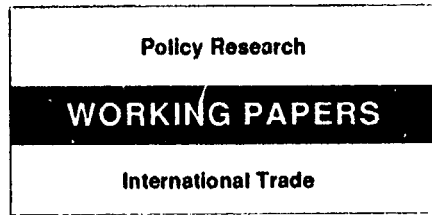


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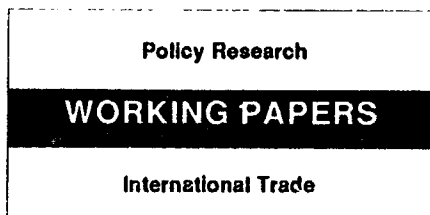


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# Is There a Case for an Optimal Export Tax on Perennial Crops?

Takamasa Akiyama

In imposing an export tax on perennial crops, a government should give less consideration to the tax's optimality and more to how the tax affects the perennial's long-term production and the distribution of welfare.



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This paper—a product of the International Trade Division, International Economics Department—is part of a larger effort in the department to analyze and evaluate trade policies in developing countries. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington DC, 20433. Please contact Grace Ilogon, room S7-033, extension 33732 (39 pages). February 1992.

The idea of an optimal export tax on a commodity is based on the assumption that by imposing a tax, a country can improve its welfare (the sum of producer surplus and government revenues) when it faces a downward-sloping demand curve for the commodity. The idea is thought to be particularly relevant to producers with large world market shares for primary commodities for which the price-elasticity of demand is low. An export tax is considered necessary because the scattered farmers' expected marginal revenue is higher than the marginal revenue of the country as a whole.

Akiyama uses a model to calculate the optimal tax and to evaluate the effect of the tax and other factors on welfare. Simulation results show that the optimal level of the export tax depends on how farmers and government form their expectations of future prices. He found that the tax is indeterminate when the government does not know how farmers form their expectations and when farmers' expectations are independent of recent prices or taxes. The government can only impose an "estimated" optimal tax

because the tax to be imposed depends on the government's expectations of world prices. Whether the tax is optimal or not depends on whether the government's expectations are met by reality. To impose a realistic tax, the government needs to know the farmers' expectations and the prospects for world prices of a particular perennial.

Akiyama's numerical example shows that national welfare is not very sensitive to the tax rate. But the tax does significantly affect the distribution of benefits between farmers and government—and significantly affects long-term production. The numerical example also shows quantitatively how much interest rates, exchange rates, and marketing and production costs affect welfare and, in the long run, the perennial subsector.

Akiyama concludes that in imposing an export tax on perennials, a government should give less consideration to the tax's optimality and more to how the tax affects welfare distribution and long-term production.

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## Is There a Case for an Optimal Export Tax on Perennial Crops?

by

Takamasa Akiyama\*

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## Introduction

The idea of an optimal export tax is based on the assumption that the tax-imposing country can thereby increase its total welfare (i.e., the sum of producer surplus and government revenue), when it faces a downward-sloping demand curve for the commodity. This proposition is thought to be particularly relevant to producers with large world market shares of primary commodities with highly price-inelastic demand. An export tax is considered to be necessary because the atomistic farmers' expected marginal revenue is higher than the marginal revenue of the country as a whole. Hence, the tax is imposed to change the farmers' marginal revenue to that of the whole country.

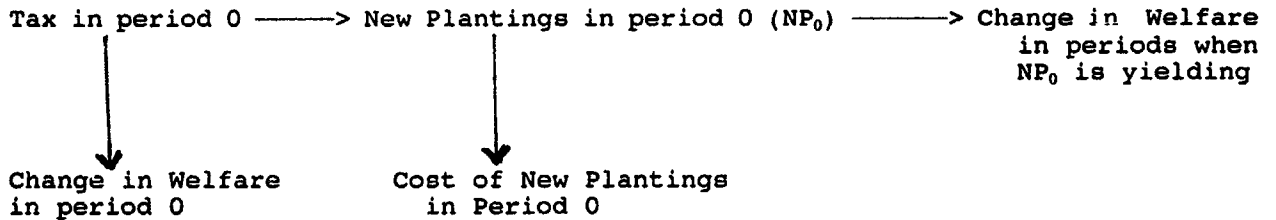
Trivedi and Akiyama (forthcoming) has a literature review on this issue. An analytical solution for the optimal export tax for crops with a short gestation period (annuals) is well-known (see e.g., Chapter 7 of W.M. Corden, 1974). But because of the difficulty caused by the complex dynamics in supply of perennial crops, an analytical solution has not been developed to this problem. To evaluate the effects of the tax on welfare, it is indispensable to take the long-term supply response into account as noted by Deaton and Benjamin (1987). The approach taken by Imran and Duncan (1988) to calculating optimal taxes on four perennial crops under short- and long-run supply elasticities, which is an extension of Repetto (1972), is clear but does not take the dynamics of supply into account. Trivedi and Akiyama do take the dynamics of supply into account and calculate the impacts of the export tax on welfare but avoid the question of optimality.

This paper is in a sense a sequel to Trivedi and Akiyama and shows that, with some reasonable assumptions, the optimal tax for perennials can be solved analytically. The analysis shows that the optimal tax solution obtained by Imran and Duncan is a special case. The paper goes beyond Imran and Duncan to show, in some detail, the relationships among key variables such as the exchange rate, production costs, farmer expectations, and taxes, and also provides solutions for calculating the magnitude of welfare changes under

different tax rates.

Two approaches to determining the optimal tax are given here. The first is under the assumption of a zero short-term supply price elasticity and finds the optimal tax through equating marginal cost and expected marginal revenue of new plantings, which is the investment variable. This approach is straightforward but cannot handle the effects of the tax on welfare in the short-run arising from non-zero short-term price elasticity of supply. The second approach expresses the national welfare directly in terms of the tax and finds the maximum welfare tax level. The second approach can handle the assumption of non-zero short-run supply response.

The two approaches are shown graphically below.



In the figure above, the first approach starts from the second column (New Plantings) while the second starts from the first column (Tax in period 0). The second approach takes into account all the effects of the first approach by linking the tax rate to the new plantings and hence is more general.

The remainder of the paper is organized as follows. Section I provides an analysis of farmers' expected marginal revenue from new plantings without a consideration of taxes, and Section II provides the framework for

calculating country's or government's marginal revenues. Section III derives the optimal export tax for several cases. Section IV presents the more general approach to solving for the optimal tax analytically. An application of the analysis to the case of cocoa in Ghana is given in Section V. Section VI concludes.

I. Farmers' Expected Marginal Revenue from New Plantings  
When There Are No Export Taxes

Assume the short-term price elasticity of supply to be zero and hence adjustments in supply can only be made through new plantings (NP).<sup>1</sup> Assuming yield ( $Y_i$ ) to be stable, farmers' expected incremental net revenue in period  $i$  ( $i > 0$ ) from new plantings of  $NP_0$  in period 0 when there is no export tax can be expressed as

$$(1) \quad E_{f,0}(\Delta NR_f) = (E_{f,0}(WP_i) - E_{f,0}(P_{i,c})) * NP_0 * Y_i$$

where

$E_{f,0}(\Delta NR_f)$	=	Farmers' expected net incremental revenue in period $i$ due to new planting in period 0
$E_{f,0}(WP_i)$	=	Farmers' expected world price for period $i$ in period 0
$E_{f,0}(P_{i,c})$	=	Farmers' expected cost of maintaining, and harvesting a unit area of the commodity plantings made in period $i$ .

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<sup>1</sup> New plantings here include re-plantings.

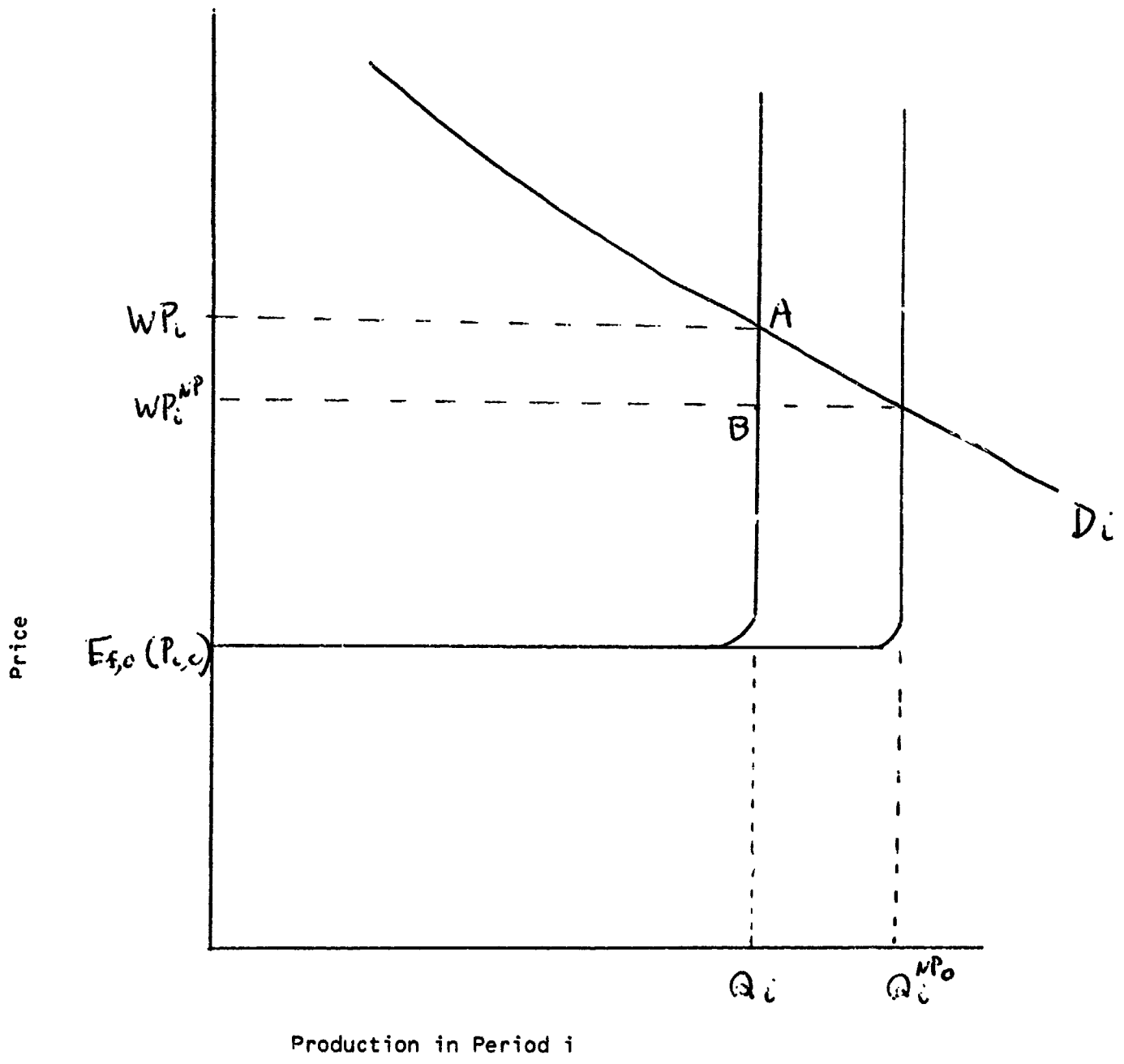


Figure 1. Effects of New Plantings on Supply and World Price

$Y_i$  = Yield in period  $i$ .

Figure 1 illustrates this graphically where  $Q_i$  and  $Q_i^{NP_0}$  are production in period  $i$  without and with  $NP_0$ , and  $D_i$  is the export demand curve facing the country.

$NP_0$  produces  $Q_i^{NP_0} - Q_i$  in period  $i$ , i.e.,

$$(2) \quad Q_i^{NP_0} - Q_i = NP_0 \cdot Y_i$$

Under the assumption of zero short term price elasticity of supply, the country produces  $Q_i$  when there is no new planting or  $Q_i^{NP_0}$  when there is  $NP_0$  of new plantings in period 0, as long as the world price is above  $P_{i,c}$  in period  $i$ .

Assuming that the trees planted produce the commodity between the period  $m_1$  and  $m_2$ , ( $m_1 > 0$ ,  $m_2 > m_1$ ), the farmers' expected sum of the discounted future flow of net revenues from the investment of  $NP_0$  in period 0 is

$$(3) \quad E_{f,0}(NR_f) = \sum_{m_1}^{m_2} \beta_f^i (E_{f,0}(WP_i) - E_{f,0}(P_{i,c})) \cdot NP_0 \cdot Y_i$$

where

$E_{f,0}(NR_f)$  = Farmers' expected discounted future flow of net revenues from  $NP_0$

$\beta_f^i = \frac{1}{(1+r_f)^i}$ , which is the discount factor of farmers, and



$r_f$  = the interest rate farmers face

Farmer's expected marginal revenue from new plantings can be obtained by differentiating  $E_{f,0}(NR_f)$  by  $NP_0$  and hence,

$$(4) \quad E_{f,0}(MR) = \frac{\partial E_{f,0}(NR_f)}{\partial NP_0} = \sum_{m1}^{m2} \beta^i \cdot Y_i (E_{f,0}(WP_i) - E_{f,0}(P_{i,c}))$$

Equation (4) indicates that the farmers' expected marginal revenue depends on their expectation of the world price and their production costs. Because farmers usually have a good idea of the latter in real terms, it can be assumed to be a constant, PC.<sup>2</sup>

Denoting  $E_{f,0}(WP_i)$  and  $E_{f,0}(WP_i^{NP})$  to be the farmers' expected world prices with and without  $NP_0$ , respectively, and defining the expected change in the world price as (see Figure 1),

$$(5) \quad \Delta WP_i = E_{f,0}(WP_i) - E_{f,0}(WP_i^{NP})$$

the farmers' expected marginal revenue can be given using (4)

$$(6) \quad E_{f,0}(MR) = \sum \beta_i^i \cdot Y_i \cdot (E_{f,0}(WP_i) - \Delta WP_i - PC)$$

---

<sup>2</sup> All prices and costs are in real terms.

Given the marginal new plantings cost curve for period 0,  $MC(NP_0)$ , the level of new plantings will be solved by equating  $MC(NP_0)$  and (4) or

$$(7) \quad MC(NP_0) = \sum_{m1}^{m2} \beta_f^i \cdot Y_i (E_{f,0}(WP_i) - PC)$$

The solution  $NP_{,0}^*$  is shown in Figure 2 which assumes a linear MC schedule. It is clear from (7) that the interest rate has an important impact on new plantings and hence on long-term supply of perennials as noted in Trivedi (1988).

## II. Expected Marginal Revenue for Country

From the country or government's viewpoint, equation (4) is not the marginal revenue with respect to  $NP_0$  mainly because the individual farmer does not realize that  $NP_0$  causes a producer surplus loss of  $\Delta WP_i \cdot Q_i$  (or the area  $WP_i ABWP_{i,NP}$  in Figure 1).

Denoting  $E_{g,0}(WP_i)$  and  $E_{g,0}(WP_i^{NP})$  as the government's expectation of world prices with and without the effect of  $NP_0$ , respectively, the expected incremental net revenue for the country in period  $i$ ,  $E_{g,0}(\Delta NR_g)$  is

$$(8) \quad E_{g,0}(\Delta NR_g) = (E_{g,0}(WP_i) - \Delta WP_i - PC) \cdot NP_0 \cdot Y_i - \Delta WP_i \cdot Q_i$$

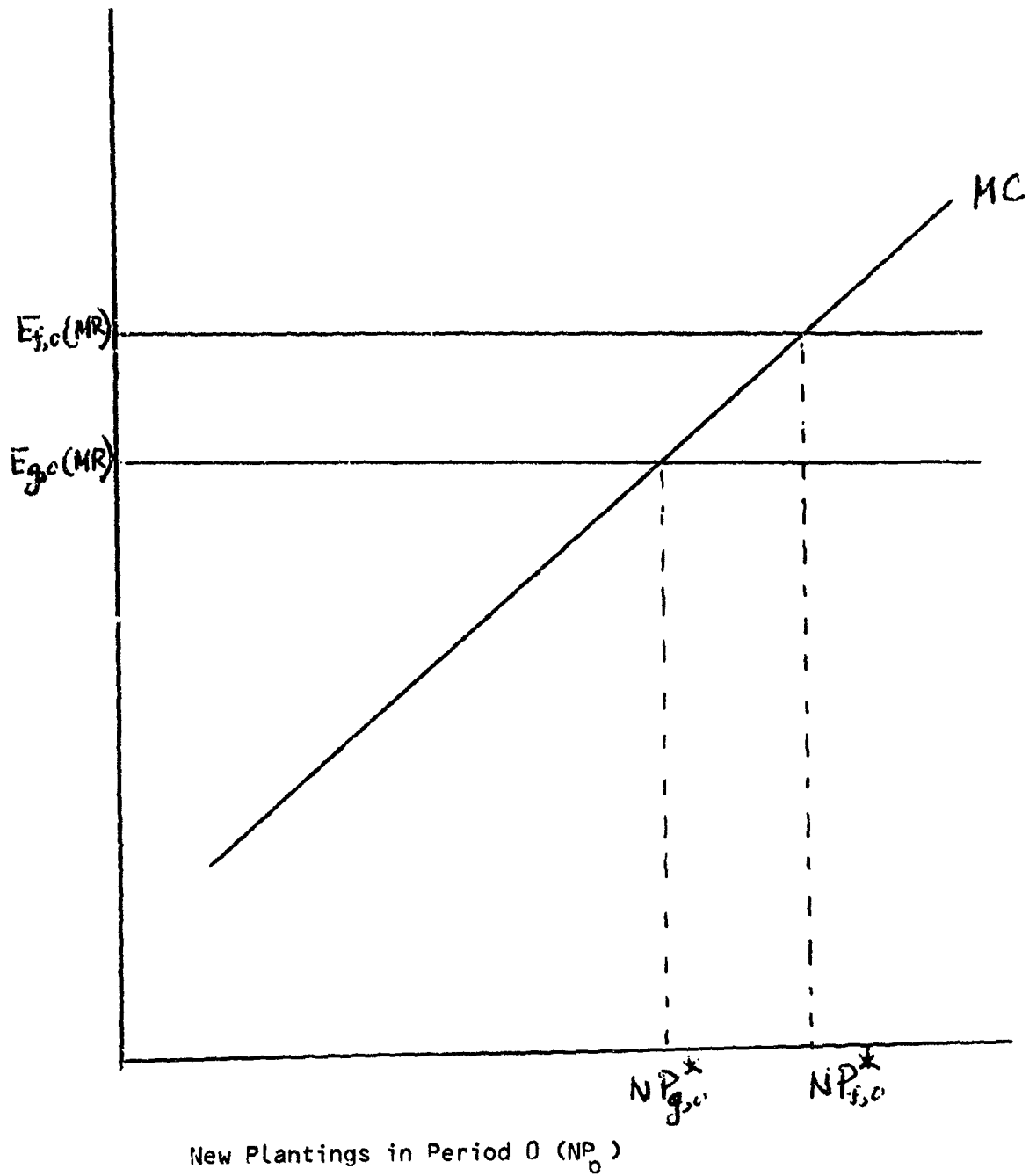


Figure 2. New Plantings Schedule

where  $\Delta WP_i = E_{g,0}(WP_i) - E_{g,0}(WP_i^{NP})$

Hence the expected marginal revenue for the country is

$$(9) \quad E_{g,0}(MR) = \sum \beta_g^i [ (E_{g,0}(WP_i) - \Delta WP_i - PC_i) \cdot Y_i - \Delta WP_i \cdot Q_i ]$$

where

$$\beta_g^i = \frac{1}{(1+r_g)^i}, \text{ discount factor for the government}$$

$r_g$  = interest rate for the government.

$\Delta WP$  can be approximated by<sup>3</sup>

$$(10) \quad \Delta WP_i = \frac{NP_0 \cdot Y_i \cdot E_{g,0}(WP_i)}{Q_i^w (e_{d,i}^w + (1 - SH_i) \cdot e_{s,i}^{Row})}$$

where

- $Q_i^w$  = World production
- $e_{d,i}^w$  = World price elasticity of demand
- $e_{s,i}^{Row}$  = Price elasticity of supply in the rest-of-world.
- $SH_i$  = Share of the country or  $Q_i/Q_i^w$

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<sup>3</sup> Derived from the elasticity of demand the country faces as given in Annex 1 of Imran and Duncan (1988). This implicitly assumes that production of other countries responds to world prices but not policies taken by the country concerned. From the author's experiences of analyzing supply of various perennial crops in a number of countries and discussing with government officials and farmers in perennial crop exporting countries, this assumption seems appropriate.

Substituting (10) into (9), we obtain

$$(11) \quad E_{g,0}(MR) = \sum \beta_g^i \cdot Y_i (E_{g,0}(WP_i) - PC) - NP_0 \sum \beta_g^i \frac{Y_i^2 \cdot E_{g,0}(WP_i)}{Q_i^v \cdot e_i}$$

$$- \sum \beta_g^i Q_i \frac{Y_i \cdot E_{g,0}(WP_i)}{Q_i^v \cdot e_i}$$

where  $e_i = \epsilon_{d,i}^w + (1 - SH_i) \cdot \epsilon_{s,i}^{Row}$

The first term of RHS of (11) is the same as  $E_{f,0}(MR)$  given by (6), the farmers' expected marginal revenue, if we assume  $\beta_f = \beta_g \cdot \Delta WP$  in (6) to be zero, and  $E_{f,0}(WP_i) = E_{g,0}(WP_i)$ . The second and third terms represent the extent to which  $E_{g,0}(MR)$  is smaller than  $E_{f,0}(MR)$  because of the downward-sloping demand curve facing the country. Because  $NP_0 \cdot Y_i$  is usually much smaller than  $Q_i$ , omission of the second term of the RHS of (11) would not much affect  $E_{g,0}(MR)$ . For the same reason  $\Delta WP_i$  in (6) can be omitted.

Hence assuming  $\beta_f = \beta_g$ , (11) can be simplified to

$$(12) \quad E_{g,0}(MR) = E_{f,0}(MR) - \sum \beta_g^i Q_i \frac{Y_i \cdot E_{g,0}(WP_i)}{Q_i^v \cdot e_i}$$

The optimal new plantings at time 0 ( $NP_0$ ), given (12), can be determined by solving

$$(15) \quad \sum \beta^i Y_i \cdot (E_{f,0}(WP_i) - TX_i) = \sum \beta^i Y_i (E_{g,0}(WP_i) - SH_i \cdot E_{g,0}(WP_i) / e_i)$$

From (15), an obvious solution for the optimal tax for  $i=m1, \dots, m2$  evaluated in period 0 is

$$(16) \quad TX_i = E_{f,0}(WP_i) - E_{g,0}(WP_i) \left(1 - \frac{SH_i}{e_i}\right)$$

Below the optimal tax is derived under different assumptions about price expectation formations. But first we examine cases in which the optimal tax cannot be determined.

(i) Cases in which the Optimal Tax Cannot be Determined

It is clear from (16) that the optimal tax cannot be determined unless farmers' and the government's expectations are specified. A likely case is the government's expectation is specified but the government does not know how farmers' expectations on prices and tax are formed. In this case, the optimal tax is indeterminate. Such situation can arise, if in the past, real producer prices have been fluctuating widely due to, for example, erratic exchange rates or tax policies and/or the inflation rate have been fluctuating widely. In these cases, farmers may have little idea what real producer prices to expect. Then optimal tax is indeterminate because whatever tax the government imposes in period 0, farmers are not likely to believe that it will persist. Therefore, taxes have no effect on farmers' expected revenues from new plantings and hence taxes have no effect on new plantings.

Even when farmers' and the governments' expectations are specified, the optimal tax is indeterminate if farmers' expectations are independent of

$$(13) \quad MC(NP_0) = E_{f,0}(MR) - \sum \beta_g^i Q_i \frac{Y_i \cdot E_{g,0}(WP_i)}{Q_i^w \cdot e_i}$$

Because  $Q_i$  is the level of production when  $NP_0 = 0$ , it is not a function of  $NP_0$ . Thus, in Figure 2  $E_{g,0}(MR)$  is a straight line below  $E_{f,0}(MR)$  with the difference being the second term of the RHS of (13). The optimal new plantings for the country is shown as  $NP_{g,0}^*$  in Figure 2.

### III. Optimal Export Tax

The purpose of a tax on the export of perennials is to put a wedge between world prices and producer prices so as to maximize the country's welfare. The optimal tax is that which makes the farmers' expected marginal revenue the same as the country's.<sup>4</sup> To this end the farmers' expectations have to be changed from  $E_{f,0}(MR)$  to  $E_{g,0}(MR)$ .

From (4) and (12), we obtain

$$(14) \quad \sum \beta_f^i Y_i (E_{f,0}(WP_i) - TX_i - PC) = \sum \beta_g^i Y_i (E_{g,0}(WP_i) - PC) - \sum \beta_g^i \cdot Y_i \cdot \frac{Q_i \cdot E_{g,0}(WP_i)}{Q_i^w \cdot e_i}$$

The general formula for the optimal tax is (14). Assuming  $\beta_f = \beta_g$  (this is assumed for the rest of the paper unless specified otherwise and  $\beta$  replaces  $\beta_f$  and  $\beta_g$ ) and denoting  $SH_i = Q_i/Q_i^w$  we obtain

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<sup>4</sup> Of course, the optimal tax is zero if farmers' expected marginal revenue is the same as the country's.

recent prices or taxes. The problem occurs because in such a case there is no link between the tax to be imposed for the periods between  $m_1$  and  $m_2$  and the tax at period 0 in view of the fact that (16) specifies the optimal tax for periods  $m_1$ - $m_2$ . Because farmers' price expectations change with time, the optimal tax rates for periods 0 are continuously indeterminate. In other words, the optimal tax is relevant only to the extent that it can change farmers expected marginal revenue flows of the future period  $m_1$  to  $m_2$ .

A particular case of interest is when price expectations held by farmers and the government are the same and are independent of recent prices or taxes. Then the optimal tax formula can be obtained by inserting  $E_{f,0}(WP_i) = E_{g,0}(WP_i)$  into (16) which gives

$$(17) \quad TX_i^{*1} = SH_i \cdot E_{g,0}(WP_i) / e_i$$

The optimal tax rate given in (17) looks similar to that given by Imran and Duncan except for the subscript  $i$ . But as discussed above, (17) cannot determine the optimal tax rate for period 0.

(ii) Farmers Expect the Current Tax or Tax Rate to Continue

The optimal tax rate can be determined if we can assume that farmers expect the current tax or current tax rate to continue.

In this case (15) becomes

$$(18) \quad \sum \beta^i Y_i E_{f,0}(WP_i) (1 - TXR_0) = \beta^i Y_i E_{g,0}(WP_i) (1 - SH_i / e_i)$$

Then the optimal tax rate at period 0 is



$$(19) \quad TXR_0^{*2} = \frac{\sum \beta^i Y_i E_{g,0}(WP_i) SH_i / e_i}{\sum \beta^i Y_i E_{f,0}(WP_i)}$$

and the producer price

$$(20) \quad PP_0^{*2} = WP_0 \left( 1 - \frac{\sum \beta^i Y_i E_{g,0}(WP_i) SH_i / e_i}{\sum \beta^i Y_i E_{f,0}(WP_i)} \right)$$

(19) implies that once the farmers' and the government's price expectations are specified, the optimal tax rate can be determined. Note that in this case the optimal tax rate is not a function of the current world price and the producer price, hence it would not change with changes in the current world price.

(iii) Farmers Expect the Current Producer Price to Continue  
(Farmers' Naive Case)

In this case, from (15)  $TX_0$  should be the level that satisfies

$$(21) \quad (WP_0 - TX_0 - PC) \sum \beta^i Y_i = \sum \beta^i Y_i \left[ E_{g,0}(WP_i) - \frac{SH_i \cdot E_{g,0}(WP_i)}{e_i} - PC \right]$$

The optimal tax is then,

$$(22) \quad TX_0^{*3} = WP_0 - \frac{\sum \beta^i Y_i E_{g,0}(WP_i) \left( 1 - \frac{SH_i}{e_i} \right)}{\sum \beta^i Y_i}$$

and the optimal tax rate

$$(23) \quad TXR_0^{*3} = 1 - \frac{\sum \beta^i Y_i E_{g,0}(WP_i) \left(1 - \frac{SH_i}{e_i}\right)}{WP_0 \cdot \sum \beta^i Y_i}$$

The producer price in this case is, from (23),

$$(24) \quad PP_0^{*3} = WP_0 (1 - TXR_0^{*3}) = \frac{\sum \beta^i Y_i E_{g,0}(WP_i) \left(1 - \frac{SH_i}{e_i}\right)}{\sum \beta^i Y_i}$$

The producer price given by (24) implies that the optimal tax should be such that the producer price not change with  $WP_0$ . This is an extreme case of a progressive tax and suggests that producer prices should be at the same level over long periods of time as other variables in (24) do not change.

(iv) Farmers' Price Expectations are Based on a Weighted Average of Current and Past Prices

A more general case of the "farmers' naive case" is when farmers' expected prices are based on a weighted average of the current and the past producer prices or

$$(25) \quad E_{f,0}(WP_1) = \sum_{j=0}^{-n} \lambda_j (WP_j - TX_j)$$

where

$$\sum_{j=0}^{-n} \lambda_j = 1$$

The optimal tax rate in this case is

$$(26) \quad TXR_0^{*4} = 1 + \frac{\sum_{j=1}^{-n} \lambda_j (WP_j - TX_j)}{\lambda_0 \cdot WP_0} - \frac{\sum \beta^i Y_i E_{g,0} (WP_i) (1 - \frac{SH_i}{\epsilon_i})}{\lambda_0 \cdot WP_0 \cdot \sum \beta^i Y_i}$$

Substituting  $PP_j = WP_j - TX_j$ , the producer price in this case is

$$(27) \quad PP_0^{*4} = WP_0 (1 - TXR_0^{*4}) = \frac{\sum_{j=1}^{-n} \lambda_j PP_j}{\lambda_0} + \frac{\sum \beta^i Y_i E_{g,0} (WP_i) (1 - \frac{SH_i}{\epsilon_i})}{\lambda_0 \sum \beta^i Y_i}$$

$PP_j$  after  $n$  periods becomes  $PP_0$  if the expected value of  $\sum \beta^i Y_i E_{g,0} (WP_i) (1 - SH_i/\epsilon_i)$  for the period  $i=m_1+n, \dots, m_2+n$  does not change from that for the period  $i=1, \dots, m$ . This is a reasonable assumption if  $n$  is short compared with  $m_1$  and  $m_2$ .

Then (27) becomes

$$(28) \quad PP_n^{*4'} = \frac{\sum \beta^i Y_i E_{g,0}(WP_i) \left(1 - \frac{SH_i}{e_i}\right)}{\sum \beta^i Y_i}$$

and the optimal tax rate is

$$(29) \quad TXR_n^{*4'} = 1 - \frac{\sum \beta^i Y_i E_{g,0}(WP_i) \left(1 - \frac{SH_i}{e_i}\right)}{WP_0 \sum \beta^i Y^i}$$

(28) and (29) imply that after n periods, the producer price becomes independent of the current world price as in the naive expectation case. Note also that the optimal tax rate and producer price become the same as the naive case of (23) and (24) respectively, after n periods.

(v) Price expectations of Farmers and Government are Based on a Weighted Average of Current and Past Prices

Assume that farmers' expected producer prices are as in (25) and the government's are

$$(30) \quad E_{g,0}(WP_i) = \sum_{j=0}^{\infty} \lambda_j^G WP_j$$

where

$$\sum_{j=0}^{\infty} \lambda_j^G = 1$$

The optimal tax rate, in this case, is

$$(31) \quad TXR_0^{*5} = 1 - \frac{\lambda_0^G}{\lambda_0} \left( 1 - \frac{\sum \beta^i Y_i SH_i / e_i}{\sum \beta^i Y_i} \right) \\ + \frac{1}{WP_0 \cdot \lambda_0} \left( \sum \lambda_j PP_j - \sum \lambda_j^G WP_j + \frac{\sum \beta^i Y_i \frac{SH_i}{e_i} \sum \lambda_j^G WP_j}{\sum \beta^i Y_i} \right)$$

and the producer price

$$(32) \quad PP_0^{*5} = \frac{\lambda_0^G}{\lambda_0} \left( 1 - \frac{\sum \beta^i Y_i \frac{SH_i}{e_i}}{\sum \beta^i Y_i} \right) WP_0 + \frac{\sum \lambda_j^G WP_j}{\lambda_0} \\ + \frac{\sum \beta^i Y_i \frac{SH_i}{e_i} \sum \lambda_j^G WP_j}{\lambda_0 \sum \beta^i Y_i} - \frac{\sum \lambda_j PP_j}{\lambda_0}$$

Note that in (31), (32) and (33), summation of  $j$  is from  $-1$  to  $-n$  for  $\lambda_j$  and from  $-1$  to  $-g$  for  $\lambda_j^G$ .

If we assume  $SH_i = 0$  and rearrange (32) we obtain

(33)

$$\lambda_0 PP_0^{*5'} + \sum \lambda_j PP_j = \lambda_0^g WP_0 + \sum \lambda_j^g WP_j$$

It can be seen from (33) that a role of the optimal tax is to change the producer price so that farmers' expected prices become the same as those of the government. Hence even when a country's market share is small, tax and subsidies can be imposed to change farmers' expectation to the government's. It should be noted that in equations (33) the optimal tax could be positive or negative (subsidy).

(vi) Effects of the Government's Price Expectations on the Optimal Tax

An important caveat to the above derivations of the optimal tax is that they are only optimal provided that the government's expectations about world prices ( $E_{g,0}(WP_i)$ ) subsequently turn out to be realized. Because future world prices are not known when an export tax is imposed, the optimal taxes as derived above are essentially "estimated" optimal taxes. The closer the government's expected world prices are to subsequently realized world prices, the closer the optimal tax is to the true optimal level.

IV. An Alternative Approach to Solving for the Optimal Export Tax

The approach taken above derived the optimal tax from equating the marginal revenue and marginal cost of new plantings. A more comprehensive approach would be to express national welfare in terms of the tax and search for the maximizing point. This approach allows us to take into account the effects of the tax on short-term supply response. The case considered here is that where farmers' price expectations are naive. Other cases can be derived similarly.

(i) Effects of Export Tax on Welfare in Period 0

In period 0, the tax affects new plantings and hence the cost of new plantings. Also, it affects the producer surplus and the government revenue as shown in Figure 3.

Farmers undertake new plantings up to the point where their expected marginal revenue is equal to the marginal cost. Thus,

$$(34) \quad E_{t,0}(MR) = f(NP_0)$$

Then the total cost of new plantings in period 0 is

$$(35) \quad CNP_0 = \int_0^{NP_0} f(NP_0) dNP_0$$

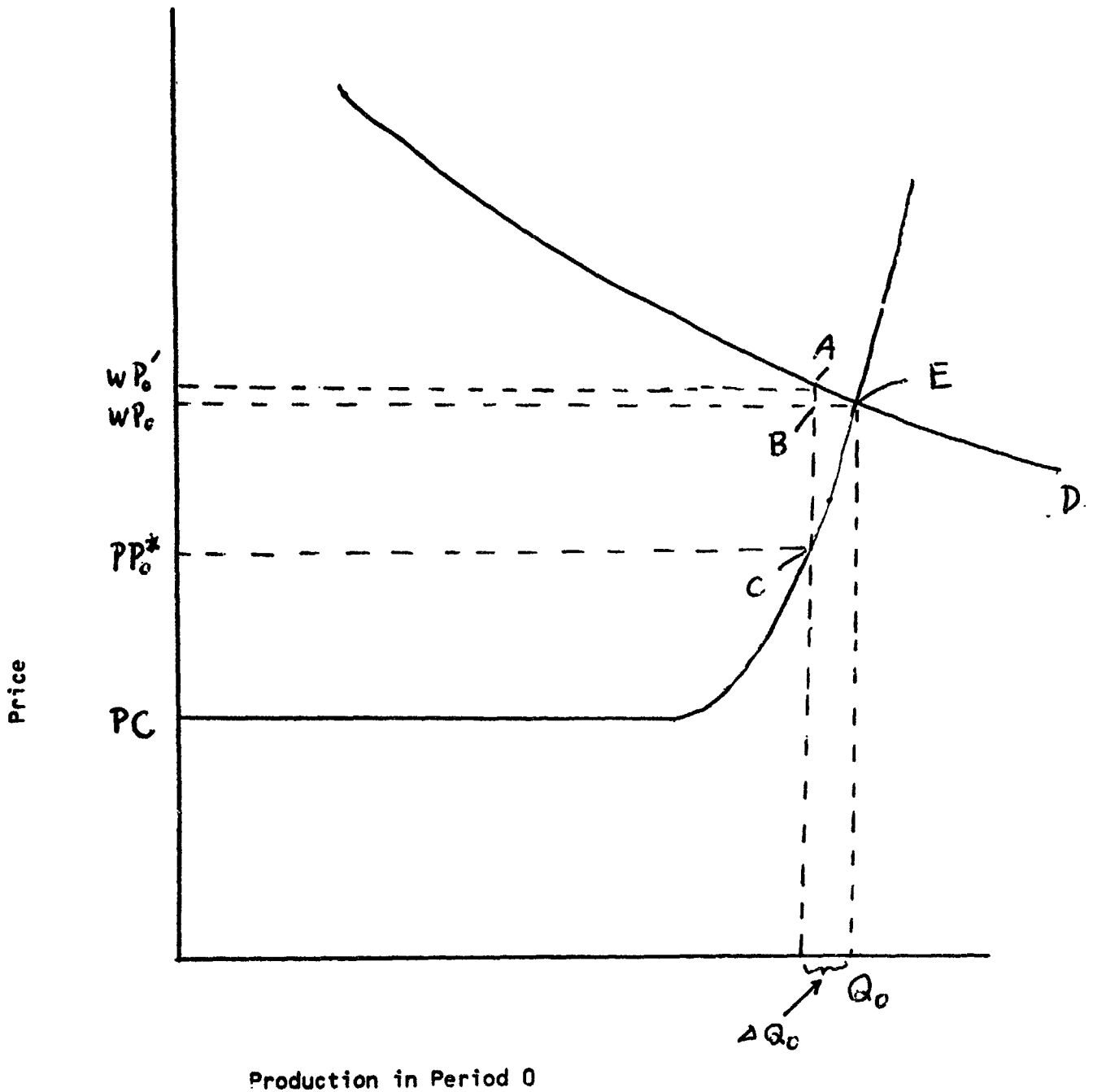


Figure 3: Effects of Export Tax on Welfare in Period 0



Assume the marginal cost curve for the new plantings in period 0 to be linear, i.e.,

$$(36) \quad MC(NP_0) = a_0 + a_1 NP_0$$

Given an export tax, new plantings when farmers' price expectations are naive are equal to

$$(37) \quad NP_0 = \frac{\sum \beta^i Y_i (WP_0 - TX_0 - PC) - a_0}{a_1}$$

The cost of new plantings in period 0 can be derived by inserting (39) into (37)

$$(38) \quad CNP_0 = \frac{[\sum \beta^i Y_i (WP_0 - TX_0 - PC)]^2 - a_0^2}{2a_1}$$

In Figure 3,

$$(39) \quad \Delta D = -e_{s,0} \frac{WP'_0 - WP_0}{WP_0} \cdot D_0$$

where  $D_0$  = demand facing the country in period 0 when there is no tax  
 $WP_0$  = world price without tax  
 $WP'_0$  = world price when tax is imposed

$\epsilon_{s,0}$  = price elasticity of supply in period 0

$$(40) \quad \Delta Q_0 = -\epsilon_{s,0} \frac{WP_0 - PP'_0}{WP_0} \cdot Q_0$$

where  $Q_0$  = supply of the country without tax  
 $\Delta Q_0$  = change in supply of the country due to tax  
 $PP'$  = producer price with tax

Also, by definition

$$(41) \quad PP'_0 = (1 - TXR_0) WP'_0$$

Because  $\Delta D_0 = \Delta Q_0$  and  $D_0 = Q_0$ , inserting (41) into (40) and equating it with (39), we obtain

$$(42) \quad \Delta WP_0 = WP'_0 - WP_0 = \frac{\epsilon_{s,0} \cdot TXR_0 \cdot WP_0}{\epsilon_0 - \epsilon_{s,0} \cdot TXR_0 + \epsilon_{s,0}}$$

The welfare change in period 0,  $\Delta W_0$ , due to imposition of the export tax is

$$(43) \quad \Delta W_0 = \Delta PP_0 (Q_0 - \Delta Q_0) - \frac{1}{2} \Delta Q_0 (WP_0 - PP'_0)$$

The first term of the RHS of (43) is the area  $WP'_0 ABWP_0$  and the second term is

the area BCE in Figure 3. Because  $\epsilon_{s,0}$  is small in the case of perennials,  $Q_0$  is considerably bigger than  $\Delta Q_0$ , and hence (43) can be approximated by

$$(44) \quad \Delta W_0 = \Delta WP_0 \cdot Q_0$$

Substituting (42) into (44), we obtain the formula for the change in welfare as,

$$(45) \quad \Delta W_0 = \frac{\epsilon_{s,0} \cdot WP_0 \cdot Q_0 \cdot TXR_0}{\epsilon_0 + \epsilon_{s,0} (1 - TXR_0)}$$

(ii) The Effects of an Export Tax on Welfare During Periods when New Plantings are Bearing

The welfare effects of the tax over this period ( $i = m1, \dots, m2$ ) can be obtained from (12) assuming that the subsequently realized prices are the government's expected prices.

$$(46) \quad \Delta W_{m1-m2} = \sum \beta^i Y_i \cdot NP_0 \left[ E_{g,0}(WP_i) - \frac{SH_i \cdot E_{g,0}(WP_i)}{\epsilon_i} - PC \right]$$

Substituting (37) for  $NP_0$  in (46) gives the welfare change as a function of tax

$$(47) \quad \Delta W_{m1-m2} = \sum \beta^i Y_i \left[ E_{g,0}(WP_i) - \frac{SH_i \cdot E_{g,0}(WP_i)}{\epsilon_i} - PC \right] \frac{\sum \beta^i Y_i (WP_0 - WP_0 \cdot TXR_0 - PC) - a_0}{a_1}$$

(iii) Solving for the Optimal Tax

The expected total national welfare in period 0 ( the year when new plantings are being made)  $TW_0$ , can be expressed as

$$(48) \quad TW_0 = -CNP_0 + \Delta W_0 + \Delta W_{m1-m2}$$

Substituting (38), (45) and (47) into (48) and taking the derivative of  $TXR_0$  and setting it to zero gives,

$$(49) \quad Z^2 WP_0 (\sum \beta^i Y_i)^2 - Z^2 WP_0 (\sum \beta^i Y_i)^2 \cdot TXR_0$$

$$+ a_1 e_0 \cdot e_{s,0}^2 \cdot Q_0 - Z^2 \sum \beta^i Y_i \sum \beta^i Y_i E_{g,0} (WP_i) \left(1 - \frac{SH_i}{e_i}\right) = 0$$

where  $z = \epsilon_0 - \epsilon_{s,0} \cdot TXR_0 + \epsilon_{s,0}$

Hence, the optimal tax rate is

$$(50) \quad TXR_0^{*3'} = 1 - \frac{\sum \beta^i Y_i \left(1 - \frac{SH_i}{e_i}\right)}{WP_0 \sum \beta^i Y_i} + \frac{a_1 \cdot e_0 \cdot e_{s,0}^2 \cdot Q_0}{Z^2 WP_0 (\sum \beta^i Y_i)^2}$$

Substituting (23), i.e., the optimal tax rate without taking the short-term effect into account, into (50), gives

$$(51) \quad TXR_0^{*3'} = TXR_0^{*3} + \frac{a_1 \epsilon_0 \epsilon_{s,0}^2 Q_0}{Z^2 WP_0 (\sum \beta^t Y_t)^2}$$

(51) is a cubic function of  $TXR_0^{*3'}$  because  $Z$  is a function of tax.

The implication of (51) is that when the short-term price elasticity of supply ( $\epsilon_{s,0}$ ) is non-zero, the optimal tax derived from taking only the long-term supply response into account should be adjusted upward (the second term of the RHS of (51) is positive) to take into account the effects of the tax on welfare in period 0. It is evident from (51) that the larger  $Q_0$ , the larger the adjustment.

#### V. Quantification of the Optimal Tax

A computer model was constructed on the basis of the above specifications to calculate optimal tax and welfare for perennial crop exporting countries. The model was applied to several major cocoa producing countries to estimate the optimal export tax.<sup>5</sup> However, only the results for Ghana are reported here.

The main inputs required for the model are;

- (i) Forecasts of world cocoa prices,
- (ii) Forecasts of cocoa production by the rest of the world consistent with (i),
- (iii) Forecasts of cocoa production of the country concerned without any new plantings,

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<sup>5</sup> Details of the model applications to and assumptions used for several major cocoa producing countries in Africa are given in Coleman, Varangis and Akiyama (forthcoming).

- (iv) Cocoa yield curve for the country,
- (v) Real discount rate,
- (vi) Area under cocoa in recent years,
- (vii) Recent data on new plantings and producer prices,
- (viii) Marketing costs,
- (ix) Average production costs,
- (x) Assumptions about how the farmers and the government form price expectations.

The main outputs of the model are:

- (i) Sum of discounted flow of producer surplus, government revenues, the sum of the two which is the national welfare, and export revenues,
- (ii) Optimal tax rates -- the optimal tax rate can be calculated under various assumptions about the way farmers and governments form price expectations. The tax rates can also be made exogenous,
- (iii) Forecasts of new plantings, area under cocoa, and production for the country.
- (iv) Revised world prices -- the model calculates a new set of world price forecasts consistent with new plantings projected by the model,

Projected world prices and production by the rest of the world were obtained from the World Bank's world cocoa model. The welfare values have been calculated for a 30-year period starting from 1991 and evaluated at 1991.

Government revenue is defined as the sum of the discounted flow of tax revenues from the commodity over the next 30 years, i.e.,

(52)

$$W_G = \sum \beta^i Q_i WP_i TXR_i$$

Farmers' welfare is defined as the sum of the discounted flow of producer surplus less the new planting costs, i.e.,

(53)

$$W_f = \sum \beta_f^i Q_i (WP_i - TXR_i WP_i - PC) - \sum \beta_f^i CNP_i$$

The national welfare is the sum of (52) and (53).

Model simulations were carried out under various assumptions. All welfare values are in constant 1991 terms. These assumptions and the results for Ghana are given in Table 1. In Table 1 "Tax = Optimal" implies that the model calculated the optimal tax for each year. "Optimal - 10%" implies that the model was run with an exogenously-fixed tax rate of the optimal rate plus 5% every year. Cases IX and X are with exogenously-fixed tax rates of 0% and 30%, respectively. "Net Producer Surplus" is defined as "Producer Surplus" less "Cost of New Plantings". For expectations, "Naive" implies that farmers expect the current real producer price to continue. "WB Project" implies that the government uses the World Bank's cocoa price projections as the base but also takes into account the effects on world prices of future new plantings in the country. This implies that the government has perfect foresight about world prices as it is assumed in the model calculations that the prices projected by the World Bank adjusted for the effect of the country's production are actually realized. "Weighted" implies that the government's price expectation is that of equation (30) where  $\lambda_0^G=0.5$ ,  $\lambda_1^G=0.3$ ,  $\lambda_2^G=0.2$  and  $\lambda_j=0$  for  $j=-3, \dots, -n$ .

**Table 1: Ghana: Simulation Results on Changes in the Export Tax on Cocoa**

Case	Export Tax Rate			Producer Price for Cocoa		
	Year 1	Year 5	Year 10	Year 1	Year 5	Year 10
	----- % -----			( 1991 US\$/ton )		
<u>Government's Expectation - WB Proj.</u>						
I (Tax = Optimal - 5%)	-12	3	10	977	993	986
II (Tax = Optimal)	-7	8	15	919	926	918
III (Tax = Optimal - 5%)	-2	13	20	861	859	850
<u>Government's Expectations - Weighted</u>						
IV (Tax = Optimal - 10%)	2	6	6	817	950	1052
V (Tax = Optimal - 53%)	7	11	11	759	883	983
VI (Tax = Optimal)	12	16	16	701	816	915
VII (Tax = Optimal + 5%)	17	21	21	643	749	845
VIII (Tax = Optimal + 10%)	22	26	26	585	681	775
IX (Tax = Fixed at 10%)	0	0	0	840	1029	1137
X (Tax = Fixed at 30%)	30	30	30	492	627	722
XI (Tax = Optimal, MC=\$270/ton)	12	16	17	746	857	950
XII (Tax = Optimal, HC=\$300/ton)	12	16	17	696	807	900
XIII (Tax = Optimal, FDS=10%)	10	13	12	725	856	985
XIV (Tax = Optimal, ER=10% deval.)	13	17	18	719	825	910
XV (Tax = Optimal, W.B. Proj. lowered by 10% after 1995)	11	16	15	707	793	807

Basic Assumptions: Farmers' Price Expectation - Naive; Government's Price Expectation - Weighted; Marketing Costs (MC) - \$320/ton; Harvesting and Maintenance Costs (HC) - \$350/ton; Country's Discount Rate - 5%; Farmers' Discount Rate (FDS)=5%; Exchange rate (ER) - unchanged



Table 1 (Continued)

Case	Producer Surplus	Cost of New Plantings	Net Producer Surplus	Government Revenue	National Welfare	Production	
						Year 10	Year 20
	--- (Sum of Discounted Flows over 30 years, Million 1991 US\$) ---					-----('000 tons) -----	
I	3573	710	2863	543	3405	314	428
II	3088	542	2546	889	3435	306	398
III	2630	403	2227	1207	3433	299	369
IV	3709	728	2981	388	3369	300	428
V	3210	552	2658	748	3405	292	398
VI	2737	407	2330	1079	3409	285	369
VII	2291	290	2002	1383	3385	278	341
VIII	1872	196	1676	1660	3336	270	314
IX	4237	956	3281	0	3281	305	462
X	1482	131	1351	1913	3264	261	291
XI	2998	485	2513	1161	3673	290	386
XII	2998	485	2512	1161	3673	290	386
XIII	2675	117	2557	708	3265	265	287
XIV	3054	604	2451	1277	3728	296	408
XV	2310	301	2009	892	2901	284	344

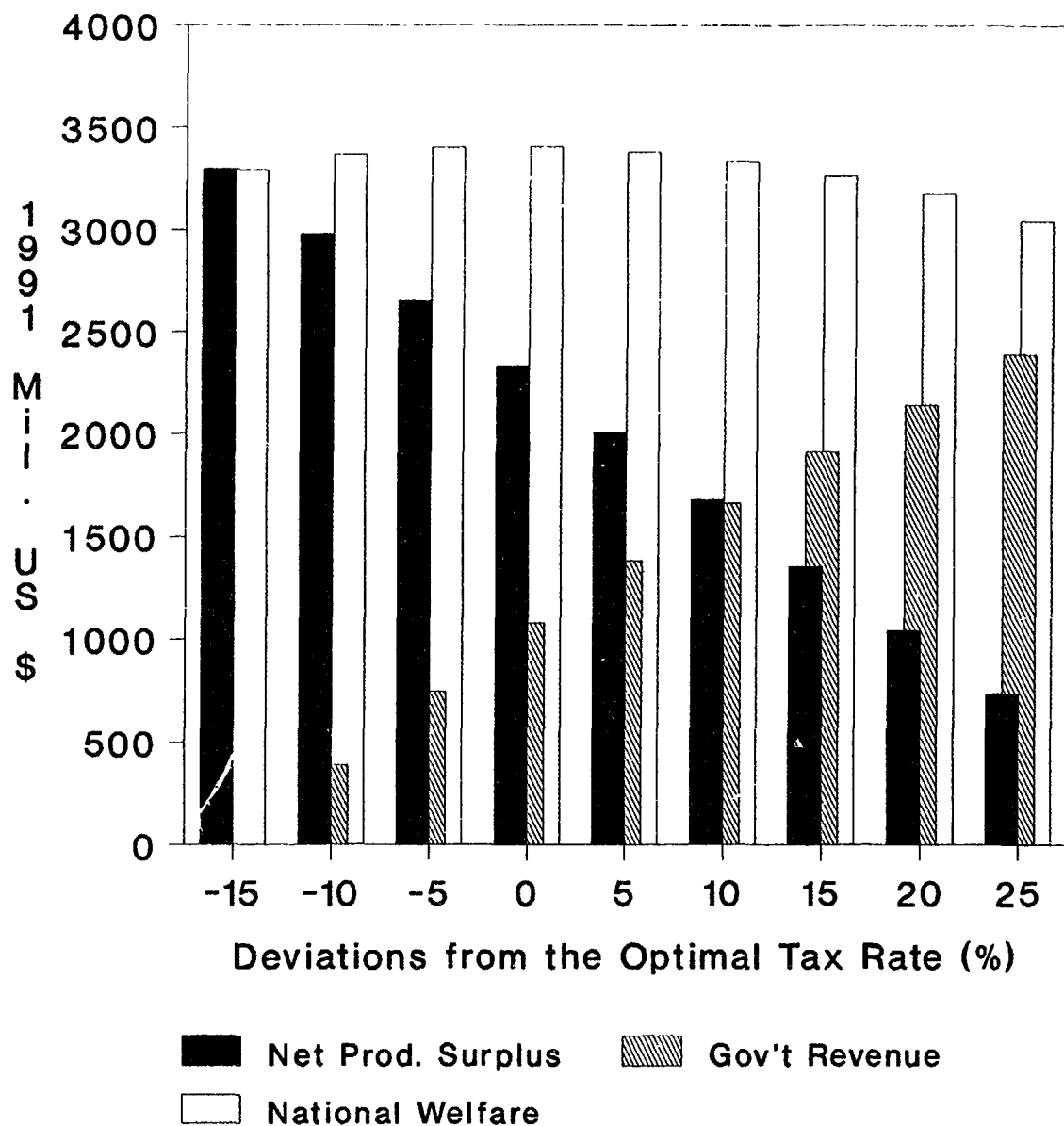
Basic assumptions used in the model are given at the bottom of Table 1. All the simulation shown in Table 1 are with the assumption that farmers' expectation is "naive" and social discount rate is 5% in real terms.

The formula used in the simulations for the optimal tax rate is that given by equation (23) for the cases in which the farmers' expectations are "Naive" and the government's "WB Proj." The formula is equation (31) for the cases in which the farmers' expectations are "Naive" and the government's "Weighted". The adjustment necessary to take into account the short-term supply response, the second term of the RHS of equation (51) for Ghana was found to be 2.5% under the assumption that the short-term price elasticity of supply,  $\epsilon_{s,0}$ , is 0.1. This adjustment is incorporated in the model.

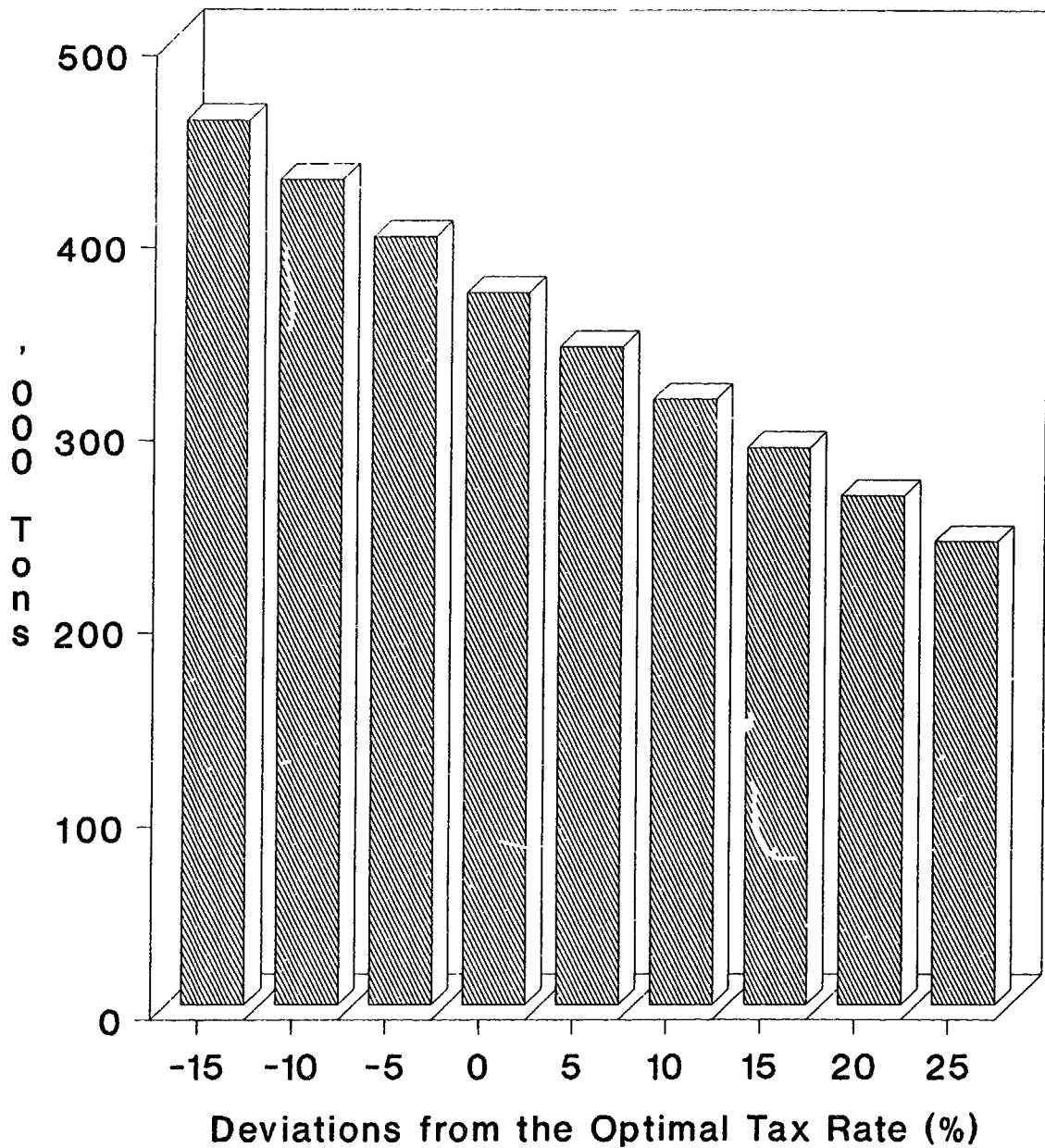
The simulation results given in Table 1 indicate that the optimal tax rates vary significantly depending on the ways in which farmers and governments form price expectations. For instance, the optimal tax rate for period 1 when the farmers' expectation are naive and the government has perfect foresight (Case II) the optimal tax rate is negative, implying subsidies. The subsidies are required because the government's best action -- given world prices are projected to increase -- is to raise producer prices substantially in period 1 to encourage new plantings so that the farmers and the government can reap larger benefits in the future when world prices are considerably higher than in period 1.

Probably the most striking revelation of the simulation results is that national welfare changes little with changes in the export tax around the optimal level. As shown in Figure 4, when the farmers' and the government's price expectations are "naive" and "weighted" respectively, the difference in national welfare between an optimal tax case (Case VI) and 10% above the optimal (Case VIII), is only 2.1%. However, producer welfare and government revenues

**Fig. 4: Ghana: Impact of Changes in  
Export Tax on Cocoa.**  
(Sum of Discounted Flows Over 30 Years)



**Fig. 5: Ghana: Effect of Changes in  
Cocoa Export Tax on Long-Term Production  
(Projected Production in Year 2011)**



change sharply. When the tax is increased by 10% throughout the period (Case VIII), net producers' welfare declines by 28% and the government's revenue increases by 54%. Another observation is that the effect of changes in the export tax on production over the long-run is large. The model projects production in year 2011 to be 15% and 28% lower if the tax is 10% and 20% higher than the optimal tax respectively (see Table 1 and Figure 5).

Case IX shows that if the export tax is set at zero throughout the period, the national welfare is only 4% lower than in the optimal tax case. In this case, production in the year 2011 is 25% higher at 462,000 tons. Case X shows that if the recent tax level of about 30% continues to be applied, the national welfare and the net producer surplus would be 4.3% and 4.5% lower, respectively, than the case of the optimal tax. Results here suggest that the recent actual tax rates on cocoa in Ghana have been too high and production could decline from the present level unless measures are taken on production cost, marketing cost, interest rate or real exchange rate.

The impacts on welfare of changes in marketing and production costs, the exchange rate, and the discount rate are estimated to be significant. As shown in Table 1, (Cases XI and XII) a reduction of \$50/ton in marketing costs from the current level of \$320/ton or in production costs from the current estimated \$350/ton would increase national welfare by 7.7% (see Figure 6). It is to be noted that the analysis in this paper shows that the effect on welfare of a change in marketing costs or production costs are the same. In this case, the optimal tax rates are higher because Ghana's market share increases.

Case XIII, which assumes the government's discount rate to be 5% and the farmers' to be 10%, is an interesting case. In this case, the new planting levels go down due to the high farmers' discount rate. Because of the low new plantings level, the total cost of new plantings is small and the producers' net welfare calculated using the social discount rate of 5% is higher than in the

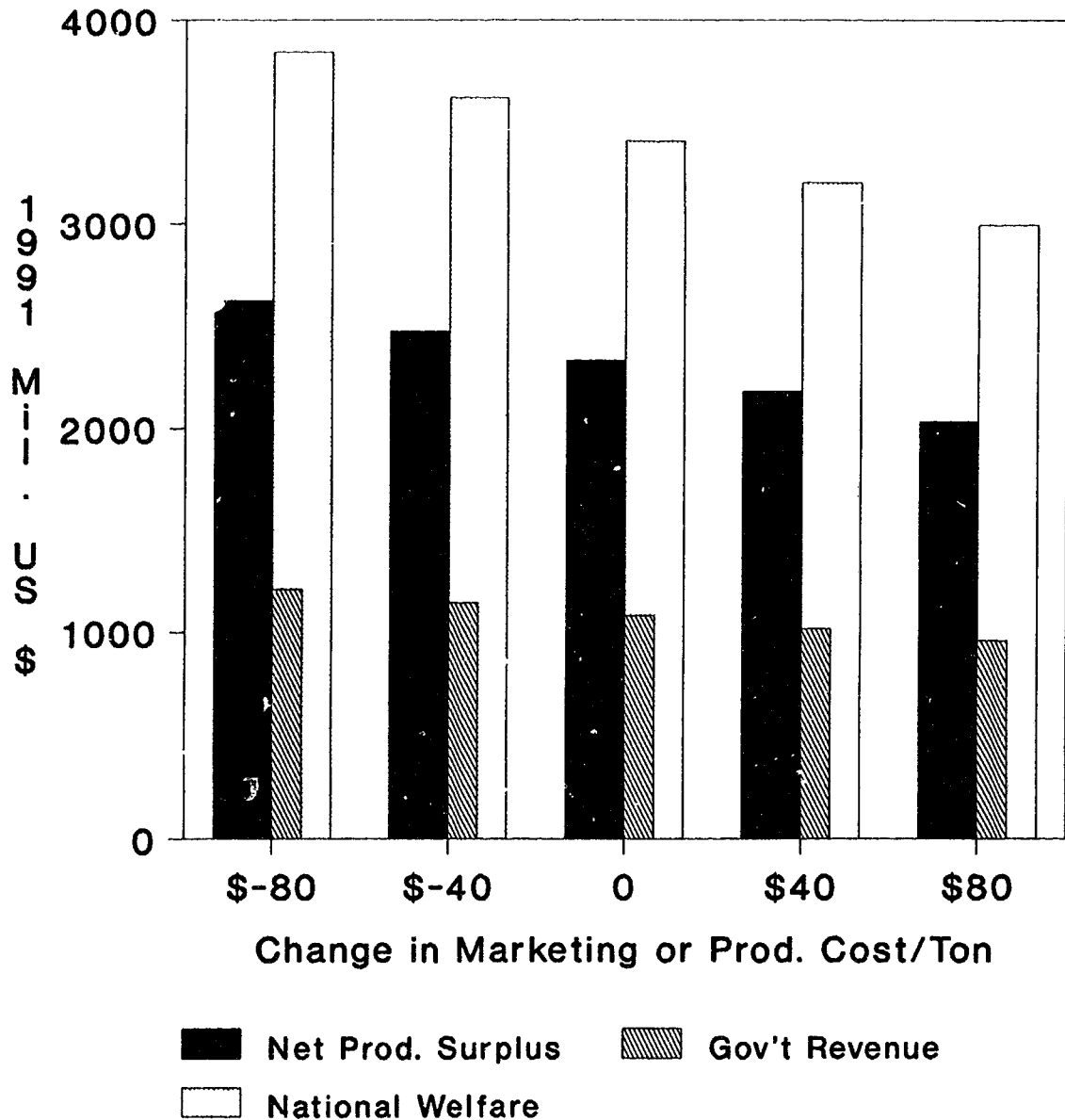
optimal case. This implies that the farmers would be living mainly on past investments and not undertaking new investments. This, has an important negative impact on long-run production. The optimal tax rates are lower because Ghana's market share declines.

The effects of a change in the real exchange rate are also significant. A 10% real devaluation would increase the national welfare in terms of constant US\$ and constant Cedis by 9% and 19%, respectively (Case XIV). However, note that the optimal tax rates are slightly higher because of Ghana's larger market share.

Case XV shows the important impact of world prices on welfare. If world cocoa prices after 1995 are 10% lower than what the Bank has projected, then national welfare would be 15% lower and the optimal tax rate is slightly lower because of Ghana's smaller share.

The findings above are basically in concordance with those of Newbery (1990). The points Newbery made include; (i) producer prices should be at least 55% of f.o.b., (ii) the risks of setting producer price too low appear to be higher than the risks in the other direction, and (iii) there appears to be good reason to try and stabilize the real producer prices through adjustments of tax rates. Newbery's last point can also be supported by the analysis in this paper because given long-term world cocoa prices, producers' incentives should not fluctuate with short-term world price fluctuations. However, with such a pricing policy, there is a risk of misjudging long-term cocoa prices and give incorrect incentives.

**Fig.6: Ghana: Welfare Effects of Changes  
in Marketing and Production Costs  
(Sum of Discounted Flows Over 30 Years)**



## VI. Concluding Remarks

The paper presents analytical solutions to the calculation of optimal tax for perennial crops and their implications for the impact on producer surplus and government reserves. It then provides the results of numerical simulations under a variety of parameter assumptions, for the case of cocoa in Ghana.

The analysis demonstrated that the basic effect of the optimal tax is to adjust the producer price so that the farmers' expected marginal revenue from new plantings becomes the expected marginal revenue of the country. The paper shows that the most important factors to be taken into account in determining the export tax on perennials are how farmers and the government form price expectations. The paper shows that when farmers' expectations are unknown or not dependent on recent prices or taxes, the optimal tax is indeterminate. Also, if the government's expected world prices are far from subsequently realized world prices, then in retrospect the optimal tax implemented would be far from the optimal level.

Analysis on the effects of price expectations on the optimal tax indicates that if a government wants to impose an optimal export tax on perennials, it needs to have good knowledge of farmers' price expectations and prospects for world prices. Under the assumption that farmers' expectations on prices and tax rates are based on recent levels, the paper showed that the optimal tax depends on a number of factors, including, the way the government forms its price expectations, the discount rate, the yield curve of new plantings, and the expected market share of the country.<sup>6</sup>

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<sup>6</sup> A factor that was not taken into account in the paper was risk preferences. If farmers are risk-averse and the government risk-neutral, the term in the bracket on the LHS of equation (16) becomes  $E_{f,0}(WP_1) - TX_1 - PC - RP$ . Where RP is the risk benefit defined in Newbery and Stiglitz (1981) as,  $0.5 R\Delta\sigma^2$  where R is the coefficient of relative risk-aversion and, in this case,  $\sigma$  is the coefficient of variation of producer prices. This implies that if farmers are risk-averse and producer prices have been fluctuating, the optimal tax rates should be lower than those derived in the paper.



The application of the analysis using a computer model for Ghana's cocoa subsector revealed that the national welfare does not vary much over a wide range of export tax rates around the optimal level, but that the export tax rate does have an important impact on the distribution of the national welfare between the farmers and the government. It also has a significant effect on production over the long-run. The computer model simulation results showed that the optimal tax rates do not vary much with exchange rates, production costs and marketing costs in the medium-run.

These results imply that when determining the level of the export tax the government should give more importance to the tax's effects on the long-term production and the distribution of the national welfare than on maximizing the national welfare, as long as the rate is not too far from the estimated optimal level (note that the government can only pose "estimated optimal tax" because the tax is dependent on the government's expected prices). A consideration in this context is the relative importance of the welfare weight of each dollar to farmers and the government.<sup>7</sup> The question of the welfare weight becomes important in deciding on the distribution of the national welfare and hence the tax rate. For example, if it is considered that the farmers' consumption of a unit of currency is more efficient in increasing the national welfare than the government's, then the distribution should be in favor of the farmers, ceteris paribus.

The simulation results also showed that for Ghana's cocoa subsector changes in the exchange rate, marketing costs, production costs, and discount rate have a significant impact not only on the national welfare but also on long-run production. Simulation results under several assumptions revealed that the recent export tax rate on cocoa in Ghana of about 30% is considerably higher than the optimal tax rate estimated in the paper. If the current tax rate is continued, production could decline from the recent level.

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<sup>7</sup> This question was also discussed in Trivedi and Akiyama (forthcoming).

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