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Learning-by-doing in Production Function: The Case of the Malaysian Rubber Estate Sector

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The main objective of this study is to determine empirically the role of the learning-by-doing variable by employing the variable elasticity of substitution (VES) production function for the Malaysian rubber estate sector. Results obtained indicate that technical progress defined by learning-by-doing has played an important role in the development of the Malaysian rubber estate sector for the period under study. The results further suggest that the appropriate production function for the Malaysian rubber estate sector is the VES production function specification and capital deepening had positively affected the performance of the Malaysian rubber industry.

Use of the concept of learning-by-doing in economics was pioneered by Arrow[1] who stated, '... *knowledge is growing in time ... knowledge has to be acquired .... The acquisition of knowledge is what is usually termed "learning" .... Learning is the product of experience. Learning can only take place through the attempt to solve a problem and therefore only takes place during activity*'. Arrow[1] further advanced that, technical change in general can be ascribed to experience, and that, it is the very activity of production which gives rise to problems for which favourable responses are selected over time. Thus, there is a time lag between the introduction of new technology and the adoption or diffusion of new technology. The gap between the introduction and the adoption of new technologies is ascribed to the learning process.

In the agricultural sector, the process of learning is important for rapid adoption of new technologies to increase output. However, the rate of diffusion of new technology differs in different regions or countries, for example, Sri Lanka, Indonesia and Malaysia have different rates of technological diffusion. Diffusion of new technology in the Malaysian rubber sector has been rapid[2]. Comparing the smallholder sector and the estate sector, the latter shows a higher rate of diffusion of new technology[3]. Despite rapid diffusion of new technology in the rubber sector, the process of learning-by-doing has been noted by Yee and Longworth[4] who stated[†], '*The magnitude of these neutral upward shifts from HYM1 to HYM2 technology and from HYM2 to HYM3 technology for the 1964, 1970 and 1976 data sets are substantially lower than the shift from USM to HYM1 technology as estimated from 1964 data set ... One explanation for the increase is that it takes time for the estate managers to learn how best to take advantage of the superior embodied technology in the new technological strata (HYM2 and HYM3)*'. On another occasion, Barlow and Jayasuria[2] indicated that in the learning process, skill acquisition and capital accumulation would be increased. The experience accumulated then, will

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[†]USM denotes unselected seedling material, and HYM1, HYM2 and HYM3 denote high yielding material recommended for commercial plantings during three different time periods, 1964, 1970 and 1976

reduce the risk and uncertainty involved in the investment of new technologies.

The main objective of this paper is to determine empirically the role of the learning-by-doing variable in the Malaysian rubber estate sector employing the variable elasticity of substitution (VES) production function. It has been recognised that the elasticity of substitution can be variable depending on the output and/or factor combinations. As the factor price ratio does not remain constant, changes will obviously vary the capital/labour ratio thus varying the elasticity of substitution. The VES production function assumes that the elasticity of substitution between capital and labour varies along the isoquant.

METHODOLOGY

Chew[5], Daud *et al.*[6] and Yee and Longworth[4] employed the Cobb-Douglas production function to the Malaysian rubber sector. However, according to Bairam[7,8,9], a more appropriate production function where learning-by-doing can be incorporated directly is the VES production function which has been popularly used in the literature because it includes the Cobb-Douglas production function as a special case[10,11,12]. Further, the elasticity of substitution is not constrained to a constant value, as it varies along the isoquant.

The VES production function used in this study is specified as:

$$Q_t = A_t e^{\Phi t} E_t^{\theta} K_t^{\alpha} L_t^{1-\alpha} e^{\mu (K/L)_t} \quad \ldots 1$$

where A_t is the initial level of technology

- E is the index of learning
- Q, K, L are the levels of output, capital and labour respectively
- Φ is the Hicks-neutral rate of exogenous technical progress
- θ is the learning coefficient
- α and $(1 - \alpha)$ are the elasticities of output with respect to capital and labour respectively
- μ is the substitution parameter
- t is time.

VES can be derived as follows, and the marginal products are defined as:

$$\partial Q/\partial K = A_t e^{\Phi t} E_t^{\theta} (K/L)_t^{\alpha - 1} e^{\mu (K/L)_t} [\alpha + \mu (K/L)_t] \quad \ldots 2$$

$$\partial Q/\partial E = A_t e^{\Phi t} E_t^{\theta} (K/L)_t^{\alpha-1} e^{\mu (K/L)_t} [(1-\alpha) - \mu (K/L)_t] \quad \ldots 3$$

Dividing *Equation 3* by *Equation 2* gives the marginal rate of substitution (MRS),

$$MRS_t = (K/L)_t \{[1/(\alpha + \mu (K/L)_t)] - 1\} \quad \ldots 4$$

VES is then given by:

$$\sigma_t = \frac{d\,(K/L)_t}{d\,(MRS)_t} \cdot \frac{MRS_t}{(K/L)_t}$$

$$= 1 - \{\mu (K/L)_t / [(\alpha + \mu (K/L)_t^2 - \alpha]\} \quad \ldots 5$$

Therefore, we can clearly observe that the elasticity of substitution is variable depending on the capital-labour ratio $(K/L)_t$ as shown by μ. As $\mu < O$, $\sigma < O$. If $\mu < O$, it is a labour-using situation where capital is substituted for labour. On the other hand, when $\mu > O$, capital deepening is experienced. However, it is clear from *Equation 5* that $\sigma < 1$, as $\mu < O$.

For the specification of variable learning-by-doing E, Arrow[1] suggested that E can be represented by cumulative output ΣQ, or cumulative investment ΣI. Arrow[1] pointed out that economic agents and technical changes are developed from experience gained within the production process. However, Arrow[1] favours the use of cumulative investment as an index of experience. He stated that cumulative investment as an index of learning provides more stimulant to innovation compared to, for example, cumulative output which was previously used. He also pointed out that a new machine produced and put into use is capable of changing the environment in which production takes place.

Using the same analogy, cumulative money balances ΣM, can also be used as an index of learning as cumulative money balances stimulate innovation[13]. Crouch[13] postulates that, '... *It is immediately apparent that monetaization, when viewed as a technological innovation, must lead unambiguously to higher steady-state growth values of income ... wage rate ... and the capital labour ratio...*'. Crouch's[13] argument is not without support. According to Moroney[14], it is useful to incorporate money in production theory as a source of technological change. He concluded that, '... *In this sense the invention of money might be viewed as a type of technological change both for firms and for the economy at large. ... In this simplest microeconomic context money should not be considered an ordinary input of the firm's production function. It is instead a source of technological change that may be regarded as an external economy for each firm*'. The fact is that, the important role of money in production has been empirically investigated by Sinai and Stokes[15] who provided the pioneering empirical work on this issue. Money balances act as a medium of exchange, facilitate the exchange between capital and labour for specialisation purposes and thus increase productivity. They also reduce the transaction cost and therefore, increase the economic efficiency of the money market system. More recently, Sarwar *et al.*[16] pointed out the important role of money in production. Money increases efficiency in obtaining inputs necessary for production and marketing of farm products. It facilitates the purchase of inputs in situation where the production process is lengthy and receipt of revenue is delayed.

On the other hand, McKinnon[17] pointed out that in developing countries subjected to fragmented capital markets and limited to self-finance, the accumulation of money balances can act as a conduit of investment. McKinnon[17] noted that, '*Suppose an individual saver-investor, being limited to self-finance, wants to purchase physical capital of a type that is different from his own output. He may store inventories of his own output for eventual sale when the capital assets are acquired, or he may steadily accumulate cash balances for the same purpose. The degree to which he relies on one mode or the other will depend on the real returns on holding money and the inconvenience of storing his own* product'. Thus, the greater the accumulation of money balances, the larger will be the inducement to invest. Therefore, money balances have a tendency to be positively related to the propensity to invest (theory and empirical evidence are detailed in Fry[18], Yoo[19] and Molho[20]).

Credit is a pre-requisite to diffusion of innovation[21,22], the process of innovation being endogenous. The ability of innovators to adopt new processes depends not only in the flow of new ideas and techniques available in the economy but most important of all to the availability of financial resources to undertake innovation. Schumpeter[22] stressed that, '*If anyone in an economic system in which the textile industry produces only with hand labour sees the possibility of funding a business which uses power-looms, feels equal to the task of overcoming all the innumerable difficulties, and has made the final decision, then he, first of all, needs purchasing power. He borrows it from the bank and creates his business*'. Thus, Schumpeter[22] showed that no innovation is possible without credit[23].

Barlow and Jayasuria[2] showed that due to the shortage of cash and non-existence of credit facilities in Indonesia, the rubber farmers were unable to adopt or take advantage of the new technologies. The important role of credit as an important factor to accelerate the adoption and diffusion of innovations has also been stressed by Dissanayake[24].

Based on the above literature, the following are alternative specifications for A_t:

$$A_t = A_o e^{\Phi t} E_t^{\theta} \qquad \ldots 6$$

$$A_t = A_o e^{\Phi t} \qquad \ldots 7$$

$$A_t = A_o E_t^{\theta} \quad \ldots 8$$

where $E = \Sigma Q$, or $E = \Sigma H$, or $E = \Sigma I$, or $E = \Sigma M$, or $E = \Sigma RL$. Variable ΣH and ΣRL are cumulative hectarage planted and rubber loan respectively.. In agriculture, Q and H are highly correlated, so that Q can be represented by H.

For estimation purposes, *Equation 1* is constrained to linear homogeneity by dividing both sides by K, and after substituting *Equation 6* through the *Equation 8*, transformed into logarithm, the following equations are obtained:

$$\log (Q/K)_t = \log A_o + \Phi t + \theta \log E_t + (1-\alpha) \log (L/K)_t + \mu (K/L)_t + v_t \quad \ldots 9$$

$$\log (Q/K)_t = \log A_o + \Phi t + (1-\alpha) \log (L/K)_t + \mu (K/L)_t + w_t \quad \ldots 10$$

$$\log (Q/K)_t = \log A_o + \theta \log E_t + (1-\alpha) \log (L/K)_t + \mu (K/L)_t + \Gamma_t \quad \ldots 11$$

Equation 9 proposed that technical progress is partly-exogenous and partly the result of learning-by-doing. *Equations 10* and *11* explain technical progress exclusively in terms of Hicks-neutral exogenous technical progress and learning-by-doing respectively. Further, if the estimated coefficient, μ is significant, then VES is an appropriate production function for the Malaysian rubber estate sector. Otherwise, the appropriate specification is the Cobb-Douglas production function.

Data and Method of Estimation

This study used annual time series data for the Malaysian rubber estate sector for the period 1965–86. Thus, the study is representative of the estate sector rather than the smallholder sector. Data for labour, capital, hectarage planted and output were compiled from various issues of *Rubber Statistics Handbook*[25] published by the Department of Statistics except for monetary data which was collected from various issues of *Quarterly Economic Bulletin*[26] published by Bank Negara Malaysia (see *Appendix* for detailed description of data). In this study, five versions of learning index were used, that is, cumulative output ΣQ, cumulative hectarage planted ΣH, cumulative investment ΣI, cumulative money balances ΣM, and cumulative rubber loan ΣRL. For money balances, we employed $M2$ ($\Sigma M2$) and $M3$ ($\Sigma M3$) definitions of money stocks.

The definition of capital is one of the controversial issues in studying production theory. As such, numerous definitions of capital have been given in the literature. Capital expenditure in agriculture is classified under modern *versus* traditional agriculture capital[27], durable *versus* non-durable capital[28], fixed *versus* variable capital[29], private *versus* public capital[30], *etc.* Nevertheless, the definition of capital expenditure in the border sense in the agricultural sector generally includes expenditure on land reclamation, land clearing, land improvements, irrigation, dams, farm building, dwellings, storage and warehouses, agricultural machinery and equipment (harvestors, threshors, ploughs, tractors, harrows), livestock, factor inputs (seeds, fertiliser, manure, insecticide, hired human labour), investment on research, education, skills and health for the development of human capital[31-37]. Therefore, in this study, the definition of capital expenditure includes expenditure on agriculture and plant machinery and equipment, transport equipment, new construction on residential dwellings, non-residential buildings, *etc.* The same definition of capital has been used by Habibullah[38].

All equations were estimated using ordinary least squares (OLS). However, when there was evidence of serial correlation, the maximum likelihood iterative estimation (MLE) technique of Beach and MacKinnon[39] to correct for serial correlation problem, was employed.

EMPIRICAL RESULTS

The regression results for the Malaysian rubber estate sector are presented in *Table 1*. Twenty-six equations were estimated by both OLS and MLE techniques. The estimated equations represented by *Equations 1a* and *1b* to *6a* and *6b* were equations where both definitions of technical progress; exogenous and learning-by-doing were incorporated. *Equations 7a* and *7b* incorporated only the exogenous technical progress variable, and *Equations 8a* and *8b* to *13a* and *13b* incorporated only the technical progress variable specified by learning-by-doing.

Results in *Table 1* show that the goodness of fit is satisfactory. However, regression results for ordinary least squares are not satisfactory because the Durbin-Watson (D.W.) statistics shows the presence of serial correlation. Furthermore, the coefficient $(1-\alpha)$ is greater than 1, signifying that the capital elasticity is negative which does not make economic sense[8,40]. As such, it was appropriate that the equations are estimated by the maximum likelihood estimation (MLE) procedure.

The results of MLE show that serial correlation is not present where D.W. statistics is about 2.0. However, when comparing all the equations in terms of the significance of all the parameters using t-statistics, we found that *Equations 8b* to *13b* are the appropriate specifications for log A, and therefore the most appropriate for the Malaysian rubber estate sector. We observed that all variables are significant at least at the 5% level. Furthermore, the coefficient $(1-\alpha)$ is less than 1.

The coefficient $(1-\alpha)$ which ranges from 0.90 to 0.97 implies that α ranges from 0.03 to 0.10. Thus, it suggests that the share of labour to total income during the period under study was 90% – 97% and that of capital ranges from 3% to 10%. The substitution parameters are all significant and positive. This implies that the VES production function is a more appropriate specification for the Malaysian rubber sector than the Cobb-Douglas production function. The parameters range from 0.08 to 0.13 depending on the different index of learning used. Positive values for μ imply that the variable elasticity of substitution (σ) between labour and capital are greater than unity. (The average value of σ using estimated *Equation 10b*, during the period under study, 1965 – 86, is 1.78.).

Our main interest is the importance of technical progress. Results in *Table 1* show that the learning variables are significant and positive. The learning parameter ranges from 0.07 to 0.18 depending on the different proxies of learning index used. The results suggest that learning-by-doing played a very important role in the development of the Malaysian rubber estate sector during the period under study.

This paper also presents several alternative measurements of learning index. This includes hectarage ΣH, money balance $\Sigma M2$ and $\Sigma M3$, and credit ΣRL. Our question is: Is there any significant difference between these alternatives compared to cumulative investment? To test this hypothesis, we employed the likelihood ratio test. *Table 2* shows the log-likelihood (L) value for each of the specification involving varieties of E. We observed that twice the difference in log-likelihood values for ΣQ, ΣH, $\Sigma M2$, $\Sigma M3$ and ΣRL [asymptotically distributed as chi-square (X^2) are 3.42, 3.71, 3.59, 3.64 and 1.82 respectively] are well within the critical value of the X^2 distribution at the 5% level of significance (critical value = 3.84). Therefore, we rejected the hypothesis that the alternative specifications ΣQ, ΣH, $\Sigma M2$, $\Sigma M3$ and ΣRL are not the appropriate proxies for learning index for the Malaysian rubber estate sector.

CONCLUSION

This study suggested that the VES production function specification is appropriate for the Malaysian rubber estate sector. The elasticity of substitution estimated was above unity and had a positive trend, which

TABLE 1 REGRESSION RESULTS FOR MALAYSIAN RUBBER ESTATE SECTOR

	log A_o	Φ	θ	$(1-\alpha)$	μ	R^2	D W	rho
I Technical progress is partly exogenous and partly the result of learning-by-doing								
A Where $E = \Sigma Q$								
1a OLS	–5 3662	0 72434 × 10^{2}	0 14883	1 0204	0 12076	0 9935	2 348	
	(–13 086)***	(0 92346)	(2 9634)***	(13 744)***	(3 0093)***			
1b MLE	–4 9114	0 62967 × 10^{2}	0 09730	0 96789	0 11458	0 9935	2 028	–0 308
	(–7 9500)***	(0 80269)	(1 3095)	(11 845)***	(2 7409)**			
B Where $E = \Sigma H$								
2a OLS	–5 4969	0 74442 × 10^{2}	0 16371	1 0129	0 11798	0 9934	2 344	
	(–11 958)***	(0 94568)	(2 9196)***	(13 782)***	(2 9515)***			
2b MLE	–4 9732	0 66242 × 10^{2}	0 10419	0 96085	0 11158	0 9938	2 032	–0 301
	(–7 0073)***	(0 83188)	(1 2248)	(11 889)***	(2 6740)**			
C Where $E = \Sigma I$								
3a OLS	–9 4220	–0 05787	0 93101	1 1505	0 13666	0 9951	2 7035	
	(–6 9599)***	(–2 7519)**	(3 8659)***	(13 871)***	(3 8981)***			
3b MLE	–8 6037	–0 05148	0 79153	1 1058	0 14405	0 9961	2 029	–0 547
	(–6 4292)***	(–2 6581)**	(3 3558)**	(14 767)***	(5 3284)***			
D Where $E = \Sigma M2$								
4a OLS	–9 7592	–0 09837	0 62516	1 0201	0 10587	0 9938	2 242	
	(–5 5529)***	(–2 5932)**	(3 1767)***	(14 294)***	(2 8902)***			
4b MLE	–7 7690	–0 06206	0 40696	0 96709	0 10275	0 9939	1 982	–0 277
	(–2 8380)***	(–1 0961)	(1 3368)	(12 101)***	(2 8433)***			
E Where $E = \Sigma M3$								
5a OLS	–9 6348	–0 10262	0 61185	1 0301	0 11203	0 9937	2 259	
	(–5 4420)***	(–2 5384)**	(3 0831)***	(13 857)***	(2 9493)***			
5b MLE	–7 5755	–0 06259	0 38593	0 97059	0 10631	0 9939	1 989	–0 283
	(–2 8420)***	(–1 0685)	(1 3003)	(11 646)***	(2 7916)**			
F Where $E = \Sigma RL$								
6a OLS	–5 5783	–0 00537	0 23536	0 99982	0 11762	0 9928	2 449	
	(–9 8589)***	(–0 41211)	(2 3189)**	(13 022)***	(2 7718)**			
6b MLE	–4 7723	0 00231	0 10413	0 93382	0 10546	0 9940	1 970	–0 325
	(–5 9869)***	(0 15079)	(0 74004)	(12 135)***	(2 5059)**			
II Technical progress is wholly exogenous								
7a OLS	–4 1838	0 02047		0 90197	0 06138	0 9897	1 803	
	(–36 323)***	(2 6042)**		(11 826)***	(1 4481)			
7b MLE	–4 1153	0 01366		0 89090	0 07507	0 9933	2 081	–0 137
	(–45 178)***	(2 0758)		(14 853)***	(2 2924)***			
III Technical progress is wholly the result of learning-by-doing								
A Where $E = \Sigma Q$								
8a OLS	–5 5167		0 17523	1 0101	0 12912	0 9931	2 436	
	(–14 728)***		(4 2634)***	(13 826)***	(3 3183)***			
8b MLE	–5 1705		0 13374	0 97920	0 13080	0 9935	2 013	–0 371
	(–10 935)***		(2 5571)**	(13 052)***	(3 7920)***			

TABLE 1. REGRESSION RESULTS FOR MALAYSIAN RUBBER ESTATE SECTOR (CONTD)

	log A_o	Φ	θ	$(1-\alpha)$	μ	R^2	D.W	rho
B Where E = ΣH								
9a OLS	–5.67691 (–13.612)***		0.19378 (4.2093)***	1.00105 (13 871)***	0.12614 (3.2424)***	0.9930	2 435	
9b MLE	–5.2901 (–9.9074)***		0.14762 (2.4874)**	0 97177 (13.095)***	0.12830 (3 7219)***	0.9934	2.018	–0.367
C. Where E = ΣI								
10a OLS	–5.8857 (–11 634)***		0.29194 (3.8538)***	1.0102 (13 001)***	0.09147 (2.4862)**	0.9927	2.036	
10b MLE	–5.1833 (–11.766)***		0.18341 (2.7494)**	0.95104 (15.636)***	0.09590 (3.5027)***	0.9946	2.044	–0.273
D. Where E = ΣM2								
11a OLS	–5.3033 (–12 330)***		0.12187 (3.2113)***	0 94225 (12.491)***	0.07125 (1.7925)	0 9911	1.829	
11b MLE	-4.8078 (–12.445)***		0.07643 (2.2147)**	0.90783 (14.655)***	0.08003 (2 5184)**	0 9935	2.053	–0.163
E. Where E = ΣM3								
12a OLS	–5.2333 (–12.639)***		0.11436 (3.1678)***	0.94214 (12.376)***	0.07197 (1.7992)	0.9910	1.832	
12b MLE	–4.7647 (–12 924)**		0.07178 (2.2045)**	0.90811 (14.594)***	0.08063 (2.5328)**	0.9934	2.056	–0.164
F Where E = ΣRL								
13a OLS	–5.4087 (–14.300)***		0.19956 (3.9038)***	0.99512 (13 460)***	0.11076 (2.9140)***	0.9928	2.353	
13b MLE	–4.8753 (–13.421)***		0.12347 (2.4860)**	0.94001 (15.382)***	0.10986 (3.7848)***	0.9940	1 949	–0 346

OLS and MLE denote ordinary least squares and maximum likelihood estimation, respectively.
*** Statistically significant at the 1% level.
** Statistically significant at the 5% level.
Figures within brackets are t-statistics.

Equation . $\log (Q/K)_t = \log A_o + \Phi t + \theta \log E_t + (1-\alpha) \log (L/K)_t + \mu (K/L)_t + \epsilon_t$

TABLE 2. LOG-LIKELIHOOD RATIOS (L)

Equation no.	Learning-by-doing variable	L
8b	ΣQ	29.11
9b	ΣH	28.97
10b	ΣI	30.83
11b	ΣM2	29.03
12b	ΣM3	29 00
13b	ΣRL	29.91

ımplıes that capıtal deepenıng had a posıtıve effect on the performance of the Malaysıan rubber ındustry durıng the perıod under study Further, thıs study has ındıcated that learnıng-by-doıng has played an ımportant role ın the development of the Malaysıan rubber estate sector Several alternatıves of learnıng-by-doıng varıables were tested and the results ındıcate that the model estımated can explaın Malaysıan rubber estate data quıte well However, the results are only prelımınary and subject to further research

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APPENDIX

Descriptions on Data Variables

Q	=	Total production in estate
L	=	Number of contract/hired labour in the estate
K	=	Capital expenditure of agricultural and plant machinery and equipment, transport equipment, new construction on residential dwellings, non-residential buildings (e.g. factories, offices, *etc.*)
ΣQ	=	Cumulative total production in the estate
ΣH	=	Cumulative total hectarage planted in the estate
ΣI	=	Cumulative total capital expenditure in the estate
$\Sigma M2$	=	Cumulative money stock $M2$. $M2$ includes currency in circulation, demand deposits held by non-bank private sector, savings and fixed deposits held at commercial banks.
$\Sigma M3$	=	Cumulative money stock $M3$. $M3$ equals $M2$ plus savings and fixed deposits held at National Savings Bank, finance companies and merchant banks.
ΣRL	=	Cumulative rubber loan outstanding at commercial banks
t	=	Time period, 1965 – 86