of output with respect to the j th input;
u_{ij} and v_{1i} are random disturbance terms; and
$E(\gamma_{ij}) = \overline{\gamma}_j$, $E(u_{ij}) = 0$ and $Var(u_{ij}) = \sigma_{uit}$ for j = t and zero otherwise.

Combining equations (1) and (2):

$$\ln Y_{it} = \overline{\gamma}_1 + \sum_{j=1}^{k} \overline{\gamma}_j \ln X_{ijt} + \sum_{j=1}^{n} u_{ij} \ln X_{ijt} + v_{1i} \tag{3}$$

Following Aitken's GLS method suggested by Hildreth and Houck (1968) and the estimation procedure by Griffiths (1972), the firm-specific and input-specific response coefficient estimates of the above model can be obtained. The highest magnitude of each response coefficient and intercept form the frontier coefficients of the potential production function. If γ^* are the parameter estimates of the frontier production, then, $\gamma_j^* = \max\{\gamma_{ij}\}$. The potential output of the firm can be realized when the 'best practice' techniques are used and this is given by

$$Y_{it}^* = \gamma_1^* + \sum_{j=1}^{k} \gamma_j^* \ln X_{ijt} \tag{3a}$$

The firm-specific technical efficiency is a measure of how well given inputs and technology are used and this is given by the ratio of the firm's actual realized output to that of its potential output, that is,

$$\text{Technical Efficiency}_{it} = \frac{Y_{it}}{Y_{it}^*} \tag{4}$$

Here, we consider the flexible translog production function with a time trend to capture the effects of time-related variables on output. The model for each industry using firm level data is estimated separately by:

$$Ln(Y) = a_o + a_1T + \beta LnL_{it} + \alpha LnK_{it} + \delta Ln(K_{it})Ln(L_{it}) + \eta[Ln(K_{it})]^2 + \lambda[Ln(L_{it})]^2 \tag{5}$$

where Y = Real value added output
T = Time trend
L = Labor
K = Capital
i = ith firm
t = year

3. DATA SOURCES AND CONSTRUCTION OF VARIABLES

The four two-digit industries that are investigated according to the Korean Standard Industry Classification (SIC) include the industries represented by SIC 31 (food, beverage, and tobacco industry), SIC 32 (textile, wearing apparel, and leather products industry), SIC 35 (chemicals, petroleum, and coal products industry) and SIC 38 (fabricated metal products, machinery, and equipment). The sample firms in all these industries cover manufacturing firms whose stock is listed on the Korean Stock Exchange. The firms are required to report their financial status in the *Annual Report of Korean Companies* published by Korea Investors Service, from which the data for the empirical investigation were compiled. The data from 1980-94 consists of 30 firms for SIC code 31, 31 firms for SIC code 32, 41 firms for SIC code 35, and 33 firms for SIC code 38.

The value added output of firms was deflated by the wholesale price index of each industry, with 1990 as the base year, obtained from the *Monthly Bulletin* published by Bank of Korea. Labour was measured by the number of employed workers and capital stock was given by the amount of tangible fixed assets. As reported firms' capital stock figures were already deflated but with varying base year prices, they were then made comparable with a common base year of 1990 using the gross domestic fixed capital formation deflator obtained from the *National Accounts* published by the Bank of Korea. Table 1 below provides summary statistics of the mean levels of firms' value added, capital and labour in each industry.

TABLE 1

SUMMARY STATISTICS OF FIRMS FROM 1980-94

Manufacturing Industries	No of Firms	Mean Levels of		
		Value Added	Capital	Labour
		(100,000,000 Won)		(No of Workers)
Food, Beverage & Tobacco	30	35685275	52751828	1996
Textile, Wearing Apparel & Leather Products	31	51249989	90022455	3670
Chemicals, Petroleum & Coal Products	41	24227031	35775859	989
Fabricated Metal Products, Machinery & Equipment	33	115817152	151565146	5426

It can be seen that among the four industries, the fabricated metal products, machinery, and equipment industry is the largest in terms of output and employment. The next largest is the textile, wearing apparel, and leather products industry.

4. EMPIRICAL RESULTS

The table below shows the estimates of the production frontier for all four industries. At the outset, it must be noted that the generalised one-sided likelihood ratio test statistic for the value of 0.67 for $\sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ being significantly different from zero was found to be significant since the test statistic of 29.8 exceeded the critical value of 2.71 at the 5 per cent level.[3] Thus, the variation in the error term that is explained by technical inefficiency is statistically significant, thereby indicating the appropriateness of the use of the frontier model for the data.

TABLE 2

GENERALISED LEAST SQUARES ESTIMATES OF THE RANDOM COEFFICIENT PRODUCTION FRONTIER

Variable	Coefficient Estimates for Industries of SIC Code			
	31	32	35	38
Constant (a_o)	2.08 (0.38)	4.36 (0.92)	1.77 (0.69)	1.52 (0.71)
Time Trend (a_1)	0.09 (0.04)	1.04 (0.51)	0.88 (0.29)	0.74 (0.32)
Ln K (α)	0.381 (0.11)	0.402 (0.15)	0.591 (0.28	0.518 (0.22)
Ln L (β)	0.492 (0.21)	0.516 (0.18)	0.371 (0.12)	0.425 (0.13)
$[\text{Ln}(K)]^2$ (η)	-0.016 (0.008)	-0.052 (0.021)	-0.030 (0.011)	-0.021 (0.007)
$[\text{Ln}(L)]^2$ (λ)	-0.051 (0.017)	-0.043* (0.031)	-0.029* (0.02)	-0.018 (0.009)
Ln(K) Ln(L) (δ)	-0.056* (0.047)	-0.028 (0.005)	0.061 (0.022)	0.034 (0.016)

Note: Figures in parenthesis are asymptotic standard errors.
* means that the coefficients are insignificant at the 5 per cent level of significance.
31 – food, beverage and tobacco industry;
32 – textile, wearing apparel and leather products industry;
35 – chemicals, petroleum and coal products industry; and
38 – fabricated metal products, machinery and equipment industry.

Almost all the parameters are significant at the 5 per cent level. However, these estimates do not directly indicate the production elasticities with respect to inputs but they can be evaluated at their mean levels to show that as expected, capital

[3] The critical values can be obtained from Table 1 of Kodde and Palm (1986:1246).

contributes more to output than labour in the heavy industries than in the light industries. Using these estimates and equation (4), the technical efficiency levels of firms in the industries were then calculated and summarised in the table below.

TABLE 3

TECHNICAL EFFICIENCY LEVELS OF MANUFACTURING FIRMS

	Food, Beverage & Tobacco	Textile, Wearing Apparel & Leather Products	Chemicals, Petroleum & Coal Products	Fabricated Metal Products, Machinery & Equipment
1980	90.8	85.5	62.1	74.8
1983	88.5	81.8	68.7	79.1
1987	85.7	76.1	73.2	82.8
1990	82.2	70.4	80.4	86.2
1994	77.4	65.3	84.8	88.3
Mean over 1980-94	81.2	72.1	74.5	78.3
Std Deviation	10.6	18.6	14.4	15.2

Note: 31- food, beverage and tobacco industry;
32- textile, wearing apparel and leather products industry;
35- chemicals, petroleum and coal products industry; and
38- fabricated metal products, machinery and equipment industry.

It was found that firms in all four manufacturing industries were operating below full potential as none of their technical efficiency levels reached the 100 per cent mark.[4] While on average, the food, beverage and tobacco industry and that of the fabricated metal products, machinery and equipment industry produced at 78.3 per cent and 81.2 per cent of their potential output respectively, the other two industries operated at less than 75 per cent of their maximum feasible output. There is also some variation in the mean technical efficiency levels of the industries over time as shown by their standard deviation.

There was however a distinct pattern in the technical efficiency performance of the industries as seen in the figures below (plotted using values in table 3).

The figures show that both the light industries experienced declining technical efficiency while that of the heavy industries enjoyed increasing technical efficiency.[5] Thus, the assimilation view of mastering technology and using input efficiently could be said to be more relevant for the heavy industries and not the light industries. As the heavy industries are more capital intensive than the light industries, the incentive to use capital and given technology more efficiently was stronger in the heavy industries. But the possibility of greater scale economies in the heavy industries compared to the light industries encouraged greater utilisation

[4] Similar results were obtained by Park and Kwon (1993), and Kim (2001).

[5] These trends concord with Kim's (2001) results except that the latter's technical efficiency levels are much lower than those reported in this study.

FIGURE 1

MEAN TECHNICAL EFFICIENCY LEVELS OF LIGHT INDUSTRIES

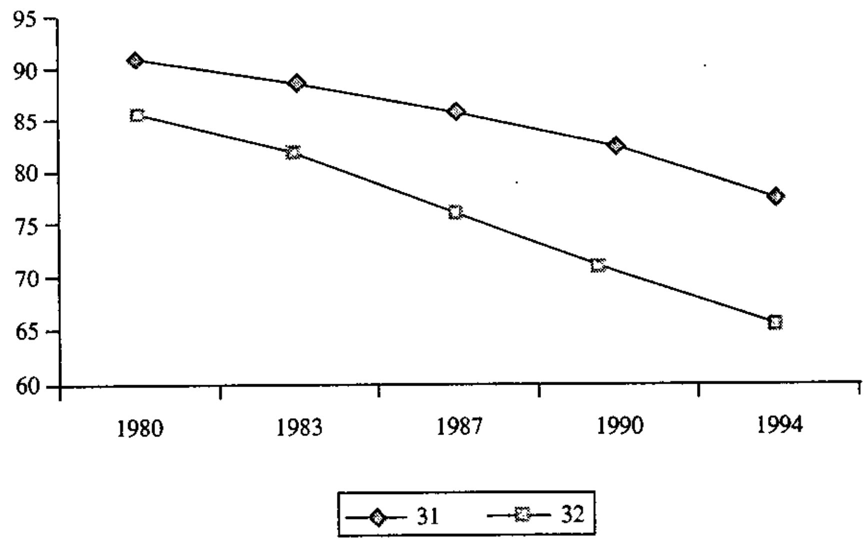
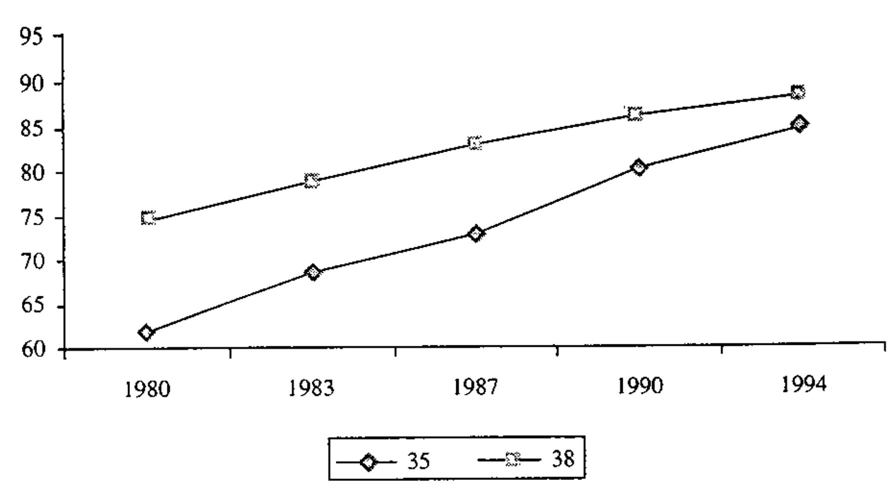


FIGURE 2

MEAN TECHNIKCAL EFFICIENCY LEVEL OF HEAVY INDUSTRIES



and hence higher technical efficiency ratios (Kim 2001). The rising domestic wage in S. Korea did not help the labour-intensive light industries to efficiently use the inputs. In addition, the government's promotion of the heavy industries and chemical sector in 1973-79 was an indication of the strength and stability of these industries in terms of employment and job opportunities, thereby providing an added advantage for these industries to attract the more skilled workers in the economy. Thus, with better quality workers, firms in these industries were more efficient and produced more output.

The figures also show that the rate of technical efficiency (given by the slope) varied within the industries in the same industry group. In the light industry group, the textile, wearing apparel, and leather products industry's technical efficiency declined more rapidly than the food, beverage, and tobacco industry. In the heavy industry group, the chemicals, petroleum, and coal industry's technical efficiency rose more rapidly than the fabricated metal products, machinery and equipment industry. Why was this so?

With the light industries, it was found that the textile, wearing apparel, and leather products, which was the leading export industry until 1986, has been declining in its importance as an export earner. This industry's share in total manufactured output has also fallen faster than the food, beverage, and tobacco industry. Thus, the excess capacity of firms in the textile, wearing apparel and leather products industry has caused technical efficiency to decline more rapidly resulting in the underproduction of output. The food, beverage, and tobacco industry's fall in technical efficiency is also cause for concern. With the heavy industries, Korea relied heavily on imported foreign technology in the form of patents and machinery imports. One possible reason for the slower increase in the technical efficiency of the fabricated metal, machinery and equipment industry is that, in the face of a large export demand, the firms in this industry were not pressured to fully understand the imported technology to produce increasingly more output.

Given the variation in the technical efficiency performance of the industries over time, a simple t-test was undertaken to see if the industry's mean technical efficiency differed significantly between 1980-84, 1987-90, and 1991-94. In particular, we are interested to gauge the possible significance of the import liberalisation (with the loosening of controls on import licenses, quotas and tariffs) and the structural adjustment policy (the reduction in government intervention to encourage competition rather than protection and to promote equal sectoral development) of the mid 1980s. For each individual industry, the t-statistic was computed for the difference in the means of the industry's technical efficiency over the 3 time periods. The results are tabulated below.

It was found that there was no significant difference in the technical efficiency performance of firms in both the light industries throughout the 1980s and mid 1990s. With both the heavy industries, the difference was statistically insignificant from the early 1980s to the late 1980s but significant from the late 1980s to the mid 1990s. Thus, it appears that the mid 1980s policies had no effect on the technical efficiency performance of the light industries but had a lagged effect (firms possibly needed time to adjust and respond positively to the policies) in improving the performance of the heavy industries.

TABLE 4

SUMMARY OF THE RESULTS FROM THE T-TEST

	From 1980-84 to 1987-90	From 1987-90 to 1991-94
Food, Beverage & Tobacco	0.98	1.05
Textile, Wearing Apparel & Leather Products	1.13	1.24
Chemicals, Petroleum & Coal Products	1.15	1.73*
Fabricated Metal Products, Machinery & Equipment	1.33	1.81*

Note: * means that the t-statistic is significant at the 10 per cent level of significance.

5. CONCLUSION

The foregoing empirical investigation showed that the textile, wearing apparel, and leather products industry and the food, beverage, and tobacco industry experienced declining technical efficiency while that of the chemicals, petroleum and coal industry and the fabricated metal products, machinery and equipment industry enjoyed increasing technical efficiency. Thus, there is some evidence of the relevance of the assimilation view in the heavy industries and chemical industry but not in the light industries. Also, within the light industries, the textile, wearing apparel and leather products industry's technical efficiency declined more rapidly than the food, beverage and tobacco industry. Within the heavy industries, the fabricated metal, machinery and equipment industry's technical efficiency rose less rapidly than the chemical, petroleum and coal products industry. However, the variation in the industries' technical efficiency was found to be significant for only the heavy industries from 1987-90 to 1991-94.

Although important, due to the unavailability of data, it was beyond the scope of this study to empirically investigate the factors responsible for both the levels and changes in the technical efficiency performance of the firms in the industries to make any conclusive analysis for the formulation of specific policy measures. Nevertheless, this study has provided interesting and important empirical results which clearly pave the path for further investigation to identify the reasons for the success and failure of assimilation in some industries.

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