LEARNING CURVES & PRODUCTIVITY IN SINGAPORE MANUFACTURING INDUSTRIES

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Paper presented at the Second Annual Conference of the Academic Network for Development in Asia (ANDA), Phnom Penh, Cambodia, 8-10 January 2010

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1 Introduction

An important determinant of production cost is the learning curve effect which exhibits systematic decline in unit costs in real terms as cumulative output increases. The phenomenon of the learning curve, sometimes also known as the experience curve, was first reported in 1936 by Wright that the number of labour hours required to produce an airplane declined systematically as the cumulative number of airplanes produced increased (Yelle, 1979; Berndt, 1991). The impact of learning on production costs was studied extensively by economists including Frank (1954), Arrow (1962) and Abernathy and Kenneth (1974). Around the mid-1960s, the notion of the learning curve was generalised by the Boston Consulting Group (1973) to encompass the behaviour of all value added costs and prices as cumulative volume or experience increase.

Today, the concept of learning curve effect is widespread and important in both the private and public sectors. In strategic management, for example, the existence of such learning curve effect can provide the rationale for a pricing and marketing strategy in which producers initially price low in order to expand sales and gain market penetration rapidly, thereby quickly accumulating experience and exploiting cost-reducing effects of such learning (Spence, 1981). The effect of learning curves on optimal pricing policies, make-or-buy decisions and consumers' welfare are being modelled and analysed (see for example, Majd and Pindyck 1989, Young 1991. The effect of the learning has been used by some economists in public sector policies to argue for government assistance to provide temporary protection to domestic manufacturers from foreign competition.

In this paper, our first objective is to empirically test the learning curve effect by estimating the learning curves in 20 manufacturing industries in Singapore (see Appendix 1 for the list). The second objective is to compare the learning curve effect across two other Asian countries by estimating the learning curves for eleven industries in South Korea and Japan. The paper begins in Section 2 by specifying the learning curve and how it is integrated with the production function conventionally used in neoclassical economics. In Section 3 the results of the estimation of the learning curve for 20 manufacturing industries in Singapore are presented and discussed followed by those of the eleven industries in South Korea and Japan in Section 4. Section 5 concludes the paper by drawing some policy implications from the results.

2 Learning Curves And Returns To Scale

The single most important factor that shapes a modern economy is *technical progress.* This encompasses all those forces which simultaneously raise the productivity of factors of production. However, technical progress has two aspects which in the real world, may be empirically difficult to distinguish in terms of measurement. But for the sake of analytical clarity, they should be considered separately.

The first aspect of technical progress is *technological change*. Technology consists of a society's stock of knowledge relating to the production of goods and services. Drucker (1993) has in fact argued that knowledge is more essential to the wealth of nations today than either capital or labour. Technology concerns the two basic economic questions of *what* goods and service can be produced and *how* they can be produced. Technological change is the change in such "production technology". It is a complex phenomenon because it concerns either the goods and services produced or the methods of production in those goods and services or both the products and method. Jackson (1982) has aptly portrayed the complexity of technological change in a three-by-three matrix:

	Methods of production		
Products/Services	Existing methods	Improved methods	'New' methods
Existing products/services	1	4	7
Improved products/services	2	5	8
'New' products/services	3	6	9

Source: Jackson, 1982, p 316.

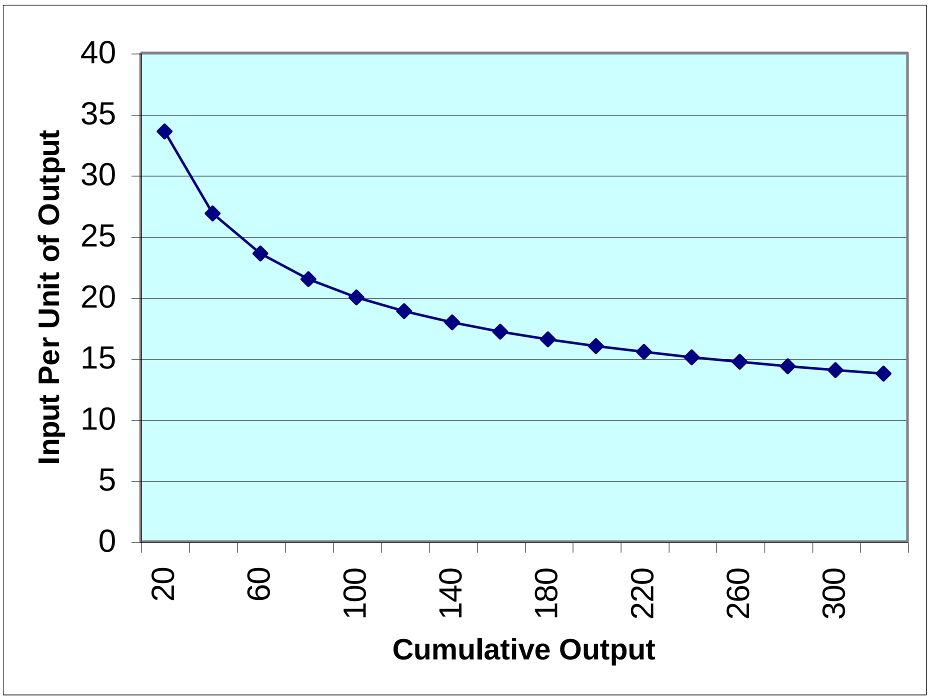
Position 1 in the matrix describes the present state of production technology. Technological change can be described as the movement from position 1 to any of the other eight positions. While it is generally possible to shift to any one of the eight cells, the most dramatic and far reaching changes would occur in a change from position 1 to 9.

The second aspect of technical progress is the learning curve effect. The learning curve is concerned with the improvement in the efficiency of a given industry using a given technology as the cumulative experience of production enables total factor productivity to rise or factor requirement per unit of output to fall. The learning curve refers especially to falling unit labour requirement.

As management and labour gain experience with production, the firm's marginal and average costs of production at a given level of output fall from several sources. Firstly, as workers become more adept with a given task, their speed increases. Second, managers learn to schedule the production process more effectively, from the flow of materials to the organisation of the manufacturing process itself. Third, engineers who may be cautious initially in their product designs may gain experience for tolerances in design which save costs without increasing defects. Better and more specialised tools and plant organisation from production engineers may also lower costs. Fourth, suppliers of materials may learn to process materials required by the firm more effectively and some of this advantage may be passed to the firm in lower material costs.

The result is that the firm learns over time as cumulative output increases. A learning curve, which is downward sloping as shown in Figure 1, describes the relationship between a firm's cumulative output and the amount of inputs (for example, labour) needed to produce a unit of output.

Figure 1: Learning Curve



The learning curve has been formulated in a number of ways. The most common form of the learning curve specified for estimation is:

$$c_t = c_{11} X_t^{-\alpha} \qquad (1)$$

or equivalently in logarithmic form

$$\ln c_t = \ln c_{11} - \alpha . \ln X_t \qquad (1')$$

c_t = labour input per units of output in time period t

c_{11} = labour input to produce the first unit of output

X_t = cumulative number of units of output produced up to (but not including) time period t

α = elasticity of unit labour input with respect to cumulative volume, $\alpha > 0$

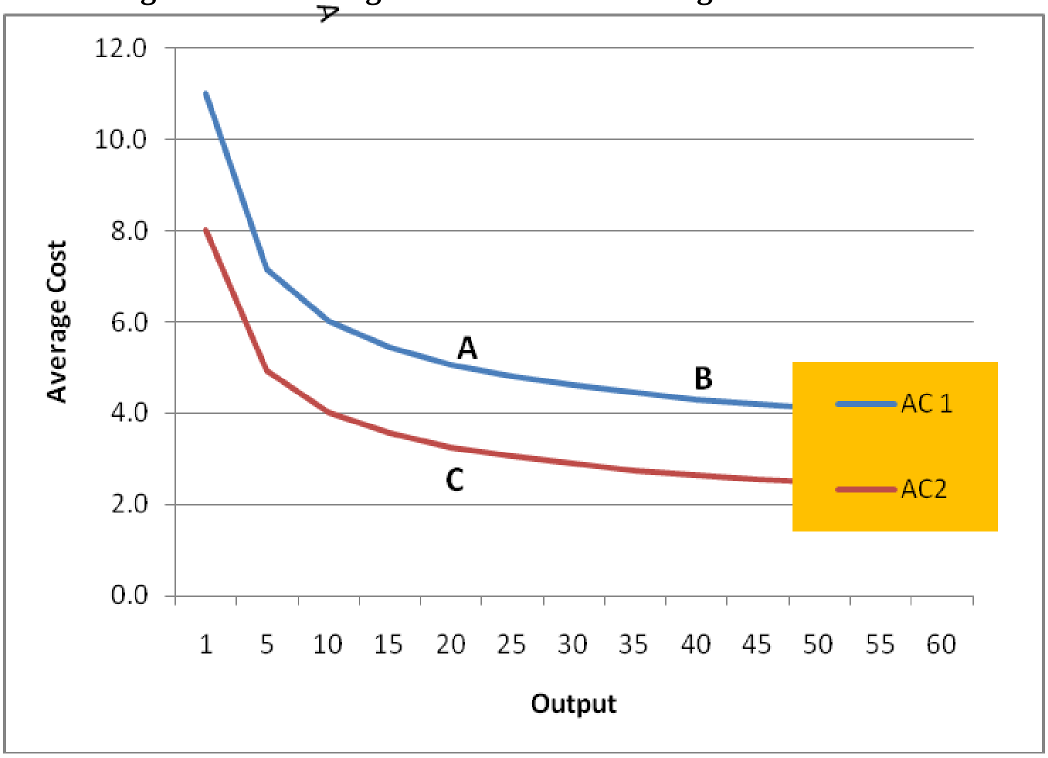
A similar form, albeit with a different elasticity, is posited for the unit real cost of production (Yelle, 1979). The value of α is usually non-negative, the larger the value of α, the more important is the learning effect. Of particular interest is the knowledge of how much is the resultant labour input per unit of output (cost per unit output) as a proportion of the initial unit labour input (cost) when the cumulative output or experience doubles[1]. This is simply given by $d = 2^{-\alpha}$. For example, when α=0.234, the value of d will be 0.85. This means that the unit labour requirement (unit cost) declines to 85 percent of its previous level when experience doubles or the experience curve is said to be an experience curve of 85 percent.

Over the years, there have been several empirical efforts made in estimating the experience curve noted above. An useful and interesting survey of about a 100 studies has been made by Pankaj Ghemawat in 1985. Among the well known applied studies include Montgomery and Day (1985), Womer (1984), and Womer and Patterson (1983). While the learning curve is explicitly recognised, the concepts of returns to scale should be made distinct from the learning curve effects especially when an accurate quantification of the latter is desired.

The distinction between the learning effect and increasing returns to scale is shown in Figure 2. AC_1 represents the long run average cost of production of a firm that enjoys increasing returns to scale in production. If there is a learning curve, the process of learning shifts the average cost curve downward, from AC_1 to AC_2, that is, a move from A to C in Figure 2. On the other hand, the change in production from A to B along AC_1 leads to lower costs due to increasing returns to scale.

[1] Disregarding the time subscript, equation (1) is written as $c = c_{11}X^{-\alpha}$. Let c' be the new value of c when the cumulative output is doubled, then $c' = c_{11}(2X)^{-\alpha}$. The ratio of c' to c is denoted by d, which is equal to $2^{-\alpha}$.

Figure 1: Increasing Return Versus Learning



In the presence of learning, the labour requirement per unit of output falls with increased production. As a result, the total labour requirement for producing more and more output increases in smaller and smaller increments. Therefore, a firm looking at high initial labour requirement as in the case of a new product may be overly pessimistic. If it wants to be in business for a long time, it will realise that once the learning effect has taken place, production costs will be lower. The learning curve thus becomes important for a firm producing a new product or deciding whether it wants to enter the industry.

From the empirical estimation point of view, we need to be able to differentiate returns to scale effect from learning effect. In this respect we need to integrate the learning curve equation with the production function in neoclassical economics. Since the seminal work of Robert Solow in 1957, a large number of empirical estimation of production function has included technical progress as an essential input to growth. The majority of these studies has treated technical progress as exogenous, that is, it is independent of the other variables in the production function.

Often a time variable is included as an explanatory variable to quantify the shift in the production function assuming a steady rate of change in technical progress. Meanwhile, there were also studies such as those of Kaldor (1957), Arrow (1962) and Eltis (1973), which treat technical progress as endogenous. Kaldor introduced the notion that technical progress is to be explained by the process of investment itself. The concept of learning by doing was incorporated into a neoclassical growth model in Arrow's 1962 paper. However, he had chosen cumulative gross investment rather than gross output as the index of experience on the ground that new machines provide more stimulation to innovation and learning. Eltis (1973) analysed the link between research and development and technical progress at the macroeconomic level.

Theoretical Derivation

In an attempt to quantify the learning curve effect, we made use of the conventional Cobb-Douglas production function that is written as:

$$Q = A.L^{\beta}.K^{\gamma} \qquad (2)$$

where L is the labour employed and K is the capital stock utilised in the production of output, Q. β and γ are parameters to be estimated and they are respectively the elasticity of output for labour and elasticity of output for capital. The sum of the two parameters, $\beta+\gamma$ is a measure of the returns to scale for the production function. A is the parameter describing the state of technology. It reflects the advances in the state of knowledge.

Advances in knowledge are certainly related to learning curve effects. It is therefore appropriate to proxy the state of knowledge at time t as the cumulative production up to time period t, raised to the power α, where α is the experience curve elasticity parameter. Thus:

$$A_t = H.X_t^{\alpha} \qquad (3)$$

From equation (2) and equation (3), we can express in logarithmic form an equation of the labour input per unit of output (L/Q) as:

$$\ln(L/Q)_t = -\ln H - \alpha \ln X_t + (1-\beta)\ln L_t - \gamma \ln K_t \qquad (4)$$

We assume that as output expands, the relationship between capital and labour is well defined and can be described by the following equation:

$$K_t = \mu L_t^{\lambda} \qquad \text{where } \mu \text{ and } \lambda \text{ are constants}$$

Other things equal, the parameter λ is indicative of the type of technical bias as production expand. When λ is greater than unity, the capital intensity as measured by the capital-labour ratio increases as output expands. Similarly, neutrality in technical progress is postulated when λ is unity.

Substituting the K_t in equation (7) by μL_t^{λ} yields:

$$\ln (L/Q)_t = (-\text{Ln } H - \gamma \ln \mu) + \alpha . \ln X_t + (1-\beta-\gamma\lambda) \ln L_t \qquad (5)$$

Equation (5) will be identical to the learning curve equation (1') only when $(1-\beta-\gamma\lambda)$ is zero. We note that we cannot obtain estimates of the parameters β, γ and λ. However, the possibility that $(1-\beta-\gamma\lambda)$ may not be zero indicates that the omission of the variable $\ln L_t$ as in the estimation of the conventional learning curve model given by equation (1') will run the peril of obtaining biased estimate of the learning elasticity, α.

The equation for empirical estimation is equation (5), which is rewritten as:

$$\ln c_t = \varphi_o + \varphi_1 \ln X_t + \varphi_2 \ln L_t + u_t \qquad (6)$$

where $c_t = (L/Q)_t$

u_t is the stochastic term,

$\varphi_o = (-\ln H - \gamma \ln \mu)$; $\varphi_1 = -\alpha$; $\varphi_2 = 1-\beta-\gamma\lambda$.

If $\varphi_2=0$, then $\lambda = (1-\beta)/\gamma$. Furthermore, if constant returns to scale is assumed, then $\beta=\gamma=0.5$. On the other hand, if $\varphi_2 =/= 0$ and constant returns to scale is assumed $(\beta+\gamma=1)$, then for given value of β the value of φ can be estimated as :

$$\lambda = 1-\varphi_2/\gamma. \qquad (7)$$

Equation (6) can be estimated by the method of ordinary least squares if data of the variables are available. The initial "stock" of experience, X_0, can be estimated by means of the recursive relationship between X in consecutive periods:

$$X_t = X_{t-1} + Q_{t-1} \tag{8}$$

For the benchmark year, X_0 is computed using equation (9):

$$X_o = Q_o/g \tag{9}$$

where g is the average growth rate of output.

3 Learning Curves in Singapore Manufacturing Industries

There is abundant literature on the industrialisation programme in Singapore spearheaded by the government through the Economic Development Board (EDB) since 1961 when the First State Development Plan (1961-65) was launched [2]. The chief characteristics of the industrialisation exercise are that the government and its many agencies provided the main infrastructure and agencies to attract direct foreign investment and multinational companies (MNCs). The government itself has government-linked companies (GLCs) in many industries as local enterprises and entrepreneurship were incipient and new. The export oriented development strategy adopted since Singapore's independence in 1965 has yielded notable results in terms of income and employment generation as well as transfer of know-how in managerial and technical expertise. The competitive edge of the economy has sharpened and the environment for learning and productivity enhancement is much fostered.

Using published data from the Census of Industrial Production (CIP) published by the Department of Statistic, Ministry of Trade and Industry for the years 1980 to 2007; we estimate the equation (6) for 20 industries in Singapore. The listing of the 20 industries is included in Appendix 1.

A rough rule of the thumb is to divide these 20 industries into the traditional and newer

[2] A good discussion of Singapore's industrialisation effort can be found in Lee (1973), Chng, et al, (1988) and Low, et al (1993).

categories where traditional ones are simply those which have been around since industrialisation began in the late 1950s and have grown and diversified with time. The newer industries like electronics and precision instruments and equipment are those which started later in response to new technology and product lines. Similarly, the transportation equipment industry has expanded to include sea and air transportation. There is no a priori assumption that older industries like food, textiles and garments, petroleum and others are less desirable or less important than electronics and precision instruments and equipment because of this rough division. The division is also not totally unambiguous because some traditional industries like food and printing and publishing have also upgraded in technology to take on a new lease in production life.

Table 1: Regression Results

		Constant	**t-Statistic**	**A**	**t-Statistic**	**φ_2**	**t-Statistic**
	Industries	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
1	FBT	9.225	10.072	-0.186	-15.121	2.053	12.318
2	TEX	11.600	11.544	-0.955	-8.026		
3	WEAP	21.400	17.134	-1.614	-13.917		
4	LEAT	10.681	4.798	-1.300	-8.660	0.462	2.971
5	WOOD	15.410	12.826	-1.305	-9.817		
6	PAPER	8.179	7.513	-0.558	-4.667		
7	PRINT	16.332	5.213	-0.367	-6.278	-1.002	-2.681
8	PETROL	3.906	1.185	-0.230	-0.861		
9	CHEM	7.783	13.312	-0.528	-9.618		
10	PHARM	15.613	8.386	-1.447	-8.134		
11	RUBB	78.309	8.270	-0.035	-7.902		
12	NMET	6.723	13.892	-0.398	-7.829		
13	BMET	13.028	5.800	-0.739	-8.349	-0.467	-2.002
14	FABMET	7.443	26.634	-0.395	-14.822		
15	MACHI	18.001	10.604	-0.228	-3.868	-1.204	-5.557
16	EMACH	19.196	67.777	-1.553	-55.839		
17	ELECT	13.416	22.988	-0.839	-18.204		
18	PRECI	3.166	1.817	-0.931	-14.138	0.905	3.721
19	TPTEQT	15.444	19.599	-1.790	-12.398	0.724	3.948
20	OMFG	5.887	2.842	-0.569	-9.978	0.351	2.083

Following the formulation in the previous section, equation (6) is estimated. The estimate of the parameter associated with the explanatory variable ln L, φ_2 is tested to see whether it is significantly different from zero. For those cases in which the null hypothesis $\varphi_2=0$ is accepted, the equation is re-estimated without the ln L variable. The results of the estimation are shown in Table 1. The industries are listed in Table 1 are in ascending order according to the magnitude of the learning elasticity.

The estimates of the learning elasticity α for the 20 industries are shown in column 2 in Table 1. The statistical significance of the α can be ascertained by the t-statistics shown in column 3. The largest α is found for the precision instrument industry, while the machinery industry has the smallest value of α. The explanatory power of the estimated equation is relatively high. None of the adjusted R^2 falls below 0.75. Twelve of the twenty industries do not reject the hypothesis $\varphi_2=0$. Thus, their learning curves can be described by the traditional functional form as in equation (1a).

The value of $d = 2^{-\alpha}$ is calculated and presented in Table 2 for the industries listed in Table 1. A graphical exposition of this information is provided in Figure 3.

Figure 3: Value of d in Ascending Order by Industries

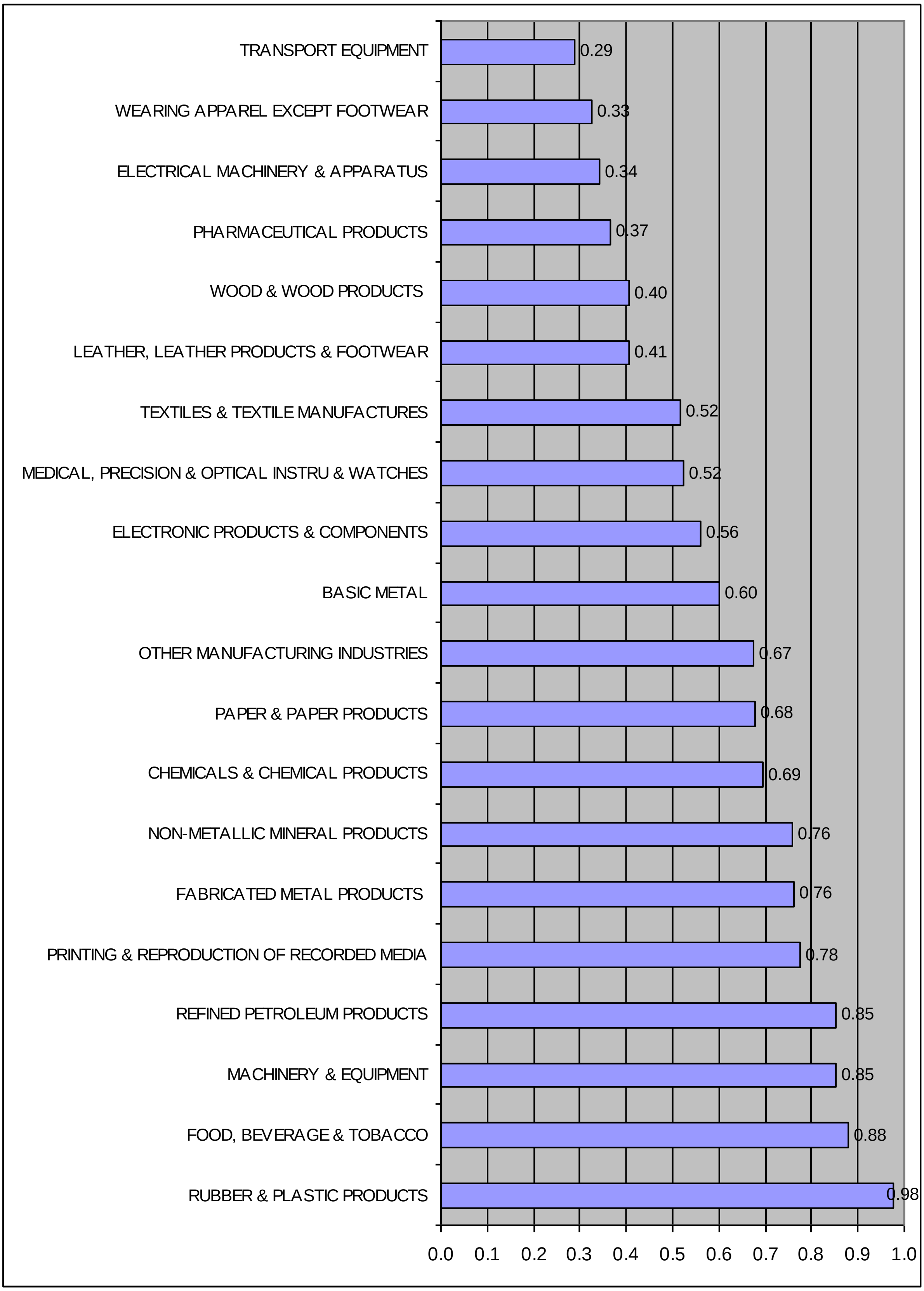


Table 2: Estimates of d and λ

		d-index	Labour Share	Capital Share	φ_2	Λ
		(1)	(2)	(3)	(4)	(5)
1	FBT	0.879	0.456	0.544	2.053	-2.771
2	TEX	0.516	0.639	0.361		1.000
3	WEAP	0.327	0.749	0.251		1.000
4	LEAT	0.406	0.604	0.396	0.462	-0.165
5	WOOD	0.405	0.633	0.367		-1.556
6	PAPER	0.679	0.506	0.494		1.000
7	PRINT	0.775	0.537	0.463	-1.002	3.165
8	PETROL	0.853	0.371	0.629		1.000
9	CHEM	0.693	0.359	0.641		1.000
10	PHARM	0.367	0.064	0.936		1.000
11	RUBB	0.976	0.577	0.423		1.000
12	NMET	0.759	0.426	0.574		1.000
13	BMET	0.599	0.451	0.549	-0.467	1.851
14	FABMET	0.761	0.557	0.443		1.000
15	MACHI	0.854	0.533	0.467	-1.204	3.578
16	EMACH	0.341	0.512	0.488		1.000
17	ELECT	0.559	0.353	0.647		1.000
18	PRECI	0.525	0.403	0.597	0.905	-0.514
19	TPTEQT	0.289	0.517	0.483	0.724	-0.497
20	OMFG	0.674	0.663	0.337	0.351	-0.040

Note: Constant returns to scale is assumed in the calculation of λ.
The share of labour is estimated as average of the ratios of employees' remuneration to total value added.

The learning effect is not uniform across the twenty industries considered. The learning effect is strongest in the transport equipment industry. Table 2 indicates that when the experience doubles, the unit labour input in that industry is reduced to about 30% of the initial unit labour input. The electronic industry, which is generally known to be the prime mover in the manufacturing sector in its contribution and dynamism, also has significant learning effects. Its unit labour requirement is reduced to 56% of the initial level when the experience doubles. The industry that shows the least learning effect among the twenty industries is the rubber processing and plastic industry. Its unit labour requirement reduces only by 2% when experience doubles. In general, we cannot assert that traditional industries like textile industry, wood and wood product, and leather and footwear industries have less learning effect than relatively new industries as precision instruments, electronics and pharmaceutical products. It is noted that traditional industries like wearing apparel and wood product industries do not fare badly in comparison to other industries.

Also included in Table 2 are the values of the factor shares[3] estimated and the values of λ when constant returns to scale is assumed. The capital-labour ratio increases or decreases when output expands depending on whether λ is greater or less than unity. In particular, when λ=1, the capital-labour ratio has remained constant as output expanded. As noted earlier, this is indicative of Hick's neutral technical progress. When λ is negative, the capital-labour ratio declines as output increases. Only six industries, namely, food and beverage, leather products, wood products, precision equipment, transport equipment, and other manufacturing have negative values of λ.

4 Conclusions and Policy Implications

While there is no explicit industrial policy in Singapore, a few features are significant and constitute the cornerstones of an industrial strategy, even if implicitly. First, given Singapore's lack of resources and a small domestic base, there may be no basis or grounds for a formal industrial targeting policy. Instead, with the strong dependence on foreign capital and manufacturing activities which are drawn into Singapore on profit maximisation and competitiveness principles, the outcome appears to be more market determined. If the government or the EDB in specific has implemented certain incentives or schemes to attract certain industries, they are reacting to opportunities offered by foreign investors, technology, markets or other factors.

On the other hand, short term gains must be balanced by some long term targets and an industrial structure which suits Singapore given its resource base and growth targets. In

[3] The share of labour is estimated as the ratio of remuneration to employees to the total value-added in a given year. The share of capital is obtained by subtraction.

particular, scaling the industrial ladder or moving from one rung to a higher level, requires the role of the government in a model which incorporates "push" and "pull" effects because of certain externalities. The push factors could come from official incentives and changing competitive environment while the pull factors are from benefits of technological change and other industry features motivating firms to upgrade and expand production. Leaving it all alone to the private sector and foreign industrialists may be not enough as there are externalities such as in human resource development or research and development facilities which the private sector alone cannot shoulder. Thus, in Porter's (1990) competitive advantage theory as well as in endogenous growth models, there is the embodiment of components or a more direct role for the government.

In designing an industrial structure, there is the choice between a comprehensive or a "niche" structure. The "niche" strategy implies promoting particular industries and build them into specialised areas in which Singapore would excel in. This seems logical and sensible since Singapore cannot afford to spread its resources and capabilities thinly across all industries. It implies that as new industries enter the industrial structure, older and traditional industries in which comparative advantage and competitive advantage have been eroded should be discarded. However, it also needs to be appreciated that various industries have different attributes of varying strength and desirability. One has to be careful not to be over indulgent in some or too critical of others. In other words, we need a well balanced array of industries which must in the long run be allowed to show their full potential in terms of the aggregate of their attributes rather than be favoured or discriminated on account of a few attributes.

The above results from the estimation of learning effects appear to confirm these features. There is a definite squeeze by the government on some industries which are labour intensive and which have not upgraded themselves sufficiently such as in the textile industry. As a result, the learning effect for the textile industry was weak. For those which have continually diversified and moved up the industrial ladder such as electronics, leather and wood products, the learning effects were realised.

The comparison of learning curve with South Korea and Japan reinforces the importance of learning. Latecomers to the industrialization game do not necessarily enjoy "shortcuts" and thereby have steeper learning curves. While technical knowledge are transferable, the skill and dexterity in operation and production could only be attained through practical doing. It is suspected that cultural factors and societal organizational structure do play a part in learning. The inqusitive and disciplined character of the Japanese workers may have contributed to the significant learning effect noted in the comparative exercise.

One immediate policy implication from these conclusions would be that Singapore should continue to have a blend of some government directed policies and market determined motivations in upgrading and refining its industrial structure. Also, the two are strictly not in conflict or mutually exclusive because the government's industrial policies are themselves drawn from feedback and in consultation with the private sector. This being the case, in contrast with planning from the top, there is no inconsistency but instead an acceleration and reaffirmation of the industrial restructuring process.

Limitations of the exercise cannot be overlooked. Due to the paucity of data we have not been able to separate the effect of output compositional change on learning effects. For future work, the relationship between direct exports and cumulative output or learning effect and the role of direct foreign investment could be further explored. Furthermore, investigation of learning at a more micro-level across countries may be suggested. For instance, the production of disk drives in the same industry across different countries may point to factors within each industry as well as those outside the industry beyond the control of the managers.

APPENDIX 1

THE 20 MANUFACTURING INDUSTRIES IN SINGAPORE

	Acronyms	Industries
0	TMFG	TOTAL MANUFACTURING
1	FBT	FOOD, BEVERAGE & TOBACCO
2	TEX	TEXTILES & TEXTILE MANUFACTURES
3	WEAP	WEARING APPAREL EXCEPT FOOTWEAR
4	LEAT	LEATHER, LEATHER PRODUCTS & FOOTWEAR
5	WOOD	WOOD & WOOD PRODUCTS EXCEPT FURNITURE
6	PAPER	PAPER & PAPER PRODUCTS
7	PRINT	PRINTING & REPRODUCTION OF RECORDED MEDIA
8	PETROL	REFINED PETROLEUM PRODUCTS
9	CHEM	CHEMICALS & CHEMICAL PRODUCTS
10	PHARM	PHARMACEUTICAL PRODUCTS
11	RUBB	RUBBER & PLASTIC PRODUCTS
12	NMET	NON-METALLIC MINERAL PRODUCTS
13	BMET	BASIC METAL
14	FABMET	FABRICATED METAL PRODUCTS EXCEPT MACHINERY & APPARATUS
15	MACHI	MACHINERY & EQUIPMENT
16	EMACH	ELECTRICAL MACHINERY & APPARATUS
17	ELECT	ELECTRONIC PRODUCTS & COMPONENTS
18	PRECI	MEDICAL, PRECISION & OPTICAL INSTRUMENTS, WATCHES & CLOCKS
19	TPTEQT	TRANSPORT EQUIPMENT
20	OMFG	FURNITURE & OTHER MANUFACTURING INDUSTRIES

The share of labour is estimated as the ratio of remuneration to employees to the total value-added in a given year. The share of capital is obtained by subtraction.

Bibliography

Abernathy, William, J and Wayne, Kenneth, (1974), "Limits of the Learning Curve", Harvard Business Review, Sep-Oct.

Andress, Frank, J, (1954), "The Learning Curve as a Production Tool", Harvard Business Review, Jan-Feb.

Arrow, Kenneth, (1962), "The Economic Implications of Learning by Doing", Review of Economic Studies, Vol 29.

Berndt, Ernst, R, (1991). The Practice of Econometrics: Classic and Contemporary. Reading, Massachusetts: Addison-Wesley Publishing Co.

Boston Consulting Group, (1973), "The Experience Curve - Reviewed, II: History", Perspectives, No 125.

Chng M.K., L. Low and M.H. Toh, (1988) Industrial Restructuring in Singapore. Singapore: Chopmen Publishers.

Drucker, Peter, (1993), The Rise of the Knowledge Society. New York: Butterworth-Heinemann.

Eltis, W.A., (1973) Growth and Distribution, London: Macmillan.

Ghemawat, Pankaj, (1985), "Building Strategy on the Experience Curve," Harvard Business Review, 63:2, March/April, pp 143-149.

Hirschmann, WB, (1965), "Profit from the Learning Curve", Harvard Business Review, Jan - Feb.

Jackson, Dudley, (1982), Introduction to Economics: Theory and Data, London, Macmillan.

Kaldor, N., (1957) "A Model of Economic Growth," Economic Journal, December.

Landau, Ralph, (1990), "Capital Investment: Key to Competitiveness and Growth", Brookings Review, Summer, pp 52 - 56.

Lincoln, Edward, J, (1988), Japan: Facing Economic Maturity. Washington DC: Brookings Institution.

Lee S. A.,(1973) Industrialization in Singapore. Australia: Longman.

Low, L., M.H. Toh, K.Y. Tan and T.W. Soon, (1993) Challenge and Response: Thirty Years of the Economic Development Board. Singapore: Times Academic Press.

Maddison, Angus, (1987), "Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment", Journal of Economic Literature. Vol XXV, June, No 2, pp 649 - 698.

Majd, Saman and Pindyck, Robert, S, (1989), "The Learning Curve and Optimal Production Under Uncertainty", Rand Journal of Economics, 20:3. Autumn, pp 331 - 343.

Montgomery, David B. and George S. Day, (1985), "Experience Curves: Evidence, Empirical Issues, and Applications," Chapter 3.6 in Howard Thomas and David Gardmer, eds., Strategic Marketing and Management, New York: John Wiley and Sons, pp 213-238.

Pack, Howard and Page, John, M, Jr, (1992), "Accumulation, Exports and Growth in the Hugh Performing Asian Economies", World Bank mimeo, November.

Porter, Michael E., (1990) The Competitive Advantage of Nations. London and Basingstoke: Macmillan Press.

Solow, Robert M., (1957) "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, August.

Spence, A, Michael, (1981), "The Learning Curve and Competition", Bell Journal of Economics, 12:1, Spring, pp 49 - 70.

Womer, N. Keith, (1984), " Estimating Learning Curves from Aggregated Monthly Data," Management Science, 30:8, August, pp 982-992

Womer, N. Keith and J. Wayne Patterson, (1983), "Estimation and Testing of Learning Curves," Journal of Business and Economic Statistics, 1:4, October, pp 265-272.

Yelle, Louis, E, (1979), "The Learning Curve: Historical Review and Comprehensive Survey", Decision Sciences, 10:2, April, pp 302 - 328.

Young, Alwyn, (1991), "Learning by Doing and the Dynamic Effects of International Trade," Quarterly Journal of Economics, 106, May, pp 369-405.

Young, Alwyn, (1992), "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore", NBER Macroeconomic Annual, National Bureau of Economic Research, USA.