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An Alternative Approach to Estimating Supply Response of a Perennial Crop

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In previous studies on natural rubber supply, lags have often been incorporated in economic and econometric models designed to explain the dynamic supply response. These lags in input and output prices have not, however, reflected directly the restrictions involved in the growth process for rubber trees. Often these lag structures have been superimposed on models based on static economic theory rather than being based on dynamic economic theory. The phenology for tree crops plays a valuable role in the determination of output levels and supply response. In this paper, the foundation of the supply response specification for rubber is the theory of adjustment cost where the production function incorporates the investment rather than the price expectation model. This was reflected in the results obtained from the impact multiplier and sensitivity analysis. The incorporation of prior information or the phenological process together with economic structure improves the dynamic property of the model.

Several distinct stages of production are involved in the supply of perennial crops. As in the livestock industry, where the biological nature of the animals provides important *a priori* information, in the estimation of supply, the phenological structure of the tree crops plays a unique role in the determination of output supply. Previous studies on NR recognised the fact that the supply response involved a dynamic process. The theoretical inclination of these studies in describing the dynamic process was the backward looking expectation model with no reference to the underlying production function[1–4], often resulting in some form of distributed lag model. Later studies did use some form of dynamic optimisation theory[5–8].

The objective of this paper is to illustrate that the incorporation of the phenological structure of a perennial crop provides useful information in the formulation of lags in the dynamic supply functions.

THEORETICAL JUSTIFICATION/CONSIDERATION

Static economic theory is rich and abundant. However, the same cannot be said of the dynamic theory of economic behaviour. Economic decisions and their implementation are not required to be instantaneous. In the dynamic models for example, the response of a physical investment is not assumed to be achieved instantaneously but rather distributed over a number of years. Thus, lags are often appropriate in economic and econometric models designed to explain the dynamic supply response. Often these lag structures are superimposed on models based on the static theory rather than on the dynamic theory[9].

The dynamics of supply response have been treated in two ways. Firstly, it has been analysed using the expectation and partial adjustment models of Koyck and Nerlove. However, this approach is limited to explaining the dynamics, in that expectations are formulated not only on past but also on future events. Problems are associated with the implied dynamic behaviour[10]. Secondly, the dynamics of supply response has been approached by using the dynamic optimisation theory *via* the adjustment cost. In this study, the output supply and input demand functions are derived from the production function. Besides this, the investment flow concept is incorporated into the analysis to reflect the dynamics of the production process. In addition to the above two approaches, it is

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forseeable that the dynamics of the production process can be recast by incorporating the adjustment cost and forward-looking expectation models. Thus, production function, investment and price expectations are important influencing elements in the formulation of dynamic supply response. What has usually been used in applied work is an unrestricted reduced form which attempts to capture all these effects. The theoretical bias of the dynamic supply function for rubber is the second approach.

Adjustment Cost Approach

Recent development of the dynamic theory has made *ad hoc* approaches to dynamic analysis of supply no longer necessary. The theory of adjustment cost has been used to provide a consistent framework for input demand and output supply[11–15]. Implications for the demand and supply functions of a firm maximising discounted profits and facing changing adjustment costs can be viewed as the 'close loop' solution to an intertemporal profit maximisation problem. Although approaches to dynamic optimisation differ, the basic approach in the theory is the same. The production function incorporates adjustment costs and the firm is assumed to maximise the present value of the objective function over a finite or infinite horizon. In all but the most specialised circumstances, price expectations are taken as fixed or assumed to be static.

Firm level. Assume that a price taker firm has a production function

$$Q \;=\; F\,[X_1(t),\ X_2(t)] \qquad \ldots 1$$

where X_1 is labour (the variable factor) and X_2 is capital (the fixed factor or factor requiring adjustment cost). The capital stock, is determined by

$$\dot{X}_2 \;=\; \frac{dX_2}{dt} = I - \delta\, X_2(t) \qquad \ldots 2$$

where δ is the depreciation rate and I is gross investment. The initial capital stock is taken to be $X_2(0)$. If the user cost of capital or the rental price is $v(r+\delta)$, the present value is maximised by a policy that maximises the expression

$$P.F[X_1(t),\ X_2(t) - WX_1(t) - v(r+\delta)X_2(t)0] \qquad \ldots 3$$

for each point of time in $t > 0$. The optimal capital stock, X_2 will then be held for all $t > 0$ if the *Function 3* is maximised. With the labour variable and capital quasi fixed and gross investment taking place, the cost per unit of gross investment assumed an increasing function of the rate of investment or internal cost in terms of output foregone must be introduced. Thus, the production *Function 1* is replaced by

$$Q(t) \;=\; F[X_1(t),\ X_2(t),\ I(t)] \qquad \ldots 4$$

The maximum problem of the firm is then recast as

$$V(0) \;=\; e^{-rt}\, P.[X_1(t),\ X_2(t),\ I(t) - WX_1(t) - vI(t)]\,dt \qquad \ldots 5$$

where F is assumed homogeneous of degree one with continuous first and second derivatives having the necessary regularity conditions and qualitative restrictions. Then, the optimising problem of the firm can be written as

$$\underset{X_1(t),\ X_2(t) \geq 0}{\text{Max}}\ V \;=\; \int_0^\infty (PQ - WX_1 - vI)e^{-rt}dt \qquad \ldots 6$$

$$\left.\begin{array}{ll} \text{subject to a)} & Q = F(X_1,\ X_2) - C(X_2), \text{ where } C \text{ is the adjustment cost, } F(I, X_2) \\ \text{b)} & X_2 = I - X_2,\ X_2(0) = X_2 \\ \text{c)} & X_1\ X_2 > 0 \end{array}\right\} \qquad \ldots 7$$

The subscript t has been omitted for convenience. The problem on *Equations 6* and *7* is amiable to the solution by the calculus of variations. Specifically, the Hamiltonian for *Equations 6* and *7* is

$$H[I,\ X_1,\ X_2,\ \lambda] \;=\; e^{-rt}\,[PF\,(X_1 X_2,) - PF(I,\ X_2) - WX_1 - vI - \lambda(I - X_2)] \qquad \ldots 8$$

The term $\lambda(I - X_2)$ adjusts for the fact that the present value of the activities taking place at time t, should reflect the value of later product due to investment activities in period t. Necessary conditions[12] for maximising *Equation 8* are

$$\left.\begin{array}{lll} \text{i)} & \dot{X}_2 = & I - X_2, X_2(0) = X_2 \\ \text{ii)} & \partial H/\partial \times 2 = & -PF_2\,(X_1, X_2, I) \\ & & -\,PF_I\,(I, X_2) \\ & & -\,(r + \delta)\,\lambda \\ \text{iii)} & \partial H/\partial X_1 = & 0 = PF_l(X_1, X_2) - W \\ \text{iv)} & \lambda = & v + PF_I(I, X_2) \\ \text{v)} & \lim_{t \to \infty} e^{-rt} = & 0 \\ \text{vi)} & -PF_I\,(I, X_2)\, e^{-rt} < 0 & \end{array}\right\} \quad \ldots 9$$

Condition (iii) has the familiar interpretation, a variable factor will be utilised until its value of marginal product is equal to its unit cost. This condition holds for every time period since all the variables are functions of time as opposed to static theory where the condition holds *rata* a single point of time. In *Condition (ii)*, $\lambda(t)$ is the discounted value at t of the alter marginal product of capital and with *Condition (iv)*, it requires that t be equated to its marginal cost which is determined by v, the cash outlay per unit of investment goods and PF which is the value of output foregone. *Conditions (ii)* and *(iv)* and the term $r + \delta$ convert a stock price to a flow price and thus introduce a flow or investment decision into the analysis. *Conditions (ii), (iii)* and *(iv)* can be written as;

$$PF_l\,(X_1, X_2) = W \quad \ldots 10$$

$$\begin{aligned} PF_2(X_1, X_2, I) &= -PF_I\,(I, X_2) - (r + \delta)v + (r + \delta)\, PF_I\,(I, X_2) \\ &= (r + \delta)\, v - PF_I\,(X_1, X_2)\,(r + \delta) \\ &= (v - PF_I)\; r + \delta \end{aligned} \quad \ldots 11$$

Equation 10 is the marginal productivity condition for labour (the variable input). *Equation 11* is the optimal behaviour where the marginal value product of capital is equated to the marginal cost of accumulating capital $(v - PF_I)$ but in the dynamic case it incorporates the flow of investment decision as represented by $(r + \delta)$.

Firm level input demand and output supply. The input demand for labour and output supply of the firm can be derived from *Equations 2, 10* and *11*. Since F is homogenous of degree one, its derivatives are homogenous of degree zero and thus can be written as functions of the ratios X_1X_2 and I/X_2. From *Equation 10*, the demand for labour is determined by

$$PF_1\,(X_1, X_2) = W$$

or

$$X_1 = X_2(t),\ D^*_1\ W/P \quad \ldots 12$$

i.e., demand for labour is a function of capital, price of the output and its own price.

For the investment demand, *Equation 11* can be rearranged as

$$PF_2\,(X_1, X_2, I) + PF_I\,(I, X_2)\,(r + \delta) = v(r + \delta) \quad \ldots 13$$

Applying Euler's Theorem to F and using *Equation 12* to eliminate X_1/X_2,

$$PF[1, D_1\ W/P,\ I/X_2] - D_1\,(W/P)\ W/P + (r + \delta - I/X_2)\ F_I\,(I/X_2) = v(r + \delta) \quad \ldots 14$$

Let the left hand side of the equation be represented by $G(I/X_2, W, P)$, then

$$PG\,(I/X_2,\ W,\ P) = v(r + \delta) \quad \ldots 14$$

If P is greater than a critical value P_c, investment demand can be solved from *Equation 14;*

$$I(t) = X_2(t),\ D_2(W/P,\ v/P,\ r,\ \delta) \quad \ldots 15$$

Investment demand is a function of capital stock, price of the variable input, price of the output, rate of discount, depreciation rate and cash outlay per unit of investment.

Substituting $X_1(t)$ and $I(t)$ into the production function, the output supply for the firm is

$$Q(t) = X_2(t),\ F\,(1,\ D_1W/P,\ D_2W/P,\ v/P,\ r,\ \delta) \quad \ldots 16$$

The firm's supply in relation to output and input demand depends on prices in ratio forms only and on present stock of capital (also on earlier investments). For example, optimising perennial crop output depends not only on the existing stock of capital (the stock of trees) but also on the investment in new trees. For long-run supply response, assuming that the price is maintained over the relevant time period, the supply output is given by the time path of $X(t)$

$$\begin{aligned} \dot{X}_2(t) &= I(t) - X_2(t) \\ &= \delta X_2(t)\, D_2(W/P,\ v/P,\ \delta,\ r) \\ &\quad - \delta X_2(t) \qquad \ldots 17 \end{aligned}$$

$$X_2(t)/\dot{X}_2(t) = D_2(W/P,\ q/P,\ \delta, r) - \delta$$

From *Equation 17* under this constant price scenario, gross investment, labour force utilisation and output[11] will grow at a rate $D - \delta$.

Industry level. In dynamic theory, the supply of output and input demand of an industry takes into consideration whether there will be entry into the industry. Assuming there is no entry, the firms face an identical set of production functions and prices. The industry demand function is

$$D(t)\, e^{-rt} = Q(t) - h[P(t)] \qquad \ldots 18$$

where $h'(P) < 0$, $h(0) = \infty$, $h(\infty) = 0$. The shift in demand, for example, is due to growth in income (θ), and the growth rate in output is given by the right hand side of *Equation 18* and further assuming that market clearance occurs at each point in time, the industry supply function is

$$Q(t)/\dot{Q}(t) = g[P(t) - \theta] \qquad \ldots 19$$

With entry of firms, the present value of capital under optimal policy, $V^*[X_2(0)/X_2(0)]$, is not equal across the industry but should be a rising function of this ratio. For fixed factor prices, $V^*[X_2(0)/X_2(0)]$ will be an increasing function of the output price P. If $g(P)$ and $g'(P) > 0$, the increase in output from new firms will alter *Equation 18* to

$$Q(t)/\dot{Q}(t) = g[P(t) + g'[P(t)] - \theta] \qquad \ldots 20$$

The industry's gross investment demand can be obtained by aggregating *Equation 15*, a function of output price and other variables, *i.e.*

$$I(t)/X_2(t) = D_2(r,\ W/P,\ q/P) \qquad \ldots 21$$

As mentioned earlier, an assumption made in the adjustment model is static expectation. This results in the investment demand of *Equation 15.* The process by which price expectations are formed and how the process is related to other decisions of the firm are important in understanding the investment demand. If the weighted average of current prices and prices previously are expected to prevail (similar to that of Koyck and Nerlove), then price expectation behaviour introduces lagged input prices into the investment model. Of course, the inputs in production function determine the prices entering the investment relationship. The reliance of price expectation behaviour on current *versus* past prices determines whether these input price variables enter as lagged or in current values. Thus, the formation of price expectations can be important in developing dynamic models of the firm.

EMPIRICAL ANALYSIS

The foundation of the supply response for rubber is based on the theory of adjustment cost where the production function incorporates the investment flow concept rather than the price expectation model. Additionally, the theory suggests the incorporation of the phenological structure of the production process.

Production occurs over a number of years involving important lags in the process. The phenological relationships between planting, maturity and removal provide important *a priori* information for the study of supply responses. According to the dynamic theory, this information enters in the form of physical accounting relationships and is critical in the determination of the supply of rubber. The phenological relationships provide valuable constraints for the economic stimuli that are presumed to influence supply responses.

PHYSICAL OR PHENOLOGICAL RELATIONSHIP

Stocks and Flow Relationship

The inter-relationship between the various stages of production can be found from the acreage data for rubber in Peninsular Malaysia. These data are divided into planted, mature and immature, new plantings and replantings, and tapped area. No information is available on removals.

Mature area can be interpreted as the productive capacity or the stock of rubber trees and new plantings as the flow or investment that determines the stock. The relationships between these stocks and flows can be written as

$$MA_t = MA_{t-1} + NP_{t-6} - REM_t \qquad ...22$$

and

$$REM_t = NP_{t-30} \qquad ...23$$

where MA_t is mature area in the current period

MA_{t-1} is mature area in the previous year

NP_{t-6} are new plantings lagged six years

REM_t is the current removal.

Thus, mature area in the current year is equal to mature area last year plus the net addition, that is the difference between the new mature area and the area that is removed. It is assumed in *Equation 23* that trees reach maturity on the seventh year and are removed after thirty years[16]. Thus, *Equation 23* unlike *Equation 22* is an assumption not an identity.

Recall that no data are available on removal. However, from the assumption in *Equation 23*, REM^*_t can be calculated as

$$REM^*_t = MA_{t-1} - MA_t + NP_{t-6} \qquad ...24$$

that is REM^*_t is the residual. Of course, *Equation 22* can be re-written as

$$MA_t = MA_{t-1} + NP_{t-6} - REM^*_t \qquad ...25$$

and hold exactly, given that removal in period t is residually determined as assumed.

In *Equation 25*, the important variable is NP_{t-6} as it determines the amount of land available for replanting thirty years hence. It is a constraint faced by the estate sector, in particular. The amount of land available for replanting is a function of removals. Land is controlled by the various state governments and several restrictions are imposed on the acquisition of new land by the estates. The effect is to hold the land base of the estates relatively constant, at least in the short run.

The ratio NP_{t-6}/REM^*_t indicates the land for replanting or new planting. For the estate sector, the average value of the ratio was 0.7213 although over the sample period the value declined from 1.0 in 1952 to 0.53 in 1980. For the smallholders, the average value of NP_{t-6}/REM^*_t was 13.763. This large value is not surprising. Government agencies were actively involved in encouraging new plantings and replantings and, more generally, the growth in natural rubber production in this sector[16].

Several other useful relationships can be derived from *Equation 25*

$$MA_t - MA_{t-1} = NP_{t-6} - REM^*_t \qquad ...26$$

or

$$MA_t - MA_{t-1} = (NP_{t-6} - REM_t) + (REM_t - REM^*_t) \qquad ...27$$

From *Equations 26* and *23*, the difference in mature area is equal to the net addition plus the difference between removal from 'long term' trend as defined in *Equation 23*. If $REM_t = REM^*_t$ the area removed is equal to area planted thirty years earlier. If the difference is positive then less area is being removed or there is a slow down in the removal process. Thus, $REM_t - REM^*_t$ can be interpreted as the 'discretionary removal' — the variable that reflects the absence or presence of new investment when attractive or unattractive incentives are provided.

Ratios of stocks to flows. Before further developing the analysis of supply based on the ratios, it will be useful to examine more completely the physical lags and relationships in rubber production. It takes on the average six to seven years for an area planted with rubber to mature. Trees are kept until they are about thirty years old after which they are removed and the area replanted with rubber or other competing crops.

Using *Equation 25,* several ratios of stocks to flows can be calculated. It is not true to assume that the addition to the mature area will be the area planted six years ago. Losses due to death and other economic factors have to be considered. Only a proportion (δ) of the area planted six years ago will be added on to the existing mature area. Thus,

$$MA_t = MA_{t-1} + NP_{t-6} - REM^*_t \qquad ...28$$

and

$$\frac{MA_t - MA_{t-1} - REM^*_t}{NP_{t-6}} \qquad ...29$$

Yearly values of δ along with the standard deviations are summarised in *Table 1.* The value of this ratio together with the identity form the physiological basis for the supply response model. One would not expect this ratio to be constant over time. For example, the period of immaturity is likely to be shortened (lengthened) when prices are high (low) due to the opportunity cost involved.

PHENOLOGICAL MODEL

Using the average values of $\hat{\delta}$ derived from above, a simple or naive model for mature area is specified. This model does not include the economic variable *i.e.* the price. The model and the derived values are used primarily to indicate the importance of the successive stages in the production process for supply. Knowledge of this information is useful in the supply response analysis.

Based on the premise that only a proportion of new planting will mature, the mature areas for both sectors can be derived by substituting the average values of δt, $\hat{\delta}$, into *Equation 28 i.e.*

$$MA_t = MA_{t-1} + NP_{t-6} - REM^*_t \qquad ...30$$

Using *Equation 30,* the mature area data series were generated.

Specifically, *Figures 1* and *2,* show the historical and data series as generated. The results obtained are surprisingly good. For both sectors the naive model tracks the historical series well. Deviations are expected as the influence of economic variables has not been taken into consideration. The incorporation of price and other economic effects into the supply response model will improve the tracking performance.

ECONOMIC ASPECTS OF SUPPLY RESPONSE

The phenological structure of this perennial crop is, clearly from the above, a major determinant in the production dynamics. No fully dynamic theory can determine the supply response without utilising these inherent characteristics. The economic variables are included to explain the variations from the long-term stock flow averages. Thus, economic variables are included to explain the variations other than long-term averages. Economically motivated behavioural equations are formulated for explaining these deviations from the ratios based on the theoretical results above.

Behavioural Equation

Based on the dynamic theory, supply responses depend not only on present stock of capital but also on earlier investments. Investment in this instance is new planting *(NP)* and the stock of capital is mature area *(MA).* Investment demand, in turn, is postulated to be the function of existing capital stock, the price of input, the price of output, the rate of discount, the cost of investment and relevant variables. Prices are introduced in ratio form only. Thus, *NP,* in the present analysis is

TABLE 1. YEARLY RATIOS OF STOCK TO FLOW

Sector	Mean	Standard deviation	Minimum value	Maximum value
Estate	0.696	0.439	−0.354	1.573
Smallholder	0.836	0.527	−0.140	2.439

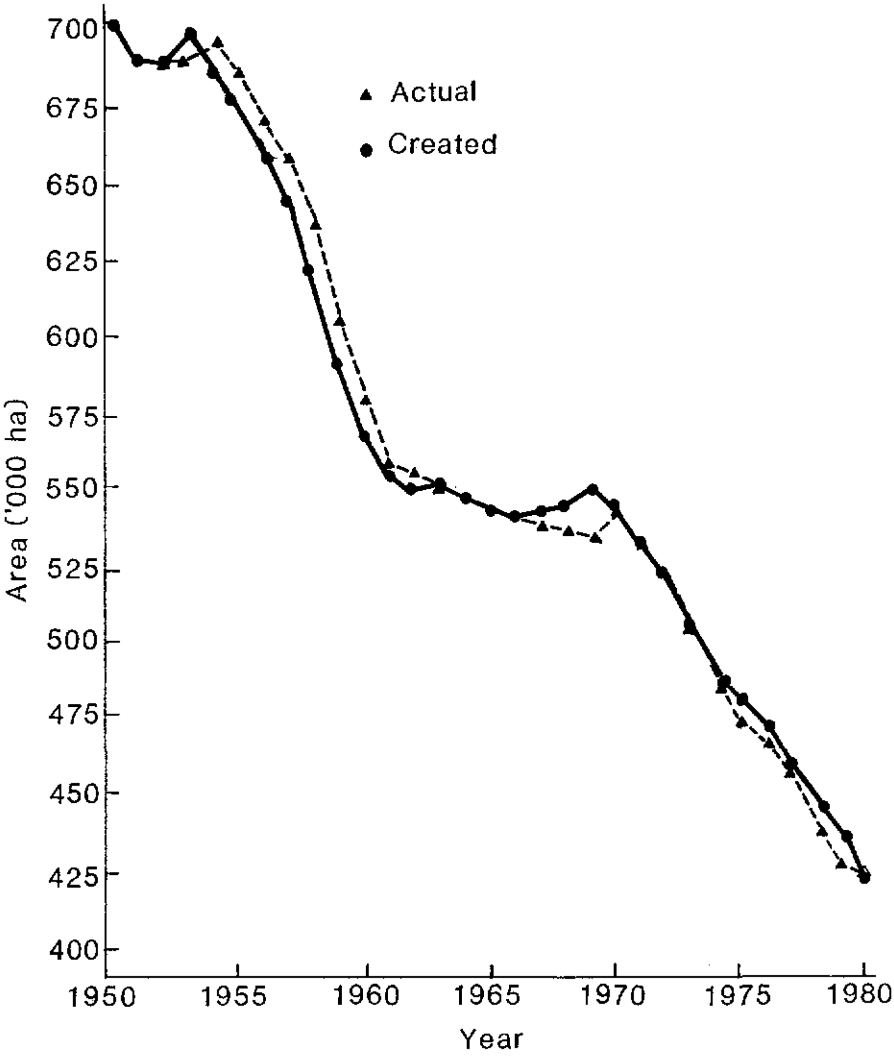

Figure 1. Plot of historical mature area and mature area created for estate sector.

hypothesised as a function of the price ratio of rubber to palm oil, the ratio of input price (namely wages), the cost of investment proxied by the discount rate, the lagged removals and new plantings. More specifically, the equations are;

$$NP^{E}_{t} = f_1(PR_t, PR_{t-1}, NP_{t-1}, REM_{t-1}, WP_t, IP_t \quad ...31$$

and

$$NP^{S}_{t} = f_2(PR_t, PR_{t-1}, NP_{t-1}, RP_t) \quad ...32$$

NP^{E}_{t} and NP^{S}_{t} are differences from long-term averages of new plantings for estates and smallholdings, respectively. In *Equations 31* and 32, PR_t and PR_{t-1} are the price ratios of RSS 1 (the noon rubber price in Kuala Lumpur) to palm oil current and lagged, WP_t is the ratio of wages to palm oil, IP_t is the ratio of discount rate to palm oil, NP_{t-1} and REM_{t-1} are new planting and removal, lagged one period. For the smallholder sector replanting grants, RP_t, is used as an explanatory variable. Past removal is not a determining

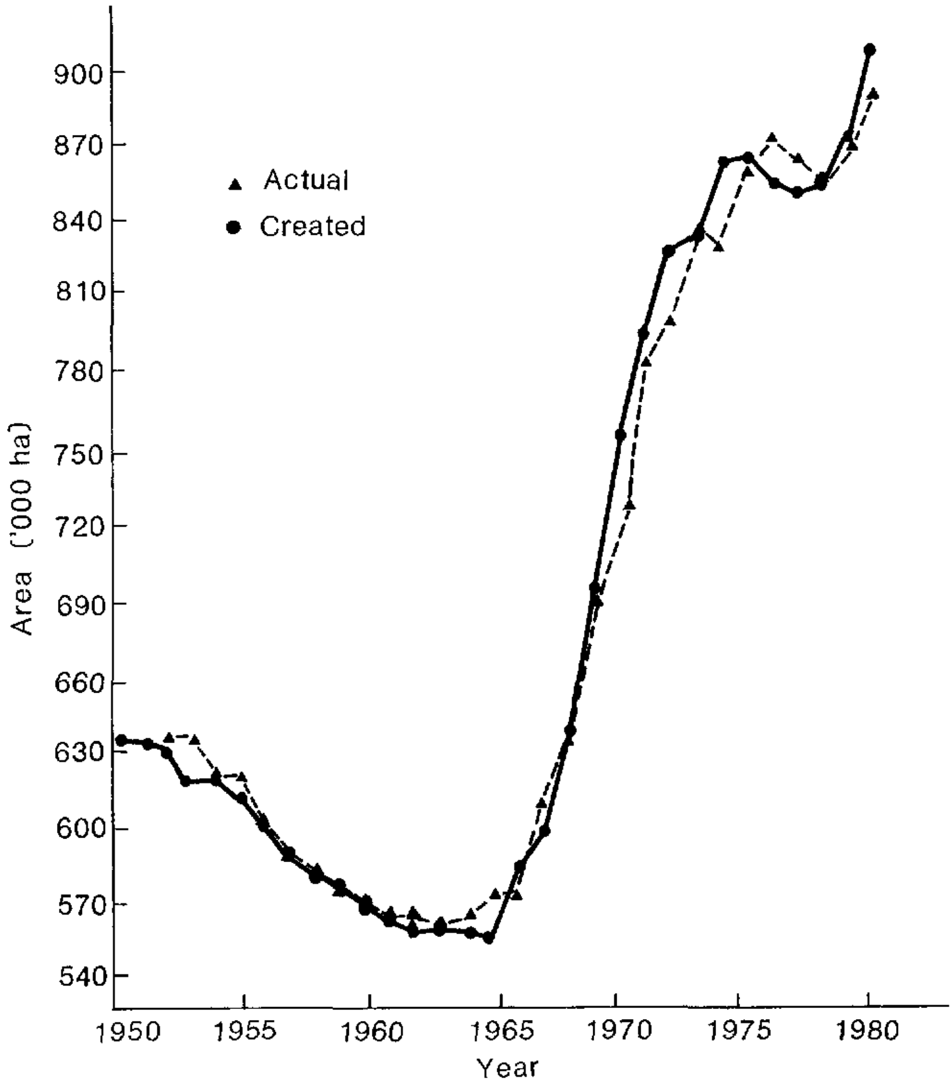

Figure 2. Plot of historical mature area and mature area created for smallholder sector.

factor in new planting for the smallholdings as compared with the estates since land is not constrained.

The flow of investment to existing stock of capital is determined by the phenological structure, namely δ. It can be observed that the ratio fluctuates from year to year. Fluctuations arise for several reasons; prices, land availability and its lagged value, thus, the variations in δ is hypothesised to be the function of such variables, or more specifically,

$$\delta^E_t = f_1(\text{RSS } 1_t,\ \delta_{t-1}) \qquad \ldots 33$$

and

$$\delta^S_t = f_2(\text{RSS } 1_t,\ REM_{t-1}). \qquad \ldots 34$$

where E_t and S_t are differences from long-term averages of investment flow for the estates and smallholdings respectively, while REM_{t-1} is removal for the last period.

Removals *(REM)* are hypothesised as a function of current and lagged prices, lagged mature area and its lagged value. The specifications are:

$$REM^E_t = f_1(RI_t, RI_{t-1}, REM_{t-1}, MA_{t-1}) \quad \ldots 35$$

and

$$REM^S_t = f_2(RI_{t-1}, REM_{t-1}) \quad \ldots 36$$

REM^E_t and REM^S_t are differences from long-term averages of removals for the estates and smallholdings respectively. For the smallholdings, it is hypothesised that removal is determined by persistence or past habits rather than economic variables as shown by *Equation 36.*

Empirical Estimates

The above specified behavioural equations were estimated using ordinary least squares for the period 1950 – 80. The use of OLS estimation was justified on the basis of its computational simplicity as well as the robustness of the parameter estimates. *Table 2* contains the estimated parameters for *Equations 31 – 36.* The reported statistics include t values, R^2 and Durbin Watson h statistics. The ordinary Durbin Watson statistics is not applicable since these equations have lagged dependent variables as regressors.

Generally, the results are consistent with *a priori* expectation for the signs of the estimated coefficients. The coefficients of lagged values are positive and less than one indicating that adjustments to changes do not occur fully in the time frame of the model specification.

FULL SUPPLY RESPONSE MODEL

The supply response model for each of the sector consists of three structural equations and three identities. Specifically, for the estate sector the specification is:

$$MA^E_t = MA_{t-1} + SNP_t - REM_t \quad \ldots 37$$

and

$$SNP_t = \delta . NP_{t-6}$$

$$\delta^E_t = f(RSS\ 1, \delta_{t-1}) \quad \ldots 38$$

$$NP^E_t = g(PR_t, PR_{t-1}, NP_{t-1}, REM_{t-1}, IP_t, WP_t) \quad \ldots 39$$

$$REM^E_t = h(RI_t, RI_{t-1}, REM_{t-1}, MA_{t-1}) \quad \ldots 40$$

$$YIELD^E_t = \text{Average yield} \quad \ldots 41$$

$$PRODUCTION^E_t = \text{Yield} \times MA_t \quad \ldots 42$$

For the smallholder sector, the specification is:

$$MA^S_t = MA_{t-1} + SNP_t - REM_t \quad \ldots 43$$

with $SNP_t = \delta . NP_{t-6}$

$$\delta^S_t = f(RSS\ 1, REM_{t-1}) \quad \ldots 44$$

$$NP^S_t = g(PR_t, PR_{t-1}, NP_{t-1}, RP_t) \quad \ldots 45$$

$$REM^S_t = h(RI_{t-1}, \text{REM}_{t-1}) \quad \ldots 46$$

$$YIELD^S_t = \text{Average yield} \quad \ldots 47$$

$$PRODUCTION^S_t = \text{Yield} \times MA_t \quad \ldots 48$$

where all variables are as previously specified.

EMPIRICAL RESULTS

Using the regression results *(Table 2),* the full model was simulated. In the *ex-post* or historical simulation, the simulated model performed well. The simulation results showed a remarkable ability of the supply response model to reproduce the endogenous variables. This inaccuracy is likely to be due to the habit or persistent behaviour of the smallholdings making them less responsive to economic factors.

To calculate the price elasticity of the supply response, a restricted reduced form for the estimated structural equations was derived. The derived reduced form offers a means of more efficiently estimating these estimators[17]. The derived short-run and long-run price elasticities from the full model are shown in *Table 3.* The results obtained from these restricted reduced form specifications are comparable to those from past studies *(Table 4).* The estimated supply response is inelastic, as expected of a perennial crop, more so in the short run than in the long run.

TABLE 2. REGRESSION RESULTS FOR THE ESTATE AND SMALLHOLDER SECTOR

Dependent variable	Price and economic variables													Statistics		Equation
	Constant	RSS 1	REM_{t-1}	PR	PR_{t-1}	RP	IP	WP	MA_{t-1}	NP_{t-1}	δ_{t-1}	IR	IR_{t-1}	R^2	D.W.h	No.
δ^E	0.289314	-0.000052	—	—	—	—	—	—	—	—	0.71396	—	—	0.507	0.5998	4.9
	(1.2433)	(0.4626)									(5.0670)					
δ^S	0.917248	0.000066	0.00236	—	—	—	—	—	—	—	—	—	—	0.007	0.0808	4.10
	(2.3205)	(0.3491)	(0.2678)													
NP^E	1.178775	—	0.04332	1.33565	0.77292	—	-142.27422	-16.43272	—	0.60469	—	—	—	0.879	0.7692	4.11
	(0.1861)		(0.2526)	(1.8910)	(0.9745)		(0.6871)	(1.0956)		(3.6658)						
NP^S	-9.95429	—	—	0.675018	0.36961	0.32152	—	—	—	0.78862		—	—	0.7063	0.9705	4.12
	(0.1170)			(0.4605)	(0.3136)	(0.2312)				(6.3381)						
REM^E	12.4807	—	0.5116	—	—	—	—	—	0.01777	—	—	5.8047	-29.9257	0.6617	-1.1422	4.13
	(0.8800)		(3.4182)						(1.0283)			(0.2369)	(1.1544)			
REM^S	25.95214	—	0.03589	—	—	—	—	—	—	—	—	—	-31.1121	0.0145	-0.0874	4.14
	(2.9024)		(0.1654)										(0.7894)			

Figures within brackets indicate the t-statistics

TABLE 3. SHORT- AND LONG-RUN PRICE ELASTICITIES OF SUPPLY[a]

Sector	Price elasticities of supply[b] Short run	Long run
Estate	0.0153359	0.400607
Smallholder	0.0036091	0.013805

[a]Calculated at the mean value
[b]Inclusive of lagged price

Naive Model for the Smallholding

The economic variables used to explain the variations in *Equations 43* and *48,* of the smallholder sector did not contribute importantly to the explanatory power of the model. Thus, it was hypothesised that the production dynamics of the smallholding is best described as determined by purely phenological phenomenon. Using the long-term averages for δ and $REM^S{}_t$, the supply response model for the smallholder sector was re-specified as .

$$MA_t = MA_{t-1} + SNP_t - REM_t \qquad ...49$$

$$\text{where } SNP_t = \delta NP_{t-6}$$

$$\delta_t = 0.83576793 \qquad ...50$$

$$NP_t = f(PR_t, PR_{t-1}, NP_{t-1}, RP_t) \qquad ...51$$

$$REM_t = 16.1956749 \qquad ...52$$

$$YIELD_t = \text{Average yield} \qquad ...53$$

$$PRODUCTION_t = \text{Yield} \times MA_t \qquad ...54$$

This simplified model was then simulated. Interestingly, the *ex-post* or historical simulations for NP_t, MA_t, and $PRODUCTION_t$ performed just as well with the simplified model as with previous models that included economic conditioning variables.

MODEL EVALUATION AND POLICY SIMULATION

Ex-post simulations are useful in policy analysis. By changing values of selected exogenous variables or letting the exogenous variables follow a different time path, an examination and comparison of what might occur as a result of alternative policies can be undertaken. Impact multipliers are calculated by comparing baseline simulation and simulations with selected shocks. The sensitivity of the model is evaluated by changing historical values of selected exogenous variables and periods of simulation.

Baseline Data Set and Simulation

Econometric models are often used to examine the impact of different shocks. If the model is linear than the dynamic properties can be calculated from the reduced form equations. The impact multipliers are, in fact, the coefficients of the derived reduced form equations. Alternatively, the reduced forms of linear models can be analysed as sets of stochastic difference equations and the dynamic properties can be determined[18].

For the non-linear models, analytic expressions of the impact multipliers are not generally available. There is no one-to-one correspondence between the structural model and the reduced form[19,20]. However, the multipliers can be approximated using non-linear simulation. First, a baseline simulation or simulation at mean values for the exogenous variables is computed. These baseline data are compared to simulations with the same exogenous data but including shocks for computing the multipliers, approximately.

Method for calculating multipliers. In order to calculate the multipliers, a method similar but less complete than Fair[20] was adopted. It is assumed that the parameters are known with certainty and all stochastic terms are eliminated. Fair used stochastic dynamic simulation while in this analysis a deterministic simulation is used. Both methods utilised a non-linear solution for the full model.

The present model which has a yearly time frame is adapted to Fair's for quarterly models. Following Fair's notation, let the ith equation for the model be

$$\phi i(y_{it} \ldots y_{Gt}, Z_{it} \ldots Z_{nt}, B_{it}) = 0$$

where y_{it} are the endogenous variables
Z_{it} the predetermined variables
B_{it} are the estimated coefficients.

TABLE 4. SUMMARY OF PAST STUDIES ON NATURAL RUBBER

Reference	Supply function estimated	Elasticities Short-run	Long-run	Feature
Stern	Pen. Malaysia	0.4661		Supply-inventory relationship
	Estate	−0.01		
	Smallholding	0.02		
Behrman	Pen. Malaysia	0.141		Adaptive expectation model
	Estate	−0.09		
	Smallholding	0.029		
	Indonesia	0.474		
	Estate	0.054		
	Smallholding	0.333		
	Thailand	0.409		
		Static	Dynamic	
Cheong	Pen. Malaysia	0.057	0.1403	1. Theory of the firm and partial adjustment model
	Indonesia	0.114	0.0720	2. Storage theory, static and extrapolative expectations
	Thailand	0.068	0.0194	3. Price of competing crop
Dowling	Thailand	0.092 to 0.265	1.205 to 2.641	Vintage production function and Almon lag
Blandford	Pen. Malaysia	0.294	0.358	Theory of capital investment
	Indonesia	0.086	0.125	
	Thailand	0.644	1.452	
World Bank	Pen. Malaysia	0.22		Partial adjustment model
	Indonesia	0.18		
	Thailand	0.25		
	Rest of the world	0.19		
Tan	Pen. Malaysia			
	Estate	0.3007	8.9245	Vintage production function and Almon lag
	Smallholding	0.6865	−1.0407	
	Indonesia			
	Estate	0.4945	5.6557	
	Smallholding	0.3586	6.6673	
	Thailand	0.3952	6.7137	

There is no error term in the equation since B_i is previously estimated. The simulation is thus non-stochastic.

Let $\bar{X}_1$ be a particular vector of exogenous variable for the period of interest ($\bar{X}_1$ in this instance is the vector of mean values) and y_{it} the simulated value of the endogenous variable i in period t. Let $\bar{X}_2$ be a vector of the exogenous variables changed by a certain percentage, then y_{it} is the simulated value of variable i which is conditional on X_2 and β. Then the difference in value for the endogenous variable due to the change in values of the exogenous variable from $\bar{X}_1$ to $\bar{X}_2$ can be calculated by

$$\gamma_{it} = \tilde{y}_{it} (\hat{\beta}_1, X_2) - y_{it} (\hat{\beta}_i, X_1) \qquad \ldots 55$$

Impact multiplier analysis. The method above was used to calculate the multipliers of the model. Multiplier estimates are reported in terms of percentage changes. Several experiments were conducted with the baseline data as reference. First, the exogenous variables were increased by 10% from their base value and the system shocked for one year only *i.e.* 1960. Second, the increased values of the exogenous variables were maintained through the period of simulation.

The exogenous variables used in the policy simulations were the price of palm oil, *PPOIL*, and export tax, *TAX*. For the policy variable *TAX*, the prices used in *NP* and *REM* were adjusted at the means for the tax.

Tables 5 and *6* show the percentage changes in values of selected endogenous variables due to a one-time or one-period shock in the exogenous variables. *Tables 7* and *8* show the selected multiplier effects due to sustained shocks to the system. These shocks are the same as the one-period shocks but are sustained throughout the simulation period.

TABLE 5. SELECTED IMPACT MULTIPLIERS DUE TO ONE-PERIOD CHANGE IN PRICE OF PALM OIL

Year	NP^S_t	MA^S_t	NP^E_t	MA^E_t	PTOTNR	RSS1NY
1960	−0.017504	0.000000	−0.001693	−0.000148	−0.000036	0.00025845
1961	−0.020099	−0.000835	−0.019827	−0.000838	−0.000337	0.00229945
1962	−0.015566	−0.000029	−0.010885	−0.000414	−0.000105	−0.00055868
1963	−0.012104	−0.000002	−0.006046	−0.000204	−0.000049	−0.00005072
1964	−0.009442	−0.000000	−0.003394	−0.000101	−0.000024	−0.00001696
1965	−0.007382	−0.000000	−0.001924	−0.000049	−0.000012	−0.00000809
1966	−0.005783	−0.000000	−0.001101	−0.000025	−0.000006	−0.00000398
1967	−0.004537	−0.000000	−0.000635	−0.000012	−0.000003	−0.00000197
1968	−0.003563	−0.000000	−0.000368	−0.000006	−0.000001	−0.00000097
1969	−0.002801	−0.000000	−0.000215	−0.000003	−0.000000	−0.00000048
1970	−0.002203	−0.000000	−0.000126	−0.000001	−0.000000	−0.00000024
1971	−0.001734	0.000000	−0.000075	−0.000000	−0.000000	−0.00000012
1972	−0.001365	0.000000	−0.000044	−0.000000	−0.000000	−0.00000005
1973	−0.001075	0.000000	−0.000026	−0.000000	−0.000000	−0.00000000
1974	−0.000847	0.000000	−0.000016	−0.000000	−0.000000	−0.00000000
1975	−0.000668	0.000000	−0.000009	−0.000000	−0.000000	−0.00000000
1976	−0.000526	0.000000	−0.000006	−0.000000	−0.000000	−0.00000000
1977	−0.000414	0.000000	−0.000003	−0.000000	−0.000000	−0.00000000
1978	−0.000327	0.000000	−0.000002	−0.000000	−0.000000	−0.00000000
1979	−0.000258	0.000000	−0.000000	−0.000000	−0.000000	−0.00000000
1980	−0.000203	0.000000	−0.000000	−0.000000	−0.000000	−0.00000000

TABLE 6. SELECTED IMPACT MULTIPLIERS DUE TO A ONE-PERIOD CHANGE IN EXPORT TAX

Year	NP^S_t	MA^S_t	NP^E_t	MA^E_t	PTOTNR	RSS1NY
1960	−0.0022367	0.00000000	−0.006562	−0.00003017	−0.000007254	0.00005247
1961	−0.0029194	−0.00016963	−0.007654	−0.00017046	−0.000068376	0.00046641
1962	−0.0022611	−0.00000609	−0.004333	−0.00008418	−0.000021220	−0.00011344
1963	−0.0017588	−0.00000022	−0.002478	−0.00004157	−0.000010029	−0.00001030
1964	−0.0013715	−0.00000001	−0.001429	−0.00002053	−0.000004936	−0.00000344
1965	−0.0010724	−0.00000000	−0.000831	−0.00001014	−0.000002437	−0.00000164
1966	−0.0008401	−0.00000000	−0.000486	−0.00000501	−0.000001203	−0.00000081
1967	−0.0006590	−0.00000000	−0.000286	−0.00000247	−0.000000594	−0.00000040
1968	−0.0005176	−0.00000000	−0.000169	−0.00000122	−0.000000293	−0.00000020
1969	−0.0004069	−0.00000000	−0.000100	−0.00000060	−0.000000145	−0.00000010
1970	−0.0003200	0.00000000	−0.000059	−0.00000030	−0.000000072	−0.00000005
1971	−0.0002519	0.00000000	−0.000036	−0.00000015	−0.000000035	−0.00000002
1972	−0.0001983	0.00000000	−0.000021	−0.00000000	−0.000000000	−0.00000000
1973	−0.0001562	0.00000000	−0.000013	−0.00000000	−0.000000000	−0.00000000
1974	−0.0001230	0.00000000	−0.000008	−0.00000000	−0.000000000	−0.00000000
1975	−0.0000969	0.00000000	−0.000005	−0.00000000	−0.000000000	−0.00000000
1976	−0.0000764	0.00000000	−0.000003	−0.00000000	−0.000000000	−0.00000000
1977	−0.0000602	0.00000000	−0.000001	−0.00000000	−0.000000000	−0.00000000
1978	−0.0000475	0.00000000	−0.000000	−0.00000000	−0.000000000	−0.00000000
1979	−0.0000374	0.00000000	−0.000000	−0.00000000	−0.000000000	−0.00000000
1980	−0.0000295	0.00000000	−0.000000	−0.00000000	−0.000000000	−0.00000000

TABLE 7. SELECTED IMPACT MULTIPLIERS DUE TO A SUSTAINED INCREASE IN PRICE OF PALM OIL

Year	NP^S_t	MA^S_t	NP^E_t	MA^E_t	PTOTNR	RSS1NY
1960	−0.10336	−0.000866	−0.046565	−0.0017999	−0.00057368	0.00191543
1961	−0.10334	−0.000866	−0.046363	−0.0018015	−0.00057404	0.00191581
1962	−0.10332	−0.000866	−0.046243	−0.0018023	−0.00057422	0.00191506
1963	−0.10330	−0.000866	−0.046178	−0.0018027	−0.00057431	0.00191500
1964	−0.10329	−0.000866	−0.046121	−0.0018029	−0.00057435	0.00191497
1965	−0.10328	−0.000866	−0.046093	−0.0018029	−0.00057437	0.00191496
1966	−0.10328	−0.000866	−0.046075	−0.0018030	−0.00057439	0.00191495
1967	−0.10327	−0.000866	−0.046064	−0.0018030	−0.00057439	0.00191495
1968	−0.10327	−0.000866	−0.046057	−0.0018030	−0.00057439	0.00191495
1969	−0.10326	−0.000866	−0.046053	−0.0018030	−0.00057439	0.00191495
1970	−0.10326	−0.000866	−0.046051	−0.0018030	−0.00057440	0.00191495
1971	−0.10326	−0.000866	−0.046049	−0.0018030	−0.00057440	0.00191495
1972	−0.10326	−0.000866	−0.046049	−0.0018030	−0.00057440	0.00191495
1973	−0.10326	−0.000866	−0.046048	−0.0018030	−0.00057440	0.00191495
1974	−0.10326	−0.000866	−0.046048	−0.0018030	−0.00057440	0.00191495
1975	−0.10325	−0.000866	−0.046047	−0.0018030	−0.00057440	0.00191495
1976	−0.10325	−0.000866	−0.046047	−0.0018030	−0.00057440	0.00191495
1977	−0.10325	−0.000866	−0.046047	−0.0018030	−0.00057440	0.00191495
1978	−0.10325	−0.000866	−0.046047	−0.0018030	−0.00057440	0.00191495
1979	−0.10325	−0.000866	−0.046047	−0.0018030	−0.00057440	0.00191495
1980	−0.10325	−0.000866	−0.046047	−0.0018030	−0.00057440	0.00191495

TABLE 8. SELECTED IMPACT MULTIPLIERS DUE TO A SUSTAINED INCREASE IN EXPORT TAX

Year	NP^S_t	MA^S_t	NP^E_t	MA^E_t	PTOTNR	RSSINY
1960	−0.014707	−0.00017595	−0.02455	−0.00036632	−0.00011649	0.000388541
1961	−0.014711	−0.00017595	−0.02441	−0.00036665	−0.00011656	0.000388491
1962	−0.014714	−0.00017595	−0.02433	−0.00036680	−0.00011660	0.000388467
1963	−0.014716	−0.00017595	−0.02427	−0.00036688	−0.00011661	0.000388455
1964	−0.014718	−0.00017595	−0.02424	−0.00036692	−0.00011662	0.000388449
1965	−0.014720	−0.00017595	−0.02422	−0.00036694	−0.00011663	0.000388446
1966	−0.014721	−0.00017595	−0.02421	−0.00036695	−0.00011663	0.000388445
1967	−0.014722	10.00017595	−0.02420	−0.00036696	−0.00011663	0.000388444
1968	−0.014722	−0.00017595	−0.02420	−0.00036696	−0.00011663	0.000388444
1969	−0.014723	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1970	−0.014723	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1971	−0.014723	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1972	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1973	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1974	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1975	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1976	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1977	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1978	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1979	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443
1980	−0.014724	−0.00017595	−0.02419	−0.00036696	−0.00011663	0.000388443

From *Tables 5* and *6*, as expected the multiplier effects of the one-period shock to the system tapered off over time. The supply shifters' effects on the estate sector were more pronounced and extended over a longer period than those of the smallholder sector. The impact of a tax increase was bigger for the estate sector than the smallholder sector with both sectors witnessing a negative percentage change in new plantings and mature area. Effects on total natural rubber production were greater for a change in *PPOIL* than for a change in *TAX*. The impacts of the supply shifters conform with economic theory where a short-term decrease in supply is expected to cause the price to increase immediately, reach a maximum and then decrease due to adjustments. For example, the percentage change in price due to *TAX* and *PPOIL* changes resulted in an increase in price in 1960, which reached a maximum in 1961 and thereafter the percentage change in price declined.

Sustained shock experiments were also conducted for both policy variables. The multiplier effects for the sustained shocks were larger than those for the one-year shocks. Sustained shocks for the supply shifters were accumulative over the years. The effects on production and price were larger than the one-period shock and tended to stabilise after a number of years.

In all these experiments it should be noted that the multiplier effect indicates the magnitude of impact of an exogenous variable on the endogenous variables. The simulations are conducted on a partial basis. For example, the multiplier effect for a change in *PPOIL* by 10% in one year caused new plantings in the smallholder sector to change by −0.00175% in the first year, a −0.0201% change in the second year and so forth, holding other factors constant. It is emphasised that other factors, the predetermined variables at the mean levels, were held constant.

Sensitivity analysis. To evaluate the model performance, similar policy simulations to those of the multipliers were carried out with different initial periods of simulations or in the initial conditions; the method of calculating the multiplier impacts was also the same. However, in this instance instead of using the baseline values, the actual historical data were used.

The exogenous variables selected for the examination were the same. In the first simulation the historical values were increased by 10% and simulation was initiated for 1975 – 80. In the second experiment, the historical values were decreased by 10% and the simulation conducted over the same period. Results of both simulations are shown in *Tables 9* and *10.*

TABLE 9. PERCENTAGE CHANGE IN IMPACT WITH 10% CHANGE IN PRICE OF PALM OIL

Year	NP^S	MA^S	NP^E	MA^E	PTOTNR	RSSINY
			10% increase			
1976	−0.011743	0.00000000	0.020640	−0.0003386	−0.00006210	0.00049078
1977	−0.026843	−0.00097271	−0.001174	−0.0023654	−0.00064551	0.00451524
1978	−0.041585	−0.00099788	−0.013298	−0.0034619	−0.00078781	0.00318518
1979	−0.055541	−0.00088835	−0.019329	−0.0037736	−0.00077474	0.00253277
1980	−0.066745	0.00070479	−0.021650	−0.0036203	−0.00069063	0.00197378
			10% decrease			
1976	0.143522	0.00000000	−0.025227	0.0003296	0.0000615	−0.0004908
1977	0.032807	0.00097210	0.011564	0.0023654	0.0006982	−0.0045175
1978	0.050826	0.00099788	0.017113	0.0034618	0.0007878	−0.0031722
1979	0.067883	0.00088834	0.025115	0.00377356	0.0007747	−0.0025245
1980	0.081577	0.00070479	0.028355	0.00362025	0.0006906	−0.0019688

TABLE 10. PERCENTAGE CHANGE IN IMPACT WITH 10% CHANGE IN EXPORT TAX

Year	NP^S	MA^S	NP^E	MA^E	PTOTNR
			10% increase		
1976	−0.001673	0.00000000	−0.009324	−0.0001036	−0.00001899
1977	−0.004758	−0.00029811	−0.025448	−0.0007650	−0.00020405
1978	−0.008010	−0.00040862	−0.035459	−0.0013216	−0.00030561
1979	−0.011743	−0.00035001	−0.046806	−0.0014918	−0.00030400
1980	−0.015252	−0.00032701	−0.058756	−0.0015616	−0.00030085
			10% decrease		
1976	0.001673	0.00000000	0.009323	0.00009876	0.00001809
1977	0.004758	0.00028411	0.025458	0.00072728	0.00019415
1978	0.008010	0.00038449	0.035419	0.00124741	0.00028818
1979	0.011743	0.00032998	0.046998	0.00140622	0.00028818
1980	0.015252	0.00030578	0.059043	0.00146574	0.00028213

Several observations can be made from the simulated results. First, the impacts of the supply shifters seemed to build up from year to year. This is the reflection of the lags in the phenological structure in the model, indicating cumulative effects of investment and disinvestment decisions. Secondly, the magnitude of the effects due to a 10% increase or decrease are about the same but in the opposite direction.

Forecasting

There are two types of forecasting, *ex post* and *ex ante*. In *ex post* forecasting exogenous variables are known with certainty while in *ex ante*, the dependent variable is forecasted by using exogenous variables whose values may or may not be known. *Ex post* forecasting can be used as a means of evaluating a model by comparing the forecast values with the historical data. It is useful not only for predictive purposes but also for sensitivity and policy analysis. The *ex post* forecast is utilised in this study.

The model was used to forecast the endogenous variables for 1981 and 1982. The forecasted values obtained were compared with the actual values of the endogenous variables. Various criteria can be used in evaluating the forecasting capability of the model, namely;

- Root mean square error
- Root mean square per cent error
- Mean percent error
- Theil inequality coefficient.

For Theil's inequality coefficient, if $U = 0$, the forecasted value is equal to the actual value and if $U = 1$, the opposite holds[21]. The endogenous variables MA^S_t, $PRODUCTION^S_t$, REM^S_t, MA^E_t performed better than others with U coefficient values falling between 0.011 and 0.046. The poorest forecasting performance was for NP^E_t. *Table 11* shows the forecasted and actual values of the endogenous variables, while *Table 12* shows the values obtained for the various statistical criteria used in evaluating the forecasting performance of the model.

CONCLUSION

The objective of the paper was to illustrate an alternative approach to estimating supply response of a perennial crop by incorporating the phenological structure. The incorporation of such *a priori* information provides useful information in the formulation of lags in the dynamic supply functions. Results obtained from the analysis showed that the incorporation captured explicitly the dynamic property of the production process thus reflecting the structural integrity of the model.

The value of incorporating the phenological process for the trees together with an adequate economic structure has wider implications for policy analysis as reflected in the results obtained from the policy simulation exercises. The effects of a one-time and sustained shocks conform with economic theory. The multiplier effects of a one-time shock to the system tapered off over time while sustained shocks

TABLE 11. FORECAST AND ACTUAL VALUES OF ENDOGENOUS VARIABLES 1981 AND 1982

Variable	1981		1982	
	Actual	Forecast	Actual	Forecast
REM^E_t	12.80000	19.8884	6.40000	19.524100
NP^E_t	38.00000	28.2707	37.80000	37.641000
δ^E_t	0.71875	0.7293	0.91416	0.814632
MA^E_t	926.90000	914.5560	943.80000	926.849000
$PRODUCTION^E$	882.30000	870.5500	902.30000	886.095000
REM^S_t	20.00000	26.6822	22.50000	22.202500
δ^S_t	3.81551	0.5461	3.74242	1.396660
MA^S_t	416.70000	405.8260	403.90000	401.251000
$PRODUCTION^S$	574.30000	585.7400	576.70000	596.700000

TABLE 12. STATISTICAL CRITERIA FOR EVALUATING FORECASTING CAPABILITY OF MODEL

Variable	Mean error	Mean percent error	Root mean square	Theil U
REM^E_t	10.106	1.302	14.292	0.479
NP^E_t	−5.159	−0.127	7.297	0.219
δ^E_t	0.005	0.128	1.414	0.646
MA^E_t	−14.678	−0.016	20.715	0.011
$PRODUCTION^E_t$	−13.978	−0.016	19.767	0.011
REM^S_t	3.192	0.174	4.515	0.098
NP^S_t	4.549	4.136	6.434	0.825
δ^S_t	−2.808	−0.742	3.970	0.257
MA^S_t	−6.7613	−0.016	9.562	0.012
$PRODUCTION^S$	−133.506	0.239	188.806	0.162

for the supply shifters were accumulative over the years. Results from the sensitivity analysis add credence, as the impact of the supply shifters seemed to build up from year to year — a reflection of the lags in the phenological structure of the model, indicating cumulative effects of investment and disinvestment decision.

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