A LITERATURE REVIEW ON SUPPLY RESPONSE OF PARENNIAL CROPS

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Abstrak

Artikel ini mencoba mereview literatur yang berkaitan dengan teori suplai, khususnya yang berkaitan dengan aplikasi teori respon penawaran pada tanaman perkebunan. Pada bagian pertama akan dibahas teori penawaran statis yang dilanjutkan dengan penawaran dinamis. Aplikasi model respon penawaran pada berbagai tanaman perkebunan dibahas pada bagian ketiga tulisan ini. Survai artikel literatur ini menujukkan adanya berbagai model suplai penawaran yang dapat digunakan pada berbagai komoditi tanaman tahunan.

Kata Kunci: respon penawaran, tanaman tahunan.

INTRODUCTION

Christopher Ritson (1977) states that agricultural product supply can be defined as the quantity offered for sale per period of time given a set of circumstances. There are two main theories to analyse the agricultural commodity supply, namely, the static theory of supply and the dynamic theory of supply. The static theory of agricultural supply shows the amount of agricultural product a producer is willing to place in the market at a specific market price whilst other influencing factors are held constant (Cochrane 1955; Ritson 1977; Tomek and Robinson 1990; Colman and Young 1993). This implies that a change in own commodity price will induce an increase in output. Conversely, the output offered will decline if the price of the commodity decreases. In theory, static supply can be explained from a knowledge of the underlying input-output relationship (production functions) or cost functions. The dynamic theory of agricultural supply, however, is more complex since the supply of agricultural products will not adjust instantaneously and completely in response to market stimuli as in the static supply theory (Colman and Young 1993). The dynamic supply theory also explains how output responds to changing in price whilst other factors are not held constant.

This paper is primarily aimed at reviewing the theory of agricultural supply. To begin with, the static theory of agricultural supply will be reviewed. Another development in the static theory will also be discussed in this section. The second section will deal with the dynamic theory of agricultural supply. Previous studies in perennial crop supply, on which this study is based, particularly palm oil, will be reviewed in the third section of this chapter. Finally, conclusions will be drawn in the fourth section.

THEORYTICAL FRAMEWORK

Static Supply Theory

Marc Nerlove and Kenneth L. Bachman (1960) stated that the production function, a summary of technological possibilities to transform input into output and substitute one output for another and one input for another, is a basic datum for all agricultural supply analysis. Tisdell (1981) defines the production function as a function of quantities of the variable factors of production that can be employed to maximise an output. In addition, the production function can be expressed in four different ways (Doll and Orazem 1984). First, it can be expressed in written form, enumerating and describing the inputs that have a bearing on output. Second, it can be shown by listing inputs and resulting outputs numerically in a table form. Third, it can be depicted in the form of a graph or a diagram. Finally, it can be written in the form of algebraic equation.

Symbolically, the production function can be specified as follows:

$$Y = f(X_1, X_2, X_3, \ldots, X_{n-1} | X_n) \qquad (3.1)$$

where Y = output produced in a given time period,

$X_1, X_2, X_2, \ldots, X_{n-1}$ = variable inputs employed to produce Y,

X_n = fixed input used to produce Y, and

f = the functional operator of the input-output relationship.

Doll and Orazem (1984) state that inputs can be categorised as variable inputs if their quantity can be varied during the production period. Conversely, if quantity cannot be varied during the production period then inputs are 'fixed'. In addition, they note that the classification of inputs into fixed and variable is used to classify the length of the production period, namely, very short run, short run, and long run. Very short run is a time period so short that all inputs are fixed. Short run is a time period of such length that at least one factor of production can be varied whilst others are fixed. The long run, on the other hand, is a time period of such length that all production factors can be varied.

The static theory of agricultural supply is constructed under some important assumptions. First, the static supply function does not involve time in any meaningful way (Nerlove and Bachman 1960). In this case, the production or supply will take place through time as prices and costs change. In other words, the firm or producer is able to change his production immediately by changing inputs. Second, an important assumption is perfect certainty (Doll and Orazem 1984). Under this assumption, the farmer or producer knows with certainty the volume of production from the use of varying inputs. He knows perfectly the price of inputs and of the commodity produced in the future. Another assumption is that the level of technology or the 'state of the art' is constant. With this assumption, Doll and Orazem (1984) state that the farmer or producer will use the most efficient process available to him; that is, the technology that yields the maximum output from a given amount of inputs. Finally, in the static agricultural supply theory, it is assumed that the farmer seeks to maximise net returns in a timeless context (Nerlove and Bachman 1960; Tomek and Robinson 1990).

One popular example of the static supply function is the Cobb-Douglas function. Chand and Kaul (1986) show that the Cobb-Douglas function has been widely used by agricultural economists in their study of technology and production behaviour of the farm firm. Among others are Lau and Yotopoulus (1972), Sidhu (1974), and Yotopoulus, Lau and Lin (1976). Ritson (1977) notes that this type of production function is popular due to its mathematical characteristics, namely, it is sufficiently flexible to encompass many typical production situations and it is easy to use because it can be easily estimated. The general form of the Cobb-Douglas production function is specified as follows:

$$Y = kX_1^p X_2^q X_3^r \dots \qquad (3.2)$$

where Y denotes output,

Xi represents input used, i = 1, 2, 3, ...

k, p, q, r are constants.

Given the production function for the firm of the form (1) or (2) and information on the nature of the relationships involved, it is possible to derive functions expressing outputs, costs, and derived demand for inputs in terms of prices of outputs and inputs.

A development of static supply theory has also been made where supply to the market is not only influenced by inputs, but is also influenced by other related factors, such as competitive crop prices. Colman and Young (1993) state that the market supply of a product will depend on the own commodity price, other commodity prices and input prices. Thus, the supply function can be specified as follows:

$$Y_i = f(P_i, P_j, P_k, p_1, p_2, \ldots, p_n) \qquad (3.3)$$

where Y_i denotes market supply for agricultural commodity *i*,

P_i represents the price of commodity *i*,

P_j and P_k are alternative commodities, say *j* and *k*, prices, and

$p_1, p_2, \ldots, p_n$ are input prices.

Given a supply function (3) above, the relationship between the supply of commodity *i* and its own price can be obtained by assuming the price of other commodities and inputs are held constant. Hence, the own price elasticity of supply can be measured and this represents the responsiveness of supply to increases or decreases in own price. Furthermore, by inclusion of other commodity prices, the cross price elasticity of supply can be estimated. This describes how much supply of product *i* will change in response to changes in other commodity prices, say *j* or *k*.

Further, it is possible to derive supply functions for many products or inputs. In this case, the multiple output supply problem can be analysed by employing a dual profit or cost function system which is more flexible than the production function with its restriction to one product (Colman 1983). For example, Ray(1982) estimates the more flexible translog of the cost function for a case in which two outputs, crops and livestock, were identified separately. Alternatively, a study by Mundlak (1963) uses transformation functions to estimate multi-product supply.

From the discussion so far, it can be concluded that the static supply curve is a one-two dimensional relationship whether for multi-products, multi-inputs firm or industry. It is extracted from a complex multi-dimensional set of functional relationships between output and input use and changes in the amounts of other products. A number of important parameters have been omitted from the list of supply function parameters, such as the price of joint products, the state of technology, the natural environment, and the institutional setting. Even though some developments have been made by inclusion of the parameters into the supply function to provide a more accurate description of production in agricultural markets, it is still inadequate (Colman and Young 1993). This is because the model used is static and thus a change in an explanatory variable causes an instantaneous and complete response in supply. In other words, there is no delay in adjustment. Another problem is that static supply is based on perfect certainty by which farmers know exactly the quantity of product that they can produce, the future price that will be received when they decide to produce and so on. In fact, there are a number of reasons for delayed adjustment and farmers or producers do not know exactly what is in the future. For these reasons, dynamic supply theory which includes the uncertainty, flexibility of fixed factors over time and technological change is needed to make agricultural supply analysis more realistic.

Dynamic Supply Theory

Unlike in static supply theory, dynamic supply theory takes time into consideration. This implies that there are possibilities to change in an output-input relationship over time and that time is associated with uncertainty. For example, agricultural output will be subject to a number of climatic and biological factors which, being outside the control of the farmer, may cause serious random fluctuations in yields. Another example is uncertainty about product price. For most agricultural products, prices are not known with certainty at planting time or when breeding plans are made. That is why, according to Colman and Young (1993), the dynamic specification of the supply function is needed.

Moreover, Colman and Young (1993) state that the need for dynamic specification of supply functions also arises because farmers will not be able or willing to adjust their production activities instantaneously in response to market stimuli. There are three reasons for this. First, there is psychological resistance to change. Farmers take time to adopt new technology or to decide to produce a commodity which lies outside the scope of traditional practices. Second, there is partial adjustment to market forces due to institutional factors. Production quotas, for instance, are designed to prevent farmers from taking full advantage of profitable opportunities for some commodities which are already believed to be in surplus. Third, the technical characteristics of agricultural production may constrain adjustment in the short run.

Nerlove and Bachman (1960) argue that the need for dynamic specification of agricultural supply is due to the role of technological change, flexibility of fixed factors over time and uncertainty.

In static supply theory, the role of technological change on the farm is ignored, or assumed away, in order to conceptualise the supply relation. In fact,, the rate of technological change adopted and its effects on the production processes are more amenable to economic analysis than some believe (Cochrane 1955; Nerlove and Bachman 1960). Through changes in technology more output can be produced with the same total resources, or, alternatively, fewer inputs are required to produce the same output. In terms of fixed production factors, Nerlove and Bachman (1960) note that fixed factors of production are not fixed for all time but can be varied in response to economic forces.

In relation to consideration of time, Cochrane (1955) distinguishes the term of supply function and supply response. Concerning the term the supply function, Cochrane (1955) shows how the quantity of a product offered for sale varies as its price varies relative to other product prices for some given time period and for given technology. This means that the supply occurs only to the movement along the supply curve (*ceteris paribus*) and describes the change in output in the short run. The supply response, however, concerns what will happen to the quantity of a commodity offered for sale when other things are not held constant. It is concerned with the output response to a price change regardless of how that response takes place - whether by employing more or fewer inputs, modifying the fixed plant or adopting technological advance and by exploiting whatever sets of conditions may obtain. In other words, supply response should be interpreted as the study of supply shifters. Therefore, the supply response is a general theory describing the short-run and long run changes in output.

The largest bodies of theory relating to supply response concern the formation of expectations and the derivation of appropriate functional forms, variables and estimating procedures to incorporate various postulated expectation generators (Colman 1983). Incorporation of expectations is one area which has received particularly intensive study. Price expectations are important in agricultural decision making, hence, they have been incorporated in formulating supply response models for a considerable period of time. Several approaches to price expectations that involve naive expectations, or the Cobweb model assumption, extrapolative expectations, adaptive expectations or the Nerlovian model assumption, and rational expectations, will be briefly discussed in this section.

One simple hypothesis about price expectations is called naive expectations. This is also known as the Cobweb model. The Cobweb model is the first formulation of expectations usually presented as an example of the relationship between dynamics and market stability and assumes that the farmers base their expectations of future prices on the price ruling at the time of planning. It can be written as:

$$P_t^e = P_{t-1} \tag{3.4}$$

where P_t^e = expected price in period *t*,

P_{t-1} = actual price in period *t-1*.

This simple hypothesis implies that since all farmers follow the same rule, the supply response equation predicts that a year of oversupply will be followed by a year of shortage followed by a year of oversupply and so on in the familiar cobweb pattern. However, the Cobweb model has not attracted much support because it assumes that farmers conduct their business in a very naive manner. First, their behaviour ignores the impact of similar actions of other farmers. Second, one might expect the farmers to learn from their experience and to benefit from that knowledge (In 1994).

The second approach is known as extrapolative expectations. This was introduced in an attempt to eliminate the extreme naivety of the Cobweb model. The extrapolative expectations hypothesis states that future price should be based not only on the past level of an economic variable, but also on its direction of change. In other words, the extrapolative expectations term in any period is equal to the price level of the previous period plus (or minus) some proportion of the change between the previous two periods (In 1994).

That is,

$$P_t^e = P_{t-1} + s(P_{t-1} - P_{t-2}) \tag{3.5}$$

where P_t^e = expected price in period *t*,

P_i = actual price in period *t-i*; *i* = 1, 2, and

s = the coefficient of expectation that represents the proportion of the change in previous price incorporated into the expectations term.

Adaptive expectations, developed by Cagan (1956), hypothesises that agents revise their expectations each period according to degree of error in their previous expectations. Compared with extrapolative expectations, which are based only on the information contained in the actual values for the preceding two periods, the adaptive expectations term reflects the entire past history of the series. The adaptive expectation (made in period *t-1*) of the price level in period t is defined as

$$P_t^e = P_{t-1}^e + b(P_{t-1} - P_{t-1}^e) \qquad 0 < b \leq 1 \tag{3.6}$$

where, P_t^e = the expected price in period *t-i*; $i = 0, 1$,

P_{t-1} = actual price in period *t-1*, and

b = coefficient of expectations.

In other words, farmers revise their previous expectations of price in each period in proportion to the difference between the actual price and their own previous forecast (Nerlove 1972). The adaptive expectation term from equation (6) can also be expressed as the summation of weighted values of past prices:

$$P_t^e = P_{t-1}^e + b(P_t - P_{t-1}^e)$$

$$P_t^e - P_{t-1}^e + bP_{t-1}^e = bP_{t-1} \tag{3.7}$$

Using L as lag-operator notation, equation (7) can be expressed as:

$$(1-(1-b)L)P_t^e = bP_{t-1}$$

$$P_t^e = \frac{b}{[1-(1-b)L]}P_{t-1} \tag{3.8}$$

Since it is assumed that $0 < b \leq 1$, it can be shown that

since $\frac{1}{1-\beta L}P_t = \sum_{i=0}^{\infty} \beta^i P_{t-i} = \sum_{i=0}^{\infty}(1-\lambda)^i P_{t-i}$

$$P_t^e = \frac{(1-\beta)P_{t-1}}{(1-\beta L)} = (1-\beta)\sum_{i=0}^{\infty}\beta^i P_{t-i-1}, \qquad or$$

$$P_t^e = (1-\beta)\sum_{i=0}^{\infty}\beta^i P_{t-i-1} \tag{7}$$

Equation (7) implies that the weights of past prices are functions of the coefficients of expectation and declining geometrically. However, some criticisms arise with the use of an adaptive expectations mechanism. First, the adaptive expectation mechanism is formally equivalent to a distributed lag with geometrically declining weights, but there is no justification for these weights. Second, the adaptive expectation hypothesis incorporates only past values of the variable being forecast. Third, mechanical application of an adaptive expectations formula does not necessarily make best use of all the information available (In 1994).

Even though there are some limitations, many agricultural supply response analyses have used the adaptive expectations hypothesis originally applied by the work of Nerlove (1958), called Nerlovian model or partial adjustment - adaptive expectation model since it is combination between partial adjustment and adaptive expectation. Askari and Cummings (1977) reported from their survey that approximately 600 versions of Nerlovian model for many crops and countries are used. The Nerlovian model basically consists of three equations:

$$A_t^D = a_0 + a_1 P_t^e + a_2 Z_t + u_t \tag{8}$$

$$P_t^e = P_{t-1}^e + \beta(P_{t-1} - P_{t-1}^e) \tag{9}$$

$$A_t = A_{t-1} + \gamma(A_t^D - A_{t-1}) \tag{10}$$

where A_t = actual area under cultivation at time *t*,

A_t^d = area desired to be under cultivation at time *t*,

P_t = actual price at time *t*,

P_t^e = expected price at time *t*,

Z_t = other exogenous factor(s) affecting supply at time *t*, and

β and γ represent the expectation and adjustment coefficients respectively.

The solution to equation (8), (9) and (10) involves only very simple algebraic manipulations. From equation (8), the expected price variable in period *t*, P_t^e, can be expressed as:

$$P_t^e = \frac{-a_0 - a_2 Z_t + A_t^D - u_t}{a_1} \tag{11}$$

Thus, the expected price variable in period *t-1* can be derived from equation (11) as:

$$P_{t-1}^e = \frac{-a_0 - a_2 Z_{t-1} + A_{t-1}^D - u_{t-1}}{a_1} \tag{12}$$

From equation (9), the expected price variable in period *t*, P_t^e, can also be written as:

$$P_t^e = \beta P_{t-1} + (1-\beta)P_{t-1}^e \tag{13}$$

then, by substituting equation (12) into equation (13), P_t^e can be specified as:

$$P_t^e = \beta P_{t-1} + (1-\beta)\{\frac{-a_0 - a_2 Z_{t-1} + A_{t-1}^D - u_{t-1}}{a_1}\} \tag{14}$$

If equation (14) is substituted into equation (8), the desired acreage in period *t*, A_t^d, can be obtained,

$$A_t^D = a_0 + a_1\{\beta P_{t-1} + \frac{(1-\beta)[-a_0 - a_2 Z_{t-1} + A_{t-1}^D - u_t]}{a_1}\} + a_2 Z_t + u_t$$

$$A_t^D = a_0 + a_1\beta P_{t-1} + (1-\beta)\{-a_0 - a_2 Z_{t-1} + A_{t-1}^D - u_{t-1}\} + a_2 Z_t + u_t$$

$$A_t^D - (1-\beta)A_{t-1}^D = a_0 + a_1\beta P_{t-1} + (1-\beta)\{-a_0 - a_2 Z_{t-1} - u_{t-1}\} + a_2 Z_t + u_t$$

$$\{1-(1-\beta)L\}A_t^D = a_0 + a_1\beta P_{t-1} + (1-\beta)\{-a_0 - a_2 Z_{t-1} - u_{t-1}\} + a_2 Z_t + u_t$$

$$\{1-(1-\beta)L\}A_t^D = a_0\beta + a_1\beta P_{t-1} - (1-\beta)a_2 Z_{t-1} - (1-\beta)u_{t-1} + a_2 Z_t + u_t$$

$$\{1-(1-\beta)L\}A_t^D = a_0\beta + a_1\beta P_{t-1} + a_2 Z_t - (1-\beta)a_2 Z_{t-1} + u_t - (1-\beta)u_{t-1} \tag{15}$$

In addition, from equation (10), the desired acreage in period *t*, A_t^d, can also be expressed as:

$$\gamma A_t^D = A_t - A_{t-1} + \gamma A_{t-1}$$

$$A_t^D = \frac{1}{\gamma}A_t - \frac{(1-\gamma)}{\gamma}A_{t-1} \tag{16}$$

Next, by substituting equation (16) into equation (15), the estimating equation is obtained,

$$\{1-(1-\beta)L\}\{\frac{1}{\gamma}A_t - \frac{(1-\gamma)}{\gamma}A_{t-1}\} = a_0\beta + a_1\beta P_{t-1} + a_2 Z_t - (1-\beta)a_2 Z_{t-1} + u_t - (1-\beta)u_{t-1}$$

$$\frac{1}{\gamma}A_t - \frac{(1-\gamma+1-\beta)}{\gamma}A_{t-1} - \frac{(1-\gamma)(1-\beta)}{\gamma}A_{t-2} = a_0\beta + a_1\beta P_{t-1} + a_2 Z_t - (1-\beta)a_2 Z_{t-1} + u_t - (1-\beta)u_{t-1}$$

$$\frac{1}{\gamma}A_t = a_0\beta + a_1\beta P_{t-1} + \frac{(1-\gamma+1-\beta)}{\gamma}A_{t-1} + \frac{(1-\gamma)(1-\beta)}{\gamma}A_{t-2} + a_2 Z_t - (1-\beta)a_2 Z_{t-1} + u_t - (1-\beta)u_{t-1}$$

$$A_t = a_0\beta\gamma + a_1\beta\gamma P_{t-1} + (2-\gamma-\beta)A_{t-1} + (1-\gamma)(1-\beta)A_{t-2} + a_2\gamma Z_t - (1-\beta)a_2\gamma Z_{t-1} + \gamma u_t - (1-\beta)\gamma u_{t-1}$$

This can be rewritten as

$$A_t = \pi_0 + \pi_1 P_{t-1} + \pi_2 A_{t-1} + \pi_3 A_{t-2} + \pi_4 Z_t + \pi_5 Z_{t-1} + v_t \tag{17}$$

where $\pi_0 = a_0\beta\gamma$, $\pi_1 = a_1\beta\gamma$, $\pi_2 = 2-\beta-\gamma$, $\pi_3 = (1-\gamma)(1-\beta)$, $\pi_4 = a_2\gamma$,

$\pi_5 = (1-\beta)a_2\gamma$, $v_t = \gamma u_t - (1-\beta)\gamma u_{t-1}$

An alternative approach is offered by the rational expectations hypothesis of Muth (1961). According to Maddock and Carter (1982), rational expectations is the application of the principle of rational behaviour to the acquisition and processing of information and to the formation of expectations. The rational expectation hypotheses states that in forming their expectations of endogenous variables, economic agents take account of the relationships among variables, described by the appropriate economic theory (Wallis 1980). Nelson (1975) stated that according to Muth's theory the rational expectation of a variable, say Z, will depend on the reduced form expression for Z in the "relevant system" and on the information set available to economic agents. Thus, the rational expectation of Z_t is the expectation of Z_t implied by the model conditional on the information, Ω_{t-1} available to economic agents at time t-1, ie, $Z_t^e = E(Z_t|\Omega_{t-1})$(Nelson 1975; Wallis 1980). The rational expectation of future price, hence, can be specified as follows:

$$P_t^e = E(P_t|\Omega_{t-1}) \tag{18}$$

Even though rational expectations is apparently plausible and is consistent with the rational behaviour assumption of economic agents, there are some objections. First, it may be unrealistic to assume that agents use all information available. Second, it may be unrealistic to assume that economic agents will use all information intelligently as the hypothesis claims. Third, it is unrealistic to assume that economic agents know with certainty the processes which generate the exogenous variables (In 1994).

To sum up, whether rational expectations will provide a better explanation of observed behaviour than adaptive expectations is still open to question. Some evidence suggests that it does not. Shonkwiler (1982) cited by Knapp (1987) found that the cobweb model performed better than rational expectations models or partial rational expectations model in explaining supply response behaviour in the Florida escarole market. A theoretical analysis developed by Frydman (1982) has also raised doubts about the possibilities of reaching rational expectations equilibrium when individual economic agents must learn the relevant parameter over time. However, Knapp (1987) believes that even if rational expectations is inferior to adaptive (or other) expectations modes in explaining previously observed behaviour, it still has value for forecasting.

PREVIOUS STUDIES ON PERENNIAL CROP SUPPLY

According to Lim (1975) and Askari and Cummings (1976), from the viewpoint of supply models with their endogenous and exogenous components, perennial crops may require special treatment on almost every level of quantitative analysis. The basic reason is a longer time horizon that must be considered by the cultivators of perennial crops. This time element may affect the representation within the supply model of factors such as output, yield, and price expectations, weather and technological inputs, each in different way. Below, some earlier analyses of perennial crops supply will be discussed briefly.

One of the earliest studies of perennial crops supply was conducted by Merril J. Bateman (1965). He developed the supply model of cocoa in Ghana using a dynamic Nerlovian supply model. The Bateman model is respecified in terms of output instead of acreage planted for which the data were not available. In this case, the Bateman model is a function of the average expected future real producer price of cocoa and the average expected future real producer price of the competing crop, coffee. Bateman assumed that expected prices, specified by discounting the value of the expected own- and substitute-prices, will be the major factors in determining the acreage planted rather than yield and cost expectations. However, Lim (1975) stated that the price expectations formation equation implicit in Bateman model is unsatisfactory for several reasons. First, in reality, the relevant prices should cover the entire life-span of the crop while in the formation of price expectations takes place only at the period $t + n$. Second, it suffers from farmer's subjectiveness in determining the rate of discount. Third, the Bateman model lacks flexibility because it is not very responsive to downward movements in the price level.

A similar approach to the study of cocoa supply has been undertaken by Berhman (1968). Unlike the Bateman model, the Berhman model uses desired acreage instead of the planted acreage. In other words, Berhman specified the desired acreage, which is transformed into an output equation because of lack of data, as a function of own and cross prices. The specification of the price expectations term in Berhman model is still Nerlovian even though the constant term includes in the equation. Lim (1975) criticised the Berhman model as having serious estimation problems since it is difficult to separate the influences of the price expectation coefficient and the output adjustment coefficient. Another criticism is that it lacks flexibility for downward movements in the price level.

Another cocoa supply analysis was by Ady (1968) and Stem (1965). Ady's study of cocoa supply follows Bateman and Berhman in which output is a function of lagged prices and lagged output. However, she included a world price term, an index of agronomic factors and an index of other economics factors (Akiyama and Trivedi 1987). Stem (1965), on the other hand, made an advance in analysing cocoa supply. He used the availability of new planting data on cocoa in Nigeria and expressed this as a linear function of lagged cocoa prices. For other nations where no such comparable planting data were available, Stem used a first difference supply model of output as a function of current and lagged own-price.

A more complete model of perennial supply is provided by French and Matthews (1971). Their model is more comprehensive and better specified than the Bateman, Berhman, Ady, or Stern models in specifying the various determinants of the basic producer output decisions. In their model, French and Matthews (1971) tried to explain not only the planting process but also removal and replacement of plants by providing five equations: new planting and replacement model, a combination of new planting and replacement model to give a desired bearing acreage model, yield variation model and a model that specifies the relationship between unobserved expectational variables and observed data. Even though French and Matthews tried to quantify separately the investment and harvest component of the output decision, the effect of harvest and investment decisions could not be separated. The main reason is that they use Ordinary Least Squares (OLS) in which the estimated coefficients could not be used to recover the structural parameters as the model was underidentified (Akiyama and Trivedi 1987). Another criticism is that French and Matthews' model is inflexible (Lim 1975).

Another model that attempted to quantify investment and harvest decisions is developed by Wickens and Greenfield (1973). The Wickens and Greenfield model consists of three structural form equations: a vintage production, investment, and supply response model for Brazilian coffee. A vintage production model is a function that relates to potential output in any year to past investment in trees by a set of constant coefficients. The second equation, an investment model, is derived from a neoclassical adjustment model which gives the standard result that optimal investment will take place at a rate which equates the marginal cost and expected discounted marginal revenue of investment. However, the supply response model or output model depends on potential output (past investment) and harvest decisions which are proxied by a distributed lag on own-price. After developing three structural forms, Wickens and Greenfield (1973) derive a reduced form supply function and estimated this using a generalised Almon lag. However, according to Akiyama and Trivedi (1987), the Wickens and Greenfield approach encounters several problems. First, it is impossible to derive coefficients of the three structural equations from the reduced form. Second, it is difficult to include non-price explanatory variables in the planting equation. Third, the polynomial form used is not necessarily a good approximate of the yield curves of perennial crops. Finally, the sum of the coefficients for actual production in period *t-1* and *t-2* seldom comes close to unity which violates a theoretical constraint on this specification.

Variants of the Wickens and Greenfield model have been widely used, one of which is the study on rubber in Sri Lanka by Hartley, Nerlove, and Peters (1987). The Hartley, *et al* model contains both a replanting equation and a new planting equation corresponding to a single Wickens and Greenfield investment model. The authors concentrated on modelling the uprooting-replanting decision and concluded that for understanding the supply response the trêatment of the relationship between production and the stock of trees was considerably more complex than specified in Wickens and Greenfield model. In addition, the Wickens and Greenfield formulation used for rubber in Sri Lanka yielded results inconsistent with the shape of the age yield profiles estimated directly, suggesting that their approach is not generally applicable and that it is not general (Hartley, *et al* 1987).

Akiyama and Trivedi (1987) estimate supply response of tea for India, Kenya, and Sri Lanka and try to explain why supply elasticities cannot be treated as time-invariant and how the integration of the production and investment decisions of the supplier helps to understand better the supply response in total. Akiyama and Trivedi use the vintage production approach which consists of three structural form equations new planting, replanting or uprooting, and output equation. These structural form equations were estimated individually facilitated by availability of detailed time series data on new plantings, replantings, and uprootings.

A more recent approach has also been used to explain the supply response of perennial crops. This approach is known as the State-Space model. This model provides a methodological approach in which structural estimation of perennial acreage response is possible in the absence of detailed data on new plantings and replanting or uprootings of perennial crops. Several studies on supply response for perennial crops based on the state-space model have been conducted, some of which conducted by Dorfman and Havenner (1991), Knapp and Konyar (1991), and Kalaitzandonakes and Shonkwiler (1992).

Dorfman and Havenner (1991) use a State-Space approach to predict the cyclical patterns which are present in the supply and demand functions of canned California olive. In their study, Dorfman and Havenner demonstrate how the State-Space model can be inserted into the familiar linear quadratic control framework, allowing the supply and demand estimates to be employed in the determination of optimal inventory levels for canned Californian olives. The supply model is formulated based on five sizes of canned olives used by the Californian olive industry. Thus, supply is modelled as the joint production of five varieties of canned olives.

As other State-Space models applied in system theory, the physical science and engineering, the supply model in state-space form used by Dorfman and Havenner (1991) consists of two matrix equations: observation or measurement and transition equation. These equations are:

$$z_{t+1|t} = A_s z_{t|t-1} + B_s e_t \qquad (19)$$

$$y_t = C_s z_{t|t-1} + e_t \qquad (20)$$

where equation (19) represents the transition equation and equation (20) is measurement equation. y_t is a (5 x 1)vector of the supply of the five sizes of canned olives in year *t*, $z_{t|t-1}$ is a (5 x 1) vector of conditional means of the states, or minimal sufficient statistics for the past history of the series y_t, e_t is a (5 x1) vector of stochastic innovations assumed equal to a zero mean and the matrices *A*, *B* and *C* are parameters to be estimated. In order to estimate the model coefficients, Dorfman and Havenner (1991) use the Hankel matrix method.

However, Knapp and Konyar (1991) use the State-Space model to analyse the supply response of California Alfalfa constrained by the limited data on new planting, removals and area in individual age groups. A State-Space approach and Kalman Filter are used to estimate the structural model including the age distribution effect in separate new planting and replanting, and age-group dynamics. Under naive price and cost expectations, the result of Knapp and Konyar study is that the estimated model provides a reasonable fit to the data, the correct signs were obtained and price coefficients are generally statistically significant. They conclude that this method is also applicable in other areas when only age-aggregated data is available.

Similar to Knapp and Konyar study, Kalaitzandonakes and Shonkwiler (1992) encounter limited detailed data on new planting and replanting when they want to estimate the new planting and replanting equation for Florida grapefruit separately. They also propose the State-Space model that allows structural estimation of systems with unobserved variables. Kalaitzandonakes and Shonkwiler (1992) note that the application of this approach gave results superior to those obtained from a single-equation reduced form specification both statistical and forecasting performance.

Kalaitzandonakes and Shonkwiler (1992) begin their study by specifying supply model for Florida grapefruit using state-space model. This model consists of an unobserved and observed model. The unobserved model, which corresponds to replanting and new planting, is specified as:

$$x_t = \Phi x_{t-1} + \gamma z_t + v_t \qquad (21)$$

where vector z_t is an observable and exogenous to the dynamic system. v_t is error term. In determining observed equation which corresponds to total planting, Kalaitzandonakes and Shonkwiler (1992) assume that total plantings, y_t , are measured without error. Thus, the total planting model is given by:

$$y_t = \alpha x_t \qquad (22)$$

Because the sum of replantings and new plantings equals total planting, equation (22) can be rewritten as:

$$y_t = \begin{bmatrix}1 & 1\end{bmatrix} x_t \qquad (23)$$

where $\begin{bmatrix}1 & 1\end{bmatrix}$ is a (1 x 2) vector of ones. Then, by assuming that initial state x_0 and disturbance, v_t, are normally distributed, specification model (21) and (23) are estimated by using the logarithmic likelihood function as follows:

$$L = constant - \frac{1}{2}\sum_{t=1}^{T}(\ln|H_t| + \eta_t H_t^{-1}\eta_t) \qquad (24)$$

where η_t denotes the innovations in y_t, ie., $\eta_t = y_t - E[y_t | y_{t-1}, y_{t-2}, \ldots z_t, z_{t-1}, \ldots]$ and H_t denotes their covariance. Innovations η_t and their covariance matrix H_t are then obtained by using the Kalman Filter. In addition, Kalaitzandonakes and Shonkwiler (1992) argue that the initial state x_0 can also be assumed to be deterministic in which an estimator not based on the Kalman Filter may be obtained. A reduced form of the state-space model can be derived by repeated substitution of (21) in (23). In this case, y_t is expressed in terms of the observable x_0 and z_t as:

$$y_t = \alpha\Phi^t x_0 + \alpha\sum_{j=1}^{t} \Phi^{t-j}\gamma_{z_j} + \alpha\sum_{j=1}^{t} \Phi^{t-j} v_j \qquad (25)$$

According to Kalaitzandonakes and Shonkwiler (1992), this system can be directly estimated through maximum likelihood or through the General Least Squares formulation as proposed by Rosenberg (1973).

CONCLUSION.

So far, the two main theories explaining agricultural supply, the static and dynamic supply theory, have been reviewed. Even though constraining by its timeless and perfect certainty assumption, the static supply theory is useful to explain the farmers behaviour in agricultural supply in the short run. On the other hand, the dynamic supply theory is required to explain a complex phenomena of agricultural product offered for sale in the market. The dynamic supply theory considers time and uncertainty associated with expectation in analysing agricultural supply. This chapter also reviews the formation of price expectation whether naive, extrapolative, adaptive, and rational expectations.

The application of dynamic supply theory on the perennial crops has also been summarised briefly. From the discussion above, it can be summed up that the literature on perennial crop supply has developed. Bateman, Berhman, Ady, and among others have developed an agricultural supply model based on a single equation regression model for either aggregate output, aggregate acreage, or changes in these variables. Akiyama and Trivedi, and Hartley, Nerlove, and Peters have also provided separate estimation of new planting and replanting equations. These studies are based on the availability of detailed data on new planting, replanting, and age distribution.

Furthermore, the recent studies on perennial crop supply is estimating new planting and replanting model based on limitation of detailed data on replanting, replanting, or distributed age-groups. Some of which are study by Dorfman and Havenner for canned California olives, Knapp and Konyar for California alfalfa, and Kalaitzandonakes and Shonkwiler for Florida grapefruit industry. Thus, with the limitation detailed data palm oil, it is interesting to analyse supply response of Indonesian palm oil by estimating replanting and new planting separately as outlined by Kalaitzandonakes and Shonkwiler (1992). However, the problem using Kalitzandonakes and Shonkwiler model remains on the unavailability data of total planting.

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