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# On Understanding Investment Behavior in Perennial Crops Production

P. K. Trivedi

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# ON UNDERSTANDING INVESTMENT BEHAVIOR IN PERENNIAL CROPS PRODUCTION

P.K. Trivedi
(Consultant)

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## TABLE OF CONTENTS



Table



Figure

## PREFACE

The supply behavior of the producers of perennials has long been recognized as a complex, multifaceted problem in agricultural development economics. In particular, an understanding of new planting and replanting decisions facing producers is of key importance in determining the long-term response of perennial producers to changes in incentives and in accounting for observed country differences in the patterns of agricultural development and growth. Such an understanding requires a comprehensive analytical framework within which one can examine producers' short-run decisions, such as the utilization of factor inputs, and long-term decisions, such as the choice of technology and the level of investment. The interrelatedness of producers' decisions is the principal subject matter of this paper and these interrelationships are discussed within the context of a comprehensive framework. This discussion is preceded by a brief account of some positive and normative issues related to investment and followed by some empirical examples, drawn from studies of tea growing in Sri Lanka and Kenya, which illustrate the diverse mechanisms determining investment responses.

Perennial crop production is important in many developing countries. Therefore, much of the advice to developing country policymakers by World Bank staff and much of the project appraisal work done in the Bank is concerned with the behavior of investment in perennial crop production. It is hoped that this paper will provide Bank staff with an enhanced view of the processes underlying investment in perennial crop production and lead in turn to improved understanding of the impact of policy changes and new technology on investment and production in these industries.

Ronald C. Duncan
Chief
International Commodity Markets Division
International Economics Department

# I. INTRODUCTION

1. The supply behavior of the producers of perennial crops is an important and complex multifaceted issue in agricultural development economics. Its importance stems from the dominance of perennial tree crops, such as cocoa, coconut, coffee, rubber, palm oil and tea, in the economies of many developing countries. The complexity is a consequence of the overwhelming importance of expectational factors arising from the intricate dynamic interdependence between the production and investment decisions of the supplier and from the dynamic structure of the production process which is characterized by long gestation lags. Questions concerning the effects of subsidies, grants, cesses and export taxes loom large in appraisals of the performance of tree-crop projects, but no clear consensus exists about their effects. Partly this may be due to the absence of a suitable theoretical framework for analysis and of relevant data to test the validity of the framework; but it is also due to wide differences within and between regions in the conditions confronting individual sectors. It is a challenge to demonstrate the operation and the effects of economic mechanisms on production processes after properly taking into account the differences of institutions and natural endowments.

2. The patterns of development in perennials show considerable diversity, both between crops and regions. Later in the paper we shall consider examples of successful growth and expansion of a tree-crop sector in one region while the same sector stagnated in another region, and examples of expansion in production arising principally from increases in yields in one subsector at the same time as another subsector was registering increases in

production largely by area expansion. Since the regions generally differ considerably not only in terms of factor endowments, the level of development of the "tree-crop" sector, the organization of production and in the nature and extent of government policies toward these sectors, the task of unraveling the role of various factors in the growth process is complex.

3. In considering the price-mediated changes, a helpful distinction is between the role of "visible" prices and that of "invisible" prices [Nerlove (1979)]. The former includes net real factor and product prices which determine both actual and expected profitability of production. Though much empirical work on perennial supply response has been concerned with the effects of "visible" prices, "invisible" prices may have a very large role in causing shifts in the short-run supply relationship because that category includes prices which can be changed by various forms of government intervention such as provision of public inputs, e.g., transport and communication, irrigation, education, health and extension services. While both kinds of prices affect actual and perceived profitability of production, and hence are potentially relevant in explaining growth patterns, a careful study of the role of "invisible" prices necessarily involves a study of the organization of production and institutions. If these considerations are neglected, an incorrect inference may be drawn about the role of price incentives in perennial production.

4. An understanding of the determinants of new planting and replanting investment decisions of the producer is of key importance 1/ when trying to

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1/ Distinction is drawn throughout the paper between investment decisions at the extensive and intensive margins. The former involves new planting, uprooting and replanting, whereas the latter involves infilling and changes in the utilization levels of fixed inputs.

account for the observed differences in the patterns of development and change. This requires a comprehensive analytical framework within which one can examine producers' short-run decisions, such as the utilization of factor inputs, as well as long-term decisions such as the choice of technology and the level of new planting and replanting. The interrelatedness of the producer's decisions constitutes the principal subject matter of the paper, but we begin with a brief discussion of some positive and normative issues related to the process of investment.

## II. INVESTMENT BEHAVIOR AND LONG-TERM SUPPLY RESPONSE

5. Conventionally, and somewhat arbitrarily, a distinction is drawn between the short-run producer decision regarding the intensity of use of variable inputs for given quantities of fixed inputs and technical conditions of production and the longer-term decision involving the quantities of fixed factors and the choice of technique of production. The supply response in the former case is measured by the short-run supply elasticity, holding constant the capital input. The typically larger long-term elasticity is the sum of the short-run elasticity and the elasticity of capital stock with respect to the output price multiplied by the elasticity of supply with respect to the capital stock [Binswanger et al. (1985)]. The latter is usually neglected in empirical work when the focus is on short-run output and price determination. However, the short-run supply function, being indexed by quantities of fixed factors, shifts as these factors undergo adjustment in response to changes in the long-term profitability of the crop. To separate the short- and long-run responses, or to produce estimates of long-run supply elasticity, a model of the adjustment of cropped area to variations in profitability is required. Empirical studies which model supply as a long distributed lag on prices without explicitly modeling the adjustment of fixed inputs will confound short- and long-run responses. In any case, an attempt to measure the long-run supply elasticity is not meaningful unless it can be shown that the capital stock adjusts in a determinate manner.

6. In dealing with perennial crops an allowance must be made for the heterogeneity of capital. From a priori considerations alone it is not clear that there will always exist a heterogeneous capital stock of unique

composition corresponding to a given configuration of prices. If this is not the case, long-run supply elasticity is not a well-defined concept. The relationship between investment and output prices is essential for estimating the long-term supply elasticity, if that concept is to be meaningful. To some extent, such a relationship subsumes within it the choice of technique of production. This should be especially obvious in cases where technical change is of the embodied variety, as in the case of high-yielding varieties, so that it cannot be implemented without investment. Moreover, an understanding of the process of diffusion of technological change and of investment are closely related.

(i) The Impact of Subsidies and Taxes

7. A major channel of influence of government on supply behavior is by means of subsidies and taxes on producers. Many countries have used subsidies for new planting, replanting and infilling to stimulate stagnant tree-crop sectors, especially the smallholder subsector. Sri Lanka and Thailand are two examples of countries where tree sectors have stagnated or declined. Though the precise reasons for this behavior are unclear, candidates include such factors as the perceived reduction in the expected profitability of production brought about by, inter alia, aging capital stock with declining productivity and "overtaxation" of sales revenues. To arrest or reverse the decline some countries have erected an extensive structure of subsidies and grants. In part, these are sometimes justified by arguing that they counteract the disincentive effects of export taxes on which some countries rely heavily. Another justification is that cash subsidies enable credit-constrained smallholders to expand production, and perhaps to adopt new and, from a

longer-term viewpoint, more profitable technologies, and to generally respond more fully to market opportunities. The appropriate structure of such tax-subsidy schemes will remain a bone of contention in the absence of detailed region- and crop-specific empirical information about their effects on producers' choices and actions. Moreover, such policies have potentially distortionary effects on producers' choices which are as yet poorly understood. By changing the relative costs and benefits of adjustment at the intensive and extensive margins, and by changing the relative profitability of alternative crops, such policies potentially influence long-term supply responses. Their actual effects are likely to depend upon various factors, including the degree of commitment to the policies as judged by the producers and the distributional effects on the producers, both of which are likely to vary considerably from region to region. As Nerlove has remarked:

> "...Because of the inevitable tendency of governments to interfere with markets and prices, however, the problems of untangling supply responses are made doubly difficult. In the short run price uncertainties may be reduced by such interventions, but reduced uncertainty is not at all clear in the long run. Uncertainty with respect to the behavior of government may be far greater than uncertainties with respect to the behavior of weather and markets. Supply response occurs in a complex and interrelated system of which government is one element. Prices and other factors such as those discussed above affect not only farm people but also numerous other institutions related to agriculture and agricultural development. The

dynamics of supply in developing countries and in agriculture in the process of transformation cannot be fully understood without taking these complex interrelationships into account."

(ii) Organization of Production

8. In conventional theoretical discussions of perennials, little attention is paid to the role played by the type of organization under which production occurs. On the other hand, in applied work a distinction is usually drawn between the economic behavior of large government or private estates and smallholders. Such a distinction is useful for there are often large differences between regions and crops in the dominant form of organization in production. The distinction has content since it is plausible that although both estates and smallholders have similar economic objectives, say maximization of net worth, the two might face rather different constraints. For example, credit market opportunities may be more limited for smallholders, and if they are dependent on family labor they may face less stringent labor market constraints. Further, estates being much more geared to large-scale production may face different adjustment costs from small producers and hence may react to market signals in a manner different from the smallholders. As an illustration, it has been observed that since 1969 the major source of growth in tea production on estates in Kenya has been a higher average yield per hectare, whereas in the smallholder sector the growth has been largely accounted for by an increase in the cropped area. Such observations strongly suggest that an exploration of the interactions between alternative forms of production organization, opportunity and constraint sets, and investment and supply decisions will aid an understanding of the dynamic process of transformation and change in agricultural development.

(iii) The Role of Institutional Factors

9. The influence of public as opposed to private inputs into the production process is now widely emphasized [Binswanger et al. (1985)]. Nerlove (1979) has discussed changes in "invisible" prices brought about by government intervention. Such changes, in combination with institutional innovations initiated by producers themselves, e.g., producer cooperatives, affect the perceived profitability of crops--in fact, that may be overlooked in a preoccupation with the role of "visible" prices on producer decisions. It is a stylized empirical fact that the short-term supply response of perennials is quite small. Whereas the "visible" prices have a role in explaining movements along the short-run supply curve, the role of "invisible" prices in determining the suppliers' new planting decisions remains to be investigated. Scattered evidence [e.g., Binswanger et al. (1985)] suggests that movements in "invisible" prices may in some cases provide a large part of the total explanation of observed change. An example of this is the growth in the participation of smallholders in Kenya tea production. Before 1960 their role was very limited, but there was an almost sevenfold increase in their production between 1960 and 1980--a growth performance not unrelated to the setting up of the Kenya Tea Development Authority (KTDA), an institution largely responsible for the smallholder participation in the tea sector in Kenya. 1/ In his study of smallholder tea production in Kenya, Etherington (1972) attached overwhelming importance to the removal of legal and other restrictions to the participation of smallholders in tea production and minor

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1/ See Lamb and Muller (1982) for an account of the role of KTDA in promoting the growth of smallholder tea planting in Kenya.

importance to variations in (visible) prices. "Invisible" prices may strongly influence the smallholder's investment decisions if they face powerful legal, informational and capital market impediments to their entry into, and subsequent successful operation in, markets for perennial crops.

## III. ANALYTICAL FRAMEWORK

10. Investment represents producers' demands for additional productive capacity to bridge the gap between the amount they would like to supply, given their expectations about future profitability, and the feasible level of production given their existing capital stocks. So a satisfactory model of investment behavior for perennial crops should be based on an integrated theory of factor demands and production which can display interrelationships between the variables that jointly determine the planned productive capacity. Planned productive capacity, also referred to as potential output, should be distinguished from feasible output. The latter is a vague concept, being analogous to the maximum attainable output. If the age-yield profile was essentially biologically determined, 1/ the concept of maximum attainable output would make sense. But usually it is not, since yields respond to factor inputs which in turn are responsive to market prices. Potential output is the level of output which is attainable by optimal profit-maximizing combination of fixed and variable inputs, given output prices. The theoretical possibility and empirical fact that producers find it optimal to adjust their potential output in different ways, operating either at the extensive or intensive margins depending upon their initial situation and future expectations, is the key to understanding their investment behavior.

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1/ A slightly different concept of "potential output" has been found useful in empirical work of Akiyama and Bowers (1982), and Hartley, Nerlove and Peters (1985). Their measure is calculated by weighting cropped areas by the average or normal yield of trees of a given maturity. The age-yield profile used should be interpreted as average values obtainable when "normal" levels of inputs are applied. Optimal input levels will vary with producer prices.

11. The most widely used model for studying perennial crop response is an adaptation of the Nerlovian supply model [Nerlove (1958)]. This framework is now regarded as unsatisfactory because it lacks an explicit dynamic optimization framework [Nerlove (1979)]. The limitation is serious because supply theory for perennials is intrinsically dynamic in the sense that: (a) there exists a biologically-determined (often rather long) gestation lag between planting and obtaining yield--a feature which induces forward-looking behavior on the part of suppliers, causing them to act on the basis of considerations of expected profitability several years after the planting decision; (b) the production process itself has dynamic features, such as the dependence between current inputs and future outputs, which are inadequately captured by the standard static production function; and (c) significant adjustment costs in the investment and divestment process will typically restrict the rate of adjustment of planned area and cause the current decisions to be constrained by past decisions.

12. An additional complication arises from the heterogeneous nature of capital. The productivity of yield-bearing trees for any given level of inputs has, in many cases, a biologically-determined life cycle. Trees of different maturities, i.e., different vintages or age-cohorts, constitute nonmalleable heterogeneous capital goods. This has two implications. First, heterogeneity leads to the possibility of capital-capital substitution in production, in addition to the usual capital-labor substitution. Specifically, it raises the possibility that producers may find it profitable on occasions to leave some of their (specific) capital idle and produce their desired output using only some of the age-cohorts. Second, since removal and replanting of existing trees (replacement) and planting on new land are alternative ways of adjusting

productive capacity, the distinction between replacement and new investment is not fundamental. Third, emergence of new varieties, hybrids and clones, with different gestation periods, permitting different combinations of inputs in production and leading to coexistence in production (often within a single productive unit) of more than a single technology or production function will reinforce these effects. As Wickens and Greenfield (1973) have recognized, a vintage production framework is likely to prove especially useful in analyzing investment in perennials. However, lack of suitable data has impeded empirical implementation of such a framework.

(i) The Nature of the Adjustment Process

13. The essential complexity in the supply response of perennials arises because of the large number of margins on which the supplier can operate to adjust production. In terms of the instrument-target taxonomy, expected net revenue is the producer's target, output is an intermediate target and the producer's problem is to choose the instruments optimally subject to the constraints which include the technical conditions of production, the availability of suitable land and labor, and credit market conditions. In an earlier paper [Trivedi (1985)] a neoclassical model of supply and factor demands for perennials was developed which is a first step toward construction of a framework for showing various margins of adjustment. 1/ The model is based on quite strong simplifying assumptions, viz., producers maximize the net present value of a revenue stream conditional on given time paths of product and factor prices, net of taxes and subsidies; they operate as price

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1/ The general problem of determining optimal capital utilization and factor demands is somewhat intractable. See Nickell (1978, Chapter 7).

takers in competitive factor and capital markets; there are a number of discrete types of technologies from which the producer can choose and to each there corresponds a vintage production function with inputs "capital" and labor, with the former being thought of as trees of different ages planted at some specified density; there exist convex costs of adjustment, relating both to new plantings and removal of existing trees, which depend not only on the rate of investment but also on the choice of technology; and labor is the only variable factor of production and can be varied freely and costlessly across different vintages.

14. The producer's problem is to determine (i) the optimal subset of technologies; (ii) the optimal subset of vintages for each type of technology; (iii) the optimal amount of employment on all capital; (iv) the optimal rate of new plantings; and (v) the optimal rate of removal and replacement of uneconomic capital. 1/

15. It may be helpful to the reader at this juncture to see the interconnections between the producer's decisions. Figure 1, together with accompanying notes, gives a largely self-explanatory schematic representation of the production process and related decisions which have been mentioned above. Note that potential output (how much to produce) is determined simultaneously with optimal factor usage (how to produce). Consider the principal insights about the investment process obtained from such a framework.

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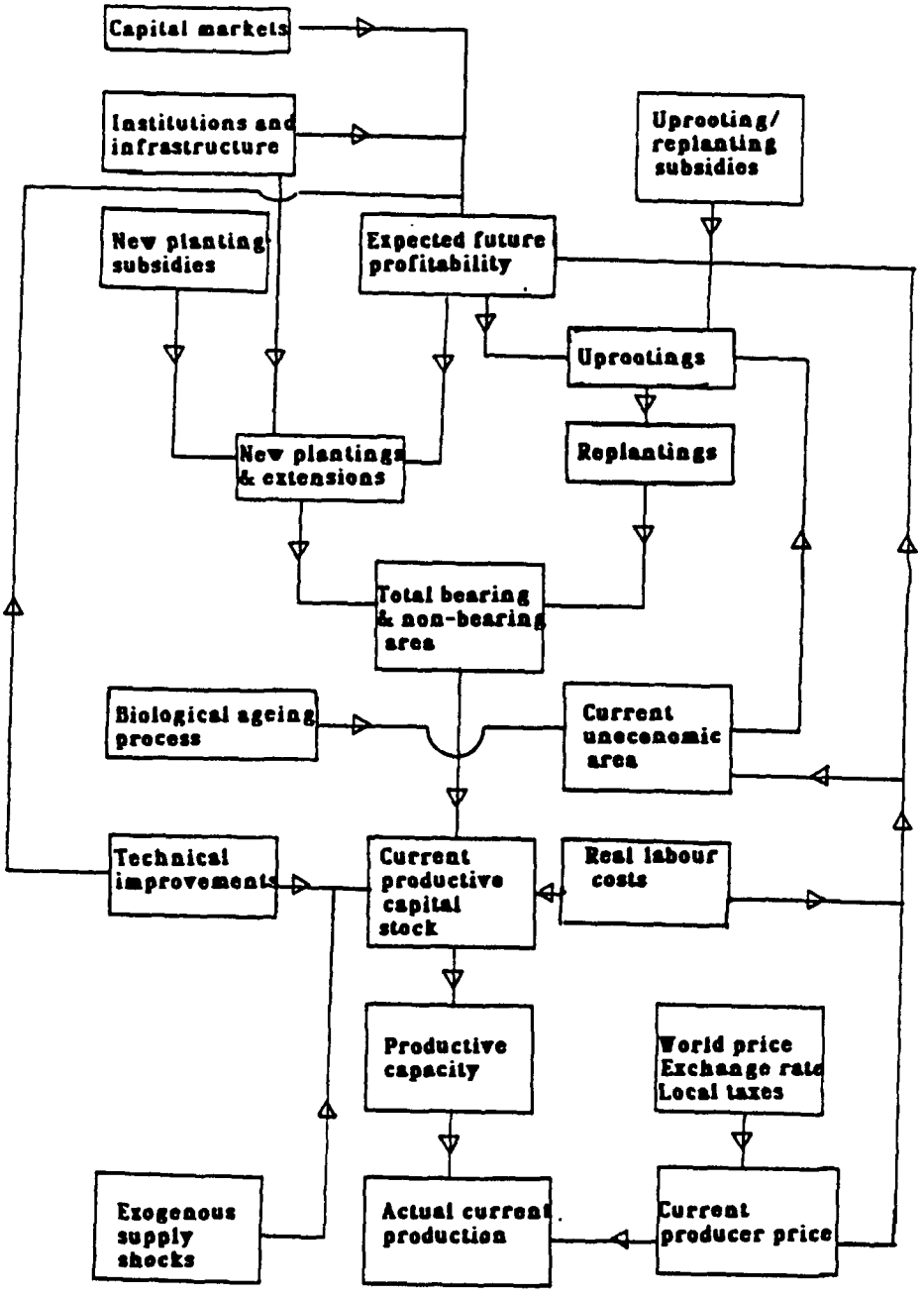
1/ The term "replanting" (by the same crop) should refer to "uprooting followed by replanting." Though there are two distinct stages involved, uprooting by itself leads to costs but no benefits unless followed by replanting. The optimal value of uprootings should be zero unless replanting by the same or different crop is perceived to be profitable. See Trivedi (1986) for further details.

Figure 1: A SCHEMATIC REPRESENTATION OF PRODUCTION PROCESS AND DECISIONS IN A PRICE-TAKING PRODUCING COUNTRY




This figure is intended to display principal linkages between variables on the supply side. Exogenous and pre-determined variables are on the extreme left and right and are linked to the endogenous variables in the centre.

16. The period-by-period solution of the optimization problem determines the time path of the producer's decision variables, conditional on the time path of all relevant prices and the given vector of capital stocks of various ages. The latter capture the dependence of current decisions on past decisions, which is a key feature of dynamic decisionmaking. For any one period, two types of solutions to the optimization problem may be distinguished; one in which the producer acts simultaneously on all margins and the other in which some decision variables have zero values. In the first case, there would be a net expansion in the cropped area occurring by a combination of new planting and replacement. For an individual producer one may observe corner solutions such as (i) zero replacement and zero new plantings, or (ii) zero replacement and positive level of new planting, or (iii) zero new plantings and a positive level of replacement. Outcome (i) may be observed if the producer finds that the most profitable way of changing output is by changing utilization levels of inputs only. Whether one observes outcome (ii) or outcome (iii) depends upon relative adjustment costs 1/ which may vary systematically from one region to another. In a later section we shall illustrate empirically how for certain crops and regions one observes most of the investment taking form (i) or (iii). But first consider the economic aspects of such behavior.

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1/ The concept of adjustment costs used here is general enough to encompass area constraints. Exhaustion of suitable land would translate in the present framework as a case of sharply rising cost of new investment.

(ii) Scrapping and Mothballing of Capacity

17. It will not generally be true that the producer will employ all available capital. Idle capital, comprising currently unprofitable vintages or cohorts, will be in the form of unharvested trees which at the margin yield a revenue which just fails to cover variable costs of production. Whether the currently unprofitable vintages should be replaced (uprooted and replanted) by the same or a different crop, or whether they should simply be kept unused ("mothballed") is part of the investment decision. The producer's demand for additional productive capacity may be met by replacement of old capacity by new capacity without any change in the total area planted, i.e., by a change in the maturity composition of productive vintages, or it could be met exclusively by an increase in the area. It is an economic decision which alternative is chosen. Adjustment costs associated with investment are likely to play a critical role in influencing this choice. Usually adjustment costs refer to the cost associated with the rate of investment, exclusive of the direct cost of investment goods, without any reference to physical constraints such as scarcity of land with suitable soil and climatic conditions. For present purposes, it is more convenient to think of such physical constraints being reflected in the speed with which costs rise. For example, if all suitable land has been used up, then this may be thought of as the case of rapidly rising adjustment costs. If we assume that only those vintages will be replaced which are uneconomic now and expected to remain so in the future, then the choice between new planting and replacement will depend on relative costs of adjustment.

18. Consider the factors which determine the structure of uneconomic vintages and the associated replacement decisions. The relevant theoretical

concept in dealing with the replacement decision is the scrapping condition of vintage production models [King (1972), Nickell (1978, Chapter 7)]. In essence this states that capital equipment will be scrapped when it fails to earn positive quasi-rents, i.e., when the gross revenue from the output it produces fails to cover the variable costs of producing that output. (For simplicity we may take labor as the only variable factor, and hence wage costs as the only relevant variable cost.) Of course, equipment may be uneconomical to use even when it is physically productive. Further, it may be uneconomic in one single period but may be expected to become productive in future. If, over the relevant horizon, the discounted value of the (expected) stream of revenue from output is less than the discounted value of the associated wage costs, the vintage will be scrapped. If the discounted revenue exceeds the discounted costs over the horizon as a whole, but revenue does not exceed costs in each and every period, then we will observe periods of capital idleness ("mothballing") interspersed with periods of capital utilization. Both the scrapping and mothballing decisions depend on expectations about product and factor prices, and it is possible that one might observe producers with highly optimistic expectations, albeit for a limited period only, mothballing rather than replacing older trees. Such a possibility is more likely when the opportunity cost of alternative use of the land is limited.

19. The age distribution of the existing tree stock will be determined jointly by the historical sequence of investment and by the scrapping decisions. Consider the role of average labor productivity 1/ in the scrapping

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1/ Other factors which cause age distributions of tree stocks to differ between regions include differences in varieties of trees, general cultural and maintenance expenditure on trees and historical incidence of plant diseases [Nickell (1978)], and influenced by the time pattern of "maintenance expenditure."

decision. Figure 2 shows three hypothetical age-yield profiles. In 2(a) the profile is monotonically declining with age, in 2(b) it has a single hump shape and in 2(c) it has an oscillating pattern. The dotted line on the vertical axis shows the real product wage. Submarginal or uneconomic vintages are those on which the average labor productivity is less than the real wage. In 2(a) all vintages older than $T^*$ are uneconomic, but in 2(b) and 2(c) some younger as well as older vintages are uneconomic at the prevailing real wage. This suggests that uneconomic vintages could arise in any age-class. French, King and Minami (1985) provide some relevant evidence. Differences in average economic life will depend not only on the physical age-yield profiles, which may or may not vary a great deal from one region to another, but also on the variable costs of production.

(iii) Time Paths of New Planting and Replanting

20. Consider the dynamic response of new planting and replanting to an unanticipated increase in the net producer price of output. This will depend in part on the existing degree of capacity underutilization measured by the productive potential of the subset of currently uneconomic vintages.

21. Given some idle capital initially, the increase in price makes it profitable to use some of the vintages. At the same time the price increase will raise the optimal utilization levels of vintages that were already economic. 1/ Hence production will rise both at the intensive and the

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1/ It has been reported that Indonesian producers of natural rubber switched to a 400% tapping intensity (daily tapping of tw half spiral cuts) system in response to sharp rises in prices in the early 1980s. The strength of such a response may reflect the producer's subjective discount rate rather than the effect of replanting subsidies.

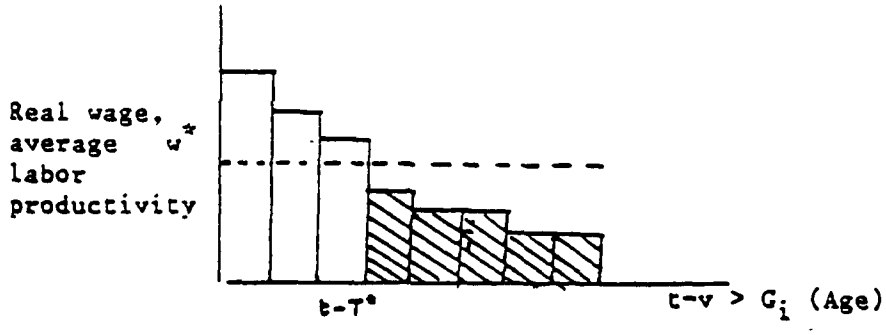


Figure 2(a): The case of montonically declining average productivity.

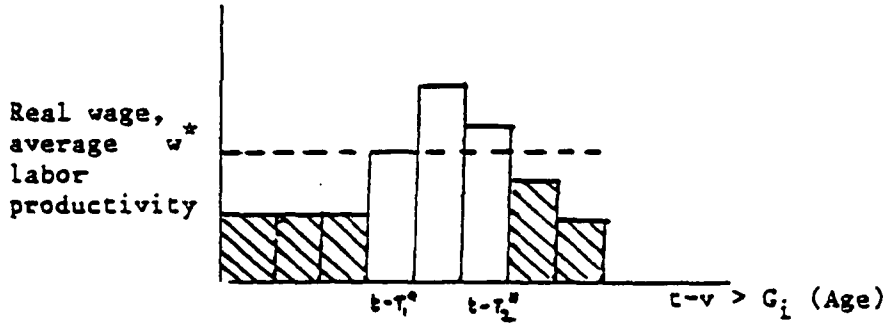


Figure 2(b): The case where average productivity-age profile has a humped shape.

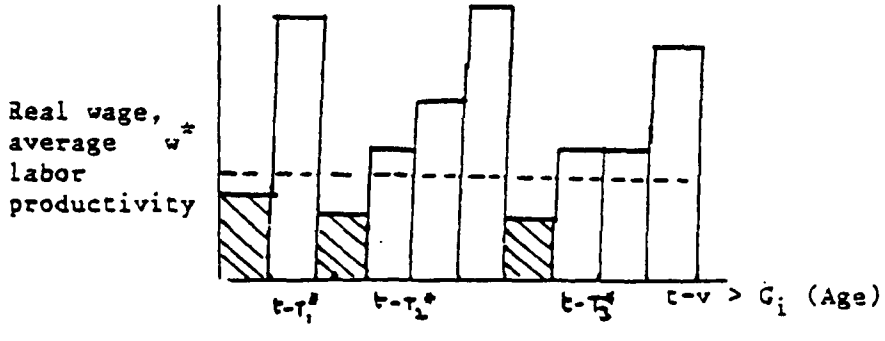


Figure 2(c): The case where average productivity-age profile has an oscillating pattern.

NOTES: Figures 2(a)-2(c) show age on the horizontal axis, and real wage and labor productivity on the vertical axis. The current time period is denoted by t and the year of the vintage by v, so age is t-v. G denotes the gestation lag. For simplicity, the diagram assumes constant input and output prices.

extensive margins. Furthermore, the removal of idle capacity will be discouraged, both because there will be less of it and because the imputed adjustment costs of such changes may be higher when the output price is higher. Further, if expectations about future output are revised, then the economic life of capital is also increased. If the price rise is expected to be "permanent," new planting will be eventually stimulated and the ratio of new planting to replanting will probably rise. In brief, the incentive for replanting is likely to be greater when demand is slack and the price low, though it may also be the case that then the potential for internal financing of such activity will also be diminished. Hence subsidy assistance with replanting is more appropriate when prices are depressed.

22. If initially there was no idle capital, of course we would expect new planting to respond faster.

## IV. SOME EMPIRICAL EVIDENCE

23. In general, one is interested in the interrelationships between all decision variables. Unfortunately, reliable data on new plantings and replantings are often not available and those on age distributions of existing stocks of trees are even more scarce. Hence, only some special forms of hypotheses can be examined empirically. Conclusions reached will necessarily be specific and may have only limited applicability. Some illustrations of investment decisions in tea growing can be provided from recent work [see Akiyama and Trivedi (1986)]. Tea is an interesting crop to study since it is extensively grown on both large estates and by smallholders, and hence provides an opportunity to test hypotheses about the differences in the behavior of the two sectors. To save space, details of data manipulations and sources have been omitted here, but see Akiyama and Trivedi.

24. The illustrations should throw some light on: (a) the price sensitivity of new planting and replanting decisions; (b) the role of replanting subsidies in stimulating uprooting and replanting of aged tree stock; and (c) the role of development institutions in the promotion of smallholder investment. All three factors constitute price incentives, in essence. But the last factor comes under the heading of "invisible" prices.

25. The empirical examples are based on the experience of just two countries, Sri Lanka and Kenya, which provide strong contrasts. Kenya has had a dynamic tea sector consisting of estates and smallholders--the latter accounting for nearly two thirds of the planted area but only one third of the production. Over the period 1963-83, the annual average growth rate of planted area for smallholders was close to 17 percent, though the rate has declined to

around 4 percent in the last 5 years. From Table 1 it can be seen that the estates sector has registered spectacular growth in yield per hectare. By contrast, both production and yields have stagnated and declined in Sri Lanka. Over the last 20 years, the rate of new planting and replanting as a proportion of total area planted has varied between 0.9 percent and 1.4 percent.

26. In terms of the nature of public intervention, the two countries also provide sharp contrasts. A major type of intervention in Sri Lanka has consisted of an extensive and complex subsidy scheme aimed at rehabilitating the tea sector. 1/ A major feature of intervention in Kenya has been the part played by the Kenya Tea Development Authority (KTDA), a development institution that has been assigned a major role in the provision of extension services and a network of factories constituting the necessary infrastructure for raising the profitability of tea production to the smallholder [Lamb and Muller (1982)]. Since the smallholders represented by the KTDA are exposed to market forces in the usual way, it is appropriate to think of this institution as influencing the "invisible" prices relevant to the producer's decisions.

(i) Kenya Smallholders and Estates Compared

27. In Table 2 we have provided econometric equations for Kenya smallholders new planting, estates new planting and estates yields per hectare. The first equation models the rate of increase of smallholders' new

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1/ Reports of the Central Bank of Sri Lanka mention the following assistance schemes for tea growers: Tea New Planting Subsidy Scheme; Rubber Into Tea Replanting Subsidy Scheme; Crop Diversification Subsidy Scheme; Tea Factory Development Subsidy Scheme; Tea Infilling Subsidy Scheme; Export Incentive Scheme for Packeted Tea; Price Support Measure Scheme.

Table 1: KENYA TEA--AREA SOWN AND YIELDS, 1971-82

| Year | Smallholders | | Estates | |
|---|---|---|---|---|
| | Area /A | Yield /B | Area /A | Yield /B |
| 1971 | 20.5 | 874 | 22.8 | 1,356 |
| 1972 | 26.5 | 1,071 | 23.3 | 1,885 |
| 1973 | 31.2 | 1,027 | 23.6 | 1,900 |
| 1974 | 34.6 | 905 | 24.1 | 1,673 |
| 1975 | 37.2 | 873 | 24.3 | 1,699 |
| 1976 | 41.4 | 811 | 24.5 | 1,741 |
| 1977 | 43.6 | 985 | 24.9 | 2,352 |
| 1978 | 46.9 | 1,004 | 25.2 | 2,433 |
| 1979 | 48.9 | 1,011 | 25.4 | 2,531 |
| 1980 | 50.7 | 821 | 25.9 | 2,278 |
| 1981 | 52.7 | 821 | 26.2 | 2,217 |
| 1982 | 54.7 | 851 | 26.4 | 2,230 |

/A Area is in 1,000 hectares
/B Yields per hectare are estimated by dividing production by total area sown with tea four years before to allow for the tea bush to mature after planting.

Source: Schluter (1984), Table 12, p. 38.

Table 2: KENYA NEW PLANTING AND YIELD EQUATIONS
(T-RATIOS IN PARENTHESES)

(1): Smallholder new plantings

$$NPR(t) = -0.1127 + 0.7487\ PRK(t-1) + 0.2077\ EXKTDA(t-1)$$
$$(1.36) \quad (1.30) \qquad (2.98)$$

$$+ 0.2009\ \Delta EXKTDA(t-1) + 0.0379\ \Delta PRK(t-1) + 0.5052 NPR(t-1)$$
$$(2.40) \qquad (0.79) \qquad (3.32)$$

$R^2 = 0.89$ SEE = 0.2977E-01 DW = 1.85

Period of fit: 1966-82

(2): Estates weighted area

$$\log AWEST = 9.6823 + 0.0196\ TR61$$
$$(469.94) \quad (16.99)$$

$R^2 = 0.96$ SEE = 0.1381E-01 DW = 1.97

Period of fit: 1972-83

(3): Estates yield

$$YLDEST(t) = -1.4695 + 0.0997\ TR61 + 6.6698\ PRK(t)$$
$$(2.34) \quad (6.10) \qquad (2.47)$$

$$+ 6.7935\ PRK(t-1) + 8.4269\ PRK(t-2)$$
$$(2.59) \qquad (3.10)$$

$R^2 = 0.78$ SEE = 0.1443 DW = 1.86

Period of fit: 1972-82

Definitions: NPR: ratio of new plantings to smallholder total area; PRK: Mombasa auction price of tea deflated by CPI; EXKTDA: per hectare KTDA development expenditure deflated by CPI; $\Delta$: first difference operator; AWEST: total estates equivalent maturity area calculated as a weighted average of areas less than 5 years, between 5 and 10 years and more than 10 years of age, with weights 0.12, 0.76, and 1.0, respectively; TR61: linear time trend with value one in 1961; YLDEST: weighted yield for estates defined as production divided by weighted area, AWEST.

plantings, denoted by NPR, as a function of lagged real producer price [PAK(-1)], current change in price (ΔPRK), the lagged level of real expenditure per hectare by the KTDA (EXKTDA) and its rate of change and finally, the lagged value of rate of new plantings. 1/ The justification for this equation is that the Kenya smallholders probably did not face an area constraint over this period [Etherington (1973)] and that the critical limitation on their plans arose from access to planting material, credit facilities, factories for processing tea leaves and expertise in the marketing of the leaf. To the extent that KTDA provided these facilities, it made it easier for the smallholder to take up growing tea. It is postulated that by maintaining a constant rate of development expenditure per hectare, the KTDA enabled more smallholders to undertake tea production and to maintain a steady growth in new planting. For an individual producer the outcome of a corner solution in which new plantings are positive but replantings are zero may be a reasonable approximation. Of course, the assumption is reasonable only as long as the availability of land is not a binding constraint. The nature of adjustment costs will change when the constraint becomes binding. The basic hypothesis underlying the specification is that the smallholders' investment occurs at the extensive margin, as they have not been in tea production long enough to have to worry about the replacement decision.

28. The estimated equation, which provides a good explanation, shows that the KTDA expenditure variable plays a key role and that the role of real producer prices has been positive, but it is also relatively minor. That is,

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1/ The equation is derived from a first-order error correction model in Akiyama and Trivedi (1986).

"invisible" prices are found to be more important than "visible" prices. This may be an overstatement; the latter category should include as an additional explanation (suggested by a priori considerations) the prices of other competing crops, possibly cereals. Further, even the smallholders' harvesting decisions and yields may be sensitive to the market price of tea. With additional data this hypothesis could be investigated more thoroughly.

29. New planting on Kenya estates has been small absolutely and relative to that by smallholders. It has also been somewhat variable, possibly reflecting the role of political uncertainty. Given the differences in the cost structures of estates and smallholders, and the greater opportunity for the use of "modern" inputs available to the estates due to their larger size and better access to information and capital markets, it is reasonable to hypothesize that unlike the latter their response to changes in expected profitability would be at the intensive rather than the extensive margin. The data presented in Table 1 are broadly consistent with this. Our attempts at modeling new plantings suggest that a simple trend provides a reasonable description of the data since 1972. On the other hand, the yield is better explained by an exponential trend, and current and lagged real prices, viz., PRK, PRK(-1) and PRK(-2), which all have statistically well-determined coefficients. This evidence supports the proposition that the estate sector is much more responsive to "visible" prices.

(ii) New Plantings, Uprootings and Replantings in Sri Lanka

30. In contrast to Kenya, the main interest in the case of Sri Lanka, where new plantings and replantings are almost equally important, is in the relative importance of real prices and subsidies. We also wish to compare the

behavior of a long-established producer like Sri Lanka with that of a relative newcomer like Kenya. But an obstacle to good econometric modeling of the replanting decision is the absence of reliable data on the age distribution of trees.

31. Equations (1), (2) and (3) presented in Table 3 pertain to, respectively, new plantings, uprootings and replantings. The new planting equation is formulated as a first order error correction model driven by variables which are important determinants of actual and expected profitability variables. These include: lagged costs of production, denoted by COP(-2), and its rate of change, ΔCOP(-2); expected real price, denoted by PRE(-1) and measured as a simple three-period moving average for four, five and six period lagged values; actual net real price, denoted by PR, and its rate of change ΔPRE; and the rate of change of current price (ΔPR). The justification for long lags in the construction of the expected price variable arises from the gestation lag. A simple weighting formula is chosen both because of its inherent plausibility when long lead periods in forecasting are involved and because of its consistency with some evidence from surveys in Sri Lanka. The index COP is a proxy for factor costs. The direct effect of an increase in COP is lower profitability of current production. But at the same time it may induce substitution toward higher yielding and more profitable varieties. The positive coefficients on the variables COP and ΔCOP may be interpreted in this way. The expected price of tea is an unobservable whose value depends on a very large number of factors, including exchange rates, cesses and export taxes. Here it has been assumed that the producer has a perception of "normal" price which is a function of the realized current price and prices in the recent past. The reported regression shows that new

Table 3: SRI LANKA NEW PLANTING, UPROOTING AND REPLANTING EQUATIONS (T-RATIOS IN PARENTHESES)

(1): New plantings

$$NPL(t) = -811.34 - 0.3108\ NPL(t-1) + 15.0035\ PRE(t-1)$$
$$(0.85) \quad (1.06) \quad (1.84)$$

$$+ 33.6261\ \Delta PRE(t-1) + 8.6650\ COP(t-2) + 23.84\ \Delta COP(t-1)$$
$$(3.84) \quad (1.89) \quad (2.25)$$

$$+ 0.5345\ \Delta PR(T)$$
$$(1.68)$$

$R^2 = 0.725$ SEE = 195.41 DW = 2.39

Period of fit: 1966-82

(2): Uprootings

$$UP(t) = -1589.9 + 0.5055\ UP(t-1) - 0.9836\ REPL(t-1)$$
$$(0.85) \quad (1.05) \quad (1.66)$$

$$+ 179.9945\ SUB(t-1) + 118.8185\ \Delta SUB(t-1)$$
$$(3.16) \quad (3.89)$$

$$+ 3.851\ PRE(t-1) + 37.4728\ \Delta PRE(t-1)$$
$$(0.22) \quad (1.31)$$

$R^2 = 0.82$ SEE = 314.93 DW = 1.88

Period of fit: 1967-82

(3): Replantings

$$REPL(t) = -118.95 + 0.4716\ UP(t) + 0.2110[UP(t-1)+UP(t-2)]$$
$$(1.76) \quad (7.93) \quad (7.46)$$

$R^2 = 0.98$ SEE = 145.56 DW = 2.04

Period of fit: 1958-82

Definitions: NPL: new plantings (hectares); UP: uprooting (hectares); REPL: replantings (hectares); SUB: replanting subsidies, deflated (SL mill. Rps. *100.0/CPI); COP: index of cost of production of tea, deflated by CPI; PR: net producer price, deflated by CPI; PRE: three-year moving average of PR, lagged three years.

plantings depend positively on PRE, and even more so on the revision to price expectation, measured by the term ΔPRE. The implied short-term price elasticity of new plantings with respect to real price in Sri Lanka is of the order of 1.5 to 2.0, which is nearly three times that in Kenya. Unfortunately, it cannot be claimed that the new planting equation is very robust and hence even such an a priori reasonable finding with respect to the role of the price variable must be treated with caution.

32. In equation (2) in Table 3, the uprooting decision has been modeled as a dynamic function of the expected price variables, PRE(-1) and ΔPRE(-1), and subsidy variables SUB(-1) and ΔSUB(-1). Lagged uprootings and replantings also appear in the model to reflect the dynamic process of adjustment. In equation (3), actual replanted area is modeled as a function of uprootings in the current year and the previous two years. This equation has a very good fit. This fact, taken together with the details of how the subsidy schemes work, suggests that this is a correct way to model the uprooting-replanting decisions. In the uprooting equation the price variables have the a priori expected positive coefficients, but their total contribution to the explanation is small compared with that of the subsidy variable which is the main determinant of uprootings. The short-term elasticity with respect to subsidy is around two; the long-term effect is a little uncertain in view of the large standard error on the coefficient of the lagged uprooting variable. However, it could be as large as four. Such values are not unexpected, but they should be treated as suggestive only because actual responses to subsidies are likely to depend upon the simplicity of the scheme and on the producer's expectations of its duration and future coverage. As has been indicated already, the Sri Lankan subsidy scheme is very complex. Although we

should expect the stock of the overaged trees to be a very important factor also [see Hartley, Nerlove and Peters (1985)], using somewhat fragmentary data on age distributions we could not validate this empirically.

33. The result that uprooting does not respond positively and strongly to price changes is consistent with the suggestion made earlier in the paper that an improvement in the expected future price makes previously uneconomic vintages economic, and hence may even reduce uprooting and stimulate higher utilization and new planting.

## V. POLICY IMPLICATIONS

34. Some of the most important policy issues concern the joint effects on producer's decisions of a policy of export taxes and cesses, which reduce the net producer price and profitability, and provision of subsidies to assist replanting (with the same or different crop) as a partial "compensation" for export taxes. It is frequently suggested that export taxes are a powerful disincentive to new investment. It has also been argued that the extensive use of replanting subsidies, as in the case of rubber in Thailand and Sri Lanka, is likely to induce producers to (a) utilize more intensively ("overexploit") their existing stock of trees; (b) lower maintenance and tree culture in a manner that reduces the bearing life of the trees; and (c) generally act in a myopic fashion.

35. At the theoretical level such a response is possible, even plausible. The critical consideration seems to be the degree to which production can adjust by a change in the utilization level of existing inputs rather than the change in the area planted. 1/ In many cases, bounds may be placed on the utilization level due to the possibility that the physical and/or economic life of the tree may be shortened by excessive utilization. Then the rational producer will equate at the margin the discounted value of the increment to net revenue resulting from overutilization against the reduction in the revenue from the loss of the tree. The higher the discount rates used in such a calculation, and the shorter the time horizon over which such a calculation

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1/ Examples of higher utilization of labor and capital in response to higher prices are "coarse plucking" in the case of tea and more frequent tapping in the case of rubber.

is done, the more attractive will appear the policy of higher current utilization compared with the alternatives. But this may well raise the level of future replacement investment. The dependence of current replacement rates on past utilization rates is a factor which should be taken into account when considering the structure of replanting subsidies. If the producer is certain that replanting subsidies will be available in the future, the incentive to pursue policies which raise current net revenue but also lower the economic life of trees is stronger. Thus replanting subsidies have their desired effect by lowering the producer's adjustment costs and by lowering the economic life of trees. It is not appropriate to complain that producers scrap their capital "too early" while there is productive capacity still left in the tree. If, on the other hand, the complaint is that the producers use (implicit) discount rates which are above the market rates, the resolution of the problem lies in the improved functioning of capital markets. An alternative policy which provides replanting subsidies only once over a multiyear cycle, will ameliorate this effect to an extent that depends on the length of time between subsidy years and the discount rate used.

36. Since investment and the choice of technique are simultaneous decisions, subsidies also affect the latter. The effect is likely to depend upon the criteria used by decisionmakers in their investment decisions. Although in theoretical work the net present value maximization is the favored criterion, in actual decisionmaking other criteria are often used. A leading example of one such criterion is the use of a fixed pay-back period. 1/ High

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1/ Investment decisions in terms of pay-back periods are discussed in Malcolmson (1975) and Perrin (1972).

discount rates and short pay-back periods in economic calculations will systematically induce a preference for technologies that yield more in earlier years of their productive life. To the extent that replanting subsidies shorten the economic life of trees, such a preference will be reinforced. On the other hand, if subsidies are seen by producers as a permanent policy feature, this may cause them to adopt a "longer view," leading them to adopt longer pay-back periods and lengthening the economic life of trees.

37. It is sometimes argued that the purpose of replanting subsidies is to enable producers to adopt high input-high output technology, and disappointment is expressed when such an aim is not achieved. For example, the Sri Lanka smallholder rubber growers have shown a marked preference for the clonal variety PB 86 even though superior alternatives are available. A possible rationalization of this preference is that PB 86 stands up better to the daily tapping system (apparently preferred by the smallholders). Though the preference for an inferior variety may at first sight appear irrational, it may be justifiable on economic grounds when one takes into account possibly high adjustment costs associated with the adoption of a more modern technology and the high discount rates used in economic calculation. On the other hand, producers' choice of technology will be conditioned by the information available to them, and this may be quite deficient. Efficient provision of information relevant to the choice of techniques of production may be no less important than subsidies in stimulating replanting.

38. Another important policy consideration is whether replanting subsidies for a particular tree crop may "distort" producer's choices in favor of the existing crop. The practical importance of this theoretically plausible effect depends on whether alternative land use is possible. Where physical and

geographical conditions rule out an alternative use of land, the main effect of replanting subsidies is simply to encourage continued production.

39. Finally, consider the relationship between replantings and new plantings. In many countries, imposition of export taxes and cesses lowers the effective net price received by producers and lowers the profitability. In principle, this should discourage both replanting and new planting. However, at the same time the use of replanting subsidies will tend to restore the balance sheet somewhat, at least in terms of the sector as a whole. But then the bias of the policy in favor of replanting over new planting is obvious. The extent of the bias depends on whether new planting is a genuine alternative or whether the typical situation is that of a corner solution with zero value for new plantings. The bias is also reduced if replanting subsidies are targeted on smallholders with negligible possibilities for net expansion, or land constraints exist which preclude new planting.

40. In considering the effects of export taxes and cesses on new planting, the key consideration is the role of actual and expected output prices in investment decisions. Though the magnitude of the effect is an empirical matter, there can be no dispute that new investment will be discouraged. Again, however, if a zero corner solution for this variable is the typical outcome, the effect will be negligible.

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