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THE IMPACT OF PRICES AND TECHNOLOGY ON THE REPLANTING OF PERENNIAL CROPS

by

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1 Introduction

The production and supply of perennial crops has been subject of many studies, all aiming at developing a model that integrates the short and long run considerations in a way that is both consistent with microeconomic theory and allows empirical verification of the resulting supply functions. Supply responses can be split into short run and long run responses. Short run responses are defined as changes in supply from a fixed stock of capital in the form of trees etc.; long run responses include changes in capacity. These long run considerations are more complicated. The complications arise from the necessity to make assumptions on how the agent includes his expected future earnings into his decision making process. In this paper, we discuss the issue of replanting of rubber trees in India in the light of the theory. In Section 2 earlier analytical efforts for various crops will be reviewed. In Section 3 we derive a framework for modelling and estimating the equations for replanting; in Section 4 we present the data and the results.

2 Survey of the literature

Central issues in the theory of replanting of perennial crops are: *expectations formation, present value calculations, trade-off between future and present income and trade-off between asset value change and income*. The first two points deal with the 'calculation' of future earnings, and their aggregation over time; the latter two points are important for the trade-off between present and future earnings.

a. expectations

"If it is impossible to make an even informed guess about the future, decision-makers are not likely to waste much effort in doing so - nor should we expect them to behave as though they did", said BERRY (1976, p. 10). Her argument is that producers face a host of uncertainties, not just prices, but also yields, exchange rates, wages, inflation, and the government. In her view, the present is of overwhelming importance and newplantings (of cocoa in her case) are mainly induced by changes in liquidity and opportunity costs.

Nevertheless all other literature has been built on the assumption that expectations do play a role, if only in order to add up the future. Theory is not able to do without, as the decision to plant has a meaning only if we consider the future. But no study of perennial crop supply has explicitly questioned the farmers on their expectations and all assume some relationship to exist between prices in the near past and present and those expected to prevail in the future. Thus, most authors assume the adaptive expectations formation. It was used by HARTLEY et al. (1987) (henceforth HNKP); FRENCH AND MATTHEWS (1971) used last year's prices, just as TRIVEDI (1992) and BATEMAN (1969); WICKENS and GREENFIELD (1973), ETHERINGTON and JAYASURIYA (1977) (EJ), AKIYAMA and TRIVEDI (1987), DORFMAN and HEIEN (1989) (DH), FRENCH, KING and MINAMY(1985) (FKM) and KALAITZADONAKES and SHONKWILER (1992) use average values of prices, of returns

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or of present values of the last four to eight years. SMITH and WETZSTEIN (1992) (SW) use cyclical patterns in weekly prices repeated over the years.

Their treatment of expectations is unsatisfactory as it obscures the effects of the present prices on the one hand (high present prices induce postponement of uprooting in view of present income opportunities) and the expected prices on the other hand (high expected prices induce replanting). Nerlove, in 1983, reports that adaptive expectations, in the form of an 'error-learning model' are a good approximation of actually reported expectations, but his application was to categorical data ("the future will be worse, equal or better") only.

b. present-value calculations

Most, if not all authors indicate that a major component in the decision procedure should be the Net Present Value (NPV) of the (expected) future income stream. They have worked this out in various ways. In the considerations the yield profile is important: what yields are to be expected, and in which years. The NPV, with a suitable discount factor (all authors use current interest rates), indicates the present value of the project. It can be thought of as being equal to the price one would get in case of sale of the rights to this future stream of income. This presumes the stream to be certain. DH investigate the effects of uncertainty: they include the variance as additional term, and surprisingly, find this to have a positive influence on newplanting. A complicating factor in this regard is that income consists of a price and a quantity; future prices in most cases are more uncertain than future quantities. SW include risk aversion using the variance of expected returns in their analysis based on weekly data of replacement/rejuvenation of laying hens. Risk-averse producers should consider less rejuvenation and replacement should occur later in the year.

An important issue is what time-frame to use. All authors use only one cycle as the appropriate time-frame (with some qualifications only in the case of FKM who consider total present stand of trees). It seems more acceptable to assume, that if one considers growing the crop, one will replant at the time that is now seen as the most advantageous and tone will continue doing so in all future cycles. Thus if the optimal year of replanting would be year T, then the NPV of this T-year period can be calculated. To convert this into the NPV of an everlasting series of T-year cycles, this must be multiplied by a factor equal to $1/[1-1/(1+r)^T]$. EJ also mention such but do not operationalize it as they run their analysis for selected combinations of fixed T and fixed technologies. To derive which T is optimal, yielding the highest NPV of an infinite number of cycles, define $NPV_{1,T}$ as the Net Present Value of 1 cycle of T years duration,

$$NPV_{1,t} = \sum_{t=0} \frac{Y_t}{(1+r)^t}$$

where Y_t is net revenues. $NPV_{inf,T}$ is the NPV of an infinite number of these cycles

$$NPV_{inf,T} = \frac{NPV_{1,T}}{1-\frac{1}{(1+r)^T}}$$

and a cycle of T years is preferred to one of T-1 years if

$NPV_{inf,T} > NPV_{inf,T-1}$, so if $Y_T > r.NPV_{inf,T}$.

In words, if net revenues in year T are higher than the discount factor times the NPV of an infinite repetition of T years duration, then T is preferred over T-1. If the discount factor is equal to the interest rate, then the condition says that if income is higher than the interest over the asset value of a new investment, this should be postponed by at least one year.

With the length of the cycle thus determined (assuming it to be constant from one cycle to the other) it is possible to calculate what the NPV is of new planting one hectare, if data are available to formulate the expectations on yields, costs and prices. The applications cited above do consider the yield profile, and often calculate, with some assumptions, the NPV of only one cycle.

In the case of natural rubber the above approach can be particularly useful, for it allows the introduction of yields that may vary with the length of the cycle. High tapping intensity leads to high bark consumption per year and the tapper returns to the original bark for a new round after a shorter period of time, causing yields of the renewed bark at that time to be lower. Normally no more than the second renewed bark can be tapped implying that trees are sooner due for replanting. Thus choosing a higher tapping intensity and therefore a lower level of T, shifts income from the future to the present. With sufficiently high discount factors, such series of short duration, high income cycles, can very well be preferred to lower income, long duration cycles. The applications cited above, do not consider such differences, with the exception of GERSOVITZ (1992), but, by completing a short cycle with years of off-farm work, he applies an incorrect mechanism to account for the differences in duration.

c. trade-off between future and present income

Decisions on replanting are assumed to be made each year. The formal rule would be equal to the one employed above: postpone replanting when income is higher than the interest over the NPV. But then, the income is (almost) certain, whereas the interest on the NPV is just one way of calculating the value of a highly uncertain future. Farmers would neither 'know' their discount factor nor the prices that will prevail in the future nor the level and pattern of future yields. As the calculated NPV is very sensitive to these three variables, it is unlikely that a calculated NPV adequately represents all farmers' perceptions of the future. And as they must certainly invest before they can reap uncertain benefits, it is clear that short term incentives such as those provided by replanting subsidies can have great impact. If the costs are reduced, then the potential losses are much less, as in the worst case the trees can be uprooted and replaced by a profitable annual crop without sizeable debts. Besides the choice for an annual crop is relatively save, and can be changed from one year to another. To tilt the balance in favour of a long term decision such as planting a perennial crop, it is required that no attractive alternative is available. Some authors do consider alternatives. BATEMAN for example includes coffee prices in his analysis of replanting of cocoa. Annual crops are not considered as relevant alternatives in the literature.

All authors find a strong influence of recent events, or of measures that apply to the near future. Thus a positive impact of subsidies can easily be found (HNKP, AT) and, after recalculating the investment equation into its effect on production, the impact of current prices appears very strong: people apparently take recent prices as indicative of future prices. TRIVEDI finds a negative impact of previous year's prices, combined with a positive sign for the expected revenues (based on last years' revenues).

The age of the farmer is important when deciding on planting rubber. Older farmers are in many cases not likely to place high value on future expected income, whereas young farmers may be more concerned. For middle aged persons, investment in rubber can promise them income that can be obtained without much family labour and thus may suit them very well when they reach old age. Such would imply lower discount factors for young and middle aged than for old growers. The articles mentioned above do not, however, distinguish discount factors, that vary with the age of the farmer.

d. trade-off between asset value change and income

We have seen above that, for rubber to be adopted, the NPV should be positive, and the alternative current income should be less than the interest over the NPV. Further, the NPV of growing rubber should also be higher than any other feasible investment alternative, i.e. the NPVs of other projects should be less. In particular, if a farmer, because of skills, discount factor, family composition, suitability of land, climate, marketing opportunities etc. is inclined towards perennial crops rather that a series of annual crops, then this farmer might consider investing in rubber, but also in e.g. coconut. The NPV of a coconut plantation should be calculated in the same way as the NPV of rubber in order to make the comparison. Thus, a rubber grower will favourably consider replanting with rubber, if:

- his present income is less than the interest over the NPV of replanting; and
- the NPV of his present stand is less than the NPV of a new stand.

The second requirement implies that farmers with immature rubber will not start new planting: the NPV of their current stand is naturally higher than the NPV of a new plantation, unless there has been a strong increase in technical progress since planting the current stand. The decisions implied by the two requirements do not coincide: the difference in NPVs may induce replanting, but this will not be done if current income happens to be high in a particular year. Similarly, income may occasionally fall below the level indicated by r*NPV of new planting, but the difference in NPVs does not make new planting attractive. The decision depends crucially on the discount factor used, and on the expected prices. High current prices may also increase the NPV of the current stand because of price expectations.

3 Modelling the replanting decision: theory with an example for peaches

The derivations of theoretical investment models are usually based on intertemporal optimisation, and on many occasions, notably by TRIVEDI and AKIYAMA & TRIVEDI, reference is made to NICKELL'S (1978) work on investment when adjustment costs are involved. Under quite stringent assumptions, including quadratic adjustment cost functions (more acres to be uprooted and replanted require quadratically increasing amounts of money), NICKELL showed that investment functions could be derived that are linear in the price of the commodity. The models also assume, in common with many models of the seventies, that adjustments are made towards a 'desired' stock, leaving aside what exactly is 'desired', but assuming this to move up and down with expected prices.

TRIVEDI took a general basis for his theoretical approach by stating that Marginal Expected Revenues (of the investment) should equal Marginal Costs of Investment. He then moves on to clarify which items should be in the left hand side or right hand side of this equation now these, can be approximated by observable variables, and so derives his estimating equation. The use of 'marginal' in the assumed start of the derivation is cumbersome. As all models are meant for the representative farmer, and therefore aggregate, it implies that the average farmer should experience increasing marginal costs in planting or replanting rubber trees. This is not likely to be the case at the micro-level. At the national level, 'marginal' can refer to the farmers (say those in non-traditional areas) who just manage to grow rubber in a profitable manner, so that rubber just marginally scores better than another crop. For an analysis of replanting, which is mainly done by traditional farmers, who sometimes quite profitably grow rubber, such 'marginal' analysis is not adequate.

Yet, the starting point should be a comparison of benefits and costs. On the benefits side, we put the (expected) net returns of replanting rubber, on the (opportunity) costs side we have the (expected) net returns to an alternative use of the resources. These resources can be land, family labour and money. Growing rubber on a hectare of land yields an income stream which is usually negative in early years, compensated by positive returns later. To compare the future stream of income with current income, the NPV can be used, but the two are not really directly comparable, as they cannot normally be traded. Let the agent have a utility function U, which has two arguments, present and future income,

U = U(Y, F); Y is income at present, F is 'future income'.

To represent future income, we use the net present value, and the discount factor that is used represents the weight that the agent attaches to the future years. As the future is uncertain, the NPV with some discount factor cannot directly be taken to be comparable with present certain income. Formulated in this way, discounting the uncertain future, from year 2 onwards, can be based on another discount factor than would be used to make the certainty-equivalent future comparable to the present. This distinction is introduced by ATTANASIO & WEBER (1988).

If growing rubber has an NPV of N, and allows him a current income of Y, and net income from other uses of the hectare of land would be V, allowing for an asset value of M, then the agent would choose rubber only if U(Y, N) $>$ U(V, M). Our particular application for the formula would be to consider replanting one hectare of rubber, giving the farmer a negative income from this hectare in the current year, compensated by a high NPV of the new rubber plantation; these benefits may be compared with those resulting from continuing tapping his stand of rubber trees for one more year.

On the left hand side we would have U[-C,N(1)], with C being the costs incurred in the first year, and N(1) the NPV of one hectare of rubber to be replanted at the optimal time of T, calculated at the end of year 1; the relation between N(1) and N(0) is that N(1) = (1+r)*(N(0)-+C). As the costs C have already been made by year 1, the NPV(1) should be higher by this amount. For profitable undertakings the difference will be greater than the costs C. On the right hand side, V is the income from continuing tapping this year, and equal to yield(i)*price(t)-costs(t). M is the NPV of a rubber stand at the end of the year, so at age i+1, to be written as N(i+1). To make the NPVs of the right hand side and the left hand side comparable we incorporate the assumption that the present rubber crop will be followed by rubber in the future at the optimal time of T, if $T>i$. If $T<i$ (and replanting should have been done earlier if prices would have been as assumed for the future), the asset value of the stand should be equal to the NPV at age zero N(0), as this is one of the possibilities for the land after this year.

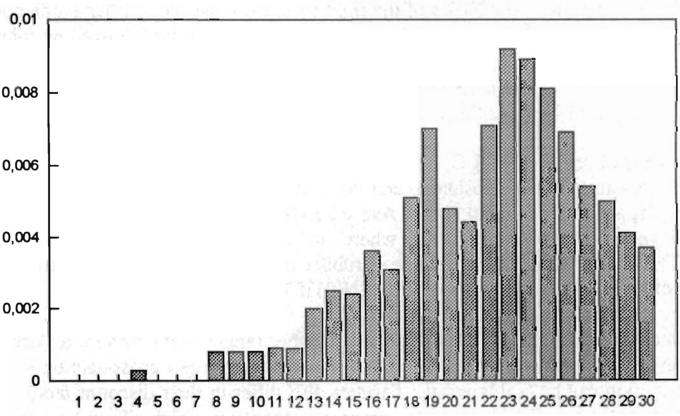
So we have as benefits of replanting U[-C, N(1)], where C are the costs in the first year (costs of uprooting and replanting, minus subsidies), and N(1) the NPV of one hectare of one year old, to be replanted again at the optimal age T. And we have as benefits of continuing tapping when trees are i years old U[Y(i), N(i+1)], where net income Y(i) are yield(i)*price(t)-costs(t,i), and N(i+1) is the NPV of one hectare of rubber of i+1 years old, to be followed by rubber at the age of T, if $T>i$, and N(i+1) is equal to N(0) if $T<i$.

For the aggregate analysis, the set of farmers growing rubber ranges from starters to farmers with very old trees. Planting shows large changes over time, so that in a cross-section in any year, the age distribution can be highly erratic. Farmers also differ in their discount factor and may differ in the alternatives available to them: perennials (coconut, palm oil etc.) or annual crops. In addition, yields will also depend on characteristics of the farm(er) like tapping skills, soil quality, use of fertilizer, stimulants etc. This means that in any age class i, for some particular year t, some farmers may decide to uproot their trees and replant the area, some may decide to uproot and find another use of the land, and some may decide to continue tapping (or at least continue growing rubber). If rubber prices move up, compared to other crops, the third group will increase, the middle group will fall and the first group will probably decrease, depending on the distribution of the discount factors.

FRENCH, KING and MINAMI present data on the removals of peach trees by age of the trees. Percentages removed are not limited to some age groups, but can be found in all groups. At young ages, the percentages first increase, then level off at the age of about 20 years. The normal lifetime for commercial peach trees is approximately 20 years. FKM have tried to establish relationships that explain how the percentage removed in each age class responds to changes in current prices (actually they used last year's revenues). At all age groups beyond a certain minimum, they found significant influences, all negative, indicating that removals are responsive to current incomes. In their application, most removals were followed by new plantings, so that the actual decision was not so much to remove the trees, but rather to plant young trees. No effects of future oriented aggregates like NPVs were reported by them. The price responsive coefficients for each age group were not equal. Figure 1 shows their distribution. The effect of income changes can be seen to increase from nil at age 0 to its maximum at the normal discarding age of around 20 years.

Our analysis above provides an explanation for both these phenomena. The attractiveness of removing trees of age i can be measured by the value of U[Y,N(i+1)], which includes current income Y and end-of-year asset value N(i+1) at age i. The higher this value, the less attractive removing will be. The effect of a change in price would be to increase Y directly, and to increase N(i+1) indirectly through its effect on the expected price in the near future. If i increases, then beyond some age (about 10 years old), N(i+1) will decrease, and so the indirect effects of changes in price on the value of U[Y,N(i+1)] will diminish. At some higher age (about 20 years old), the value of N(i+1) will no longer exceed the NPV of new planting, so that, in stead of N(i+1) we have N(0) as the second argument. At this point, the indirect effect of price changes through the asset value change will no longer change with age, but be the same for all age groups beyond this point.

Figure 1: Effect of returns (t-1) on removals (negative response coefficients)

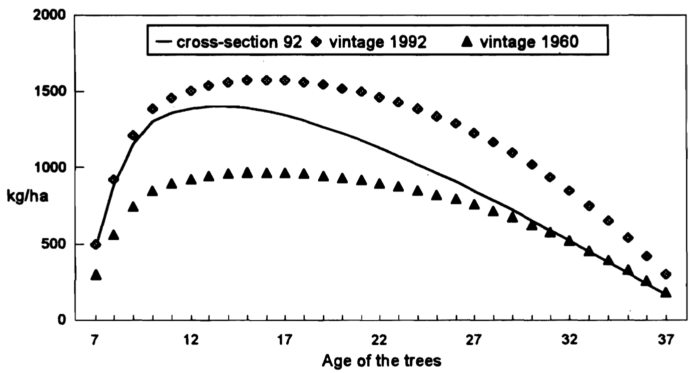


Source: French, King and Minami (1985)

4 Empirical implementation for natural rubber in India

The analysis is based on the vintage approach as described in BURGER and SMIT (forthcoming). Data for the empirical analysis of replanting behaviour come from the survey held by the Rubber Board of India and are described in BURGER et al. (1995). Yield curves are modelled to move upwards proportionately as resulting from technology at the year of planting. Results are as shown in Figure 2.

Figure 2: Yield profiles of two vintages, and cross-section estimate



The next step was to use the estimated number of tapping days, and the resulting yield to calculate the monetary returns per hectare. Gross returns are yields*price-days*wage. In addition, we used the replanting subsidies as given over the years. Direct costs involved in establishing an hectare of rubber can be divided over the first seven years after planting. The cost of tapping rubber can be put equal to the cost of the tapper. For earlier years, figures for costs and wages have been adjusted by the inflation rates.

Figure 3 shows the optimal timing of replanting over time based on two assumptions about expectations formation: one is that future price are equal to current prices; this leads to the smoother pattern. The other assumption is that future prices are equal to the average real price of Rs 30 per kg.

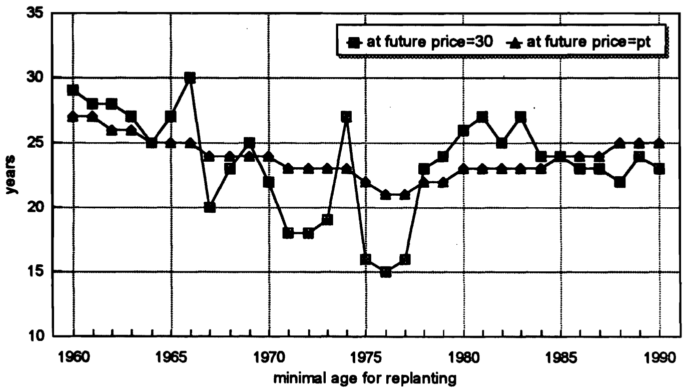
If farmers expect that prices in the future will not be as high as present prices, then replanting is postponed. This is confirmed in a regression analysis where discarding percentages (area discarded at a certain age, divided by the existing area at the start of the year in that age group) are explained from income over NPV. The analysis has been restricted to plots that were over 15 years old. The estimated equation for the share that is discarded at age *k* in year *t* is:

$$\text{Share}(t,k) = 0.41 - \underset{(8.7)}{7.72} * \text{income}(t,k)/\text{NPV}(t,0)$$

R^2=0.14; n=481,

where income is yield(t,k)*price(t)-wage(t)*days(t,k) at this age, and at current real prices, and NPV($t,0$) is the NPV at age 0 in year t (and of vintage t, therefore). The low value for the R^2 of this equation is due to the large number of zero observations. Significantly negative is the impact of current income on replanted shares. The data base for this estimation is, however, weak as inferences about the past had to be made from scanty material on timing of replanting in the past.

Figure 3: Optimal replanting age



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