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BIOECONOMIC MODELLING OF THE PRODUCTION AND EXPORT OF COCOA FOR PRICE POLICY ANALYSIS IN PAPUA NEW GUINEA

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ABSTRACT

The purpose of this paper is to describe the bioeconomic modelling procedures established to assess the worth of different price policy options in the cocoa industry in Papua New Guinea. Separate models are developed for smallholders and estates using the Stella *simulation software package. The need for bioeconomic modelling is dictated by the nature of cocoa as a perennial crop that is produced by two groups of farmers using different production technologies—estates and smallholders—and sold in an uncertain export market.*

A detailed description is given of the structure of each model, using the smallholder cocoa industry as an example. Each model comprises eight modules for estimation: economic surplus; area of trees or palms; land suitability; input-output relations; break-even values; export volumes and values; export price formation; and domestic price formation. Details are provided on the elements in each of these modules.

A set of pricing policies are selected, and their impacts on smallholders and estates assessed, for the smallholder and estate sectors of the cocoa industry in Papua New Guinea using both deterministic and stochastic analyses. The assessments are made by running simulation models for each policy option based on specified scenarios. Most simulation runs were made for future scenarios, but one run was made for the period from 1984 to 1998, to assess the impact of past price support on the profitability of smallholder cocoa production.

Results are presented and discussed for all policy options. As might be expected, they reveal a wide range of impacts, many of them positive. Devaluation and policies leading to a reduction in the opportunity cost of labour to producers offer most scope for expanding economic surplus in the cocoa industry. A planting subsidy also offers prospects of a small increase in economic surplus. On the other hand, there is little to commend input subsidies, price stabilization and short-term price support when world cocoa prices are low. The information gleaned from the results should be useful in assisting policy makers to prioritize policies that encourage future development in the tree crop industries in Papua New Guinea.

Key Words: *cocoa production, bioeconomic modelling, stochastic dominance analysis.*

MANAGING THE CHALLENGES IN POLICY ANALYSIS FOR PERENNIAL EXPORT CROPS IN DEVELOPING COUNTRIES

Perennial export crops such as cocoa provide policy analysts with major challenges when assessing the impacts of economic policy options. The first and most obvious analytical difficulty is in accounting for the very long lags in effect of a policy decision due to the long production cycle and the dynamic age-yield profiles of trees. Once governments make decisions on a price policy, its effects reverberate for many years into the future. Two other difficulties are that perennial crops are typically grown by different groups of farmers, notably estates and smallholders, using different production technologies, and their output is sold in uncertain export markets so that producers face considerable price risk.

Simulation modelling offers a way to manage these challenges, enabling policy makers in perennial crop industries to make more informed decisions. In this study, a case study is presented of the dynamic and stochastic bioeconomic simulation modelling of the production and export marketing of cocoa in Papua New Guinea. The model is used to capture the (often extended) lagged effects of government policies, exogenous events and decisions made by cocoa producers on key performance variables in the industry.

Simulation models of the cocoa industry are constructed, with separate sub-models developed for the smallholder and estate sectors. The *Stella Research Version 5.0* software package was used to construct the models (HPS 1997) based on annual time periods. The rationale for developing the models is to evaluate government price policy options on industry economic surplus.

The overriding reason for adopting the dynamic simulation modelling approach is the flexibility it gives in examining policy options. The task of carrying out sensitivity analyses by changing the values of key variables is comparatively simple.

Four other advantages of this approach in the context of tree crop industries in developing countries are:

- the parsimonious data requirements of the models
- ability to incorporate a variety of dynamic and stochastic events in the modelling process

- the relative ease for policy analysts in Papua New Guinea to use the models and interpret their results once the models have been constructed and validated
- ability within policy institutions to add to, modify and improve the models as more information comes to hand or as the demand grows for new information about industry activities or techniques.

An alternative approach would have been to construct aggregate supply functions using programming methods with farm-level data (e.g. Omamo 1998). Supply elasticities and surplus measures could be readily estimated using such models. An advantage of this approach would be that it allows missing markets and transaction costs to be included in the analysis.

OPERATIONAL REQUIREMENTS AND COMPONENTS OF THE BIOECONOMIC MODELS

Each simulation model comprises eight modules for estimation: economic surplus; area of cocoa trees (with separate modules for each cocoa tree variety); land suitability; input-output relations; break-even values; export volumes and values; export prices; and domestic price formation. These modules are similar in some respects to the blocks formulated in an analogous type of model for a perennial crop, coffee, developed by Akiyama and Coleman (1993, p. 5). Their model included blocks for price linkage, yield, profit, investment, supply, factor demand, credit and export.

The eight simulation modules, and the linkages between them, are now briefly described. Fleming and Milne (1999) give full descriptions of the modules and their algebraic specifications, covering details of the levels of operation, building blocks and simulation tools used to construct the simulations models using *Stella*, and the validation procedures.

Economic surplus module

The economic surplus module is the primary source of estimation of welfare changes brought about by specified policy interventions. A 30-year study period is designated, based on annual observations. The key output in this module is discounted economic surplus. It represents the accumulation of the annual net economic surplus over time to calculate the present value of total economic surplus. It is determined by converting (a) the total amount of annual economic surplus, less (b) plantation development costs, plus (c) net government revenue from policy interventions into present values through the discount factor. A real discount rate of 10 per cent per annum is used, which is slightly less than the rather high rate of 12 per cent applied in recent analyses by, for example, ADB (1993) and Kannapiran (1999). A sensitivity analysis was undertaken on the discount rate, which yielded an arc elasticity of the present value of economic surplus to discount rate of -1.16 between discount rates of 10 per cent and 12 per cent and -1.05 between 10 per cent and 8 per cent. As expected, present values of economic surplus increase with a decrease in discount rate and decline with an increase, but the general structure of relationships is not altered.

Economic surplus is calculated by deriving the Cobb-Douglas supply function from the Cobb-Douglas production function (defined below) and integrating to calculate the area of producer surplus above the supply function and below the cocoa price level. Given all the cocoa output is exported in Papua New Guinea, consumer surplus is assumed to be zero such that producer surplus equals economic surplus. Government revenue is calculated as the total levies collected minus the total bounties paid per annum plus other subsidies paid by the government to the cocoa industry.

A maximum output response to price is included to specify the limit to output expansion that can be achieved from an increased output price. It is set in recognition that there is a physiological limit to the extent to which gains in output can be achieved from a tree crop such as cocoa in the short run. Any additional economic surplus achieved from an increased output price beyond this maximum is derived from price effects alone.

Area module

The area module is crucial in accounting for the dynamics of perennial cropping systems through planting decisions and the effects of the ageing process of trees on their yielding capacity. It determines the total area by age group of cocoa trees in full-bearing equivalent. The initial step is to calculate the area of trees classified by age group to reflect demographic structure. The tree populations are thus determined by area for each year of the study period. Separate modules are developed to differentiate between different varieties of trees. Three varieties are specified, namely *Trinitario* and the *sg1* and *sg2* hybrid varieties.

Areas of new plantings and replantings are derived from the land suitability module, outlined in the next section. They are summed to give total plantings per year in hectares. New plantings are calculated as the sum of plantings made by producers without any planting subsidy and any plantings induced by a planting subsidy.

Age groups differ between tree varieties according to expected changes in yield potential as trees age. If data had been available and inter-regional differences in yields by age group were expected, it would have been desirable to disaggregate areas of trees by region. Areas of trees were calculated for each variety in each age group. Transfers of tree areas between age groups are controlled by outflows and inflows, and areas are accumulated for each age group. It is assumed that trees in a particular age group are evenly spread in age. This means that, for an age group of three years, one-third of the trees move to the next age group from the previous stock each year. Areas are reduced by two outflows, one to take into account the removal of old trees and a second for the infilling of recently planted trees that do not survive.

For a specified age-yield profile, it is possible to estimate the area equivalent of full-bearing trees by multiplying area by the yield index, where the age group of maximum yield over the life of the tree is set at unity. The different age groups are weighted on the basis of age-yield profiles reported by Fleming (1999a). The areas of trees of the three varieties in full-bearing equivalent hectares are summed to arrive at the total area of trees.

A plantation development cost variable is included as the amount of money in kina (the domestic currency in Papua New Guinea) that has been budgeted as the private development costs of a hectare of trees to the stage where they start to bear fruit. It includes the cost of seedlings, materials and tools, plus labour costs calculated as number of days worked in development multiplied by the estimated opportunity cost of labour.

A planting subsidy is included to estimate the area of trees qualifying for a countercyclical tree planting subsidy. It is calculated in hectares as the minimum area of trees that the government or industry organization would want planted minus the area of trees that would be planted by producers under existing economic conditions. It is assumed that the full amount of the development cost is paid as a subsidy. A five-year moving average of past new plantings is used to calculate the minimum level of new plantings that the government or industry organization (the Cocoa Board) is prepared to accept in a particular year.

Land suitability module

The land suitability module allows for different classes of land to be taken up for new planting of cocoa. Land classes are specified from which outflows take up land for use in cocoa production. Estimates from regression analyses by Ruhle and Fleming (1999) and Milne, Coelli and Fleming

(1999) are the source of the algebraic expression used in the specification of planting response to past prices of cocoa beans. Top-quality land has the highest possible yield potential, and is given an index of unity. Once it is fully used up, new plantings are taken from the medium-quality category of land, which is given an index of 0.7. Once the area of medium-quality of land is fully used up, new plantings are taken from the poor-quality category of land, which has an index of 0.4. The latter is used only when the two superior categories of land quality are all used. Once the area in this category is fully used up, no more land is available for new plantings. Areas and yield potential for each land class were obtained from Bellamy and McAlpine (1995).

The estimation of areas of replanted trees should ideally be done in a dynamic optimization framework as decisions on replanting that require the uprooting of existing cocoa trees are best modelled by comparing the long-term profitability of existing trees against that of replanted trees. A dynamic optimization framework was not used, for two main reasons. First, it has not yet been the practice of the predominant smallholders to replace existing trees before they become senile; nor is it likely to become so in the near future given their farming practices (Eric Omuru, Cocoa and Coconut Research Institute, personal communication, 1999). Second, although widespread replantings have occurred on estates over the past two decades, the sector is now small relative to smallholdings and sensitivity analysis on the timing of tree replanting in this sector showed that it does not significantly alter model results. Estate replanting has been almost entirely as a result of subsidised institutional interventions to introduce new hybrid varieties rather than a result of profit-oriented decisions made by producers. Therefore, areas are replanted as the trees reach senility on both smallholdings and estates.

Output module

Estimating the production function

The output module expresses the input-output relations for cocoa production on a per hectare basis. The two major inputs of labour and fertilizer are considered in these relations in both the smallholder and estate models. The module expresses annual yield relations and is based on a Cobb-Douglas production function. This use of a short-run static model for yields is considered adequate on the grounds that maintenance and harvesting decisions made each year that affect annual cocoa output are independent of investment decisions with long-term implications, such as planting, and need not be framed in a dynamic optimization framework.

Annual cocoa yield is estimated in Cobb-Douglas form as:

$$Y = aF^{b_F} L^{b_L} \tag{1}$$

where Y is yield per hectare, F is fertilizer, L is labour, b_F and b_L are elasticities of yield of fertilizer (0.10 for smallholders and 0.21 for estates) and labour (0.55 for smallholders and 0.48 for estates), respectively, and a is a constant (0.049 for smallholders and 0.128 for estates).

Profit maximization conditions for fertilizer and labour, respectively, are (Akiyama and Coleman (1993, p. 10):

$$P_F = P_Y a b_F F^{b_F - 1} L^{b_L} \tag{2}$$

and

$$P_L = P_Y a b_L L^{b_L - 1} F^{b_F} . \tag{3}$$

Fertilizer and labour demand equations in natural logarithms are therefore:

$$\ln F = [\frac{1}{b_F - 1}(-\ln\frac{P_Y}{P_F} - \ln a - \ln b_F) - \frac{b_L}{(b_F - 1)(b_L - 1)}(-\ln\frac{P_Y}{P_L} - \ln a - \ln b_L)]/(1 - \frac{b_F b_L}{(b_F - 1)(b_L - 1)} \tag{4}$$

and

$$\ln L = [\frac{1}{b_L - 1}(-\ln\frac{P_Y}{P_L} - \ln a - \ln b_L) - \frac{b_F}{(b_L - 1)(b_F - 1)}(-\ln\frac{P_Y}{P_F} - \ln a - \ln b_F)]/(1 - \frac{b_L b_F}{(b_L - 1)(b_F - 1)} \tag{5}$$

(Note that equations (4) and (5) differ from equations (6) and (7) presented by Akiyama and Coleman (1993, p. 11) to correct for their omission of minus signs before the expressions, $\ln\frac{P_Y}{P_F}$ and $\ln\frac{P_Y}{P_L}$.)

Cocoa output is measured in tonnes of dry beans as the product of the full-bearing equivalent area in hectares and yield in tonnes for a hectare of trees. A production function, specified as a two-input Cobb-Douglas function, is used to estimate output per hectare. It is solved once the quantities of inputs used have been calculated using first-order conditions, given the input and output prices. As indicated above, a maximum output response to price is set for an increase in cocoa price based on the physiological limits to which gains in output can be achieved from a cocoa tree in the short run.

The quantity of total labour applied to a hectare of cocoa, expressed in days per year, is allowed to vary according to the first-order conditions of the Cobb-Douglas production function. The quantity of fertilizer applied to a hectare of cocoa trees, expressed in tonnes per year, is also permitted to vary according to the first-order conditions of the Cobb-Douglas production function.

The elasticities of labour and fertilizer measure the percentage increases in output of cocoa for 1 per cent increases in inputs of labour and fertilizer, respectively.

The price of labour is measured in kina per day of the opportunity cost of labour used in production. It is valued on the basis of recent empirical evidence on market rates charged for wage labour in the main areas in which cocoa is grown in Papua New Guinea. The price of fertilizer per tonne is derived from empirical evidence of the costs paid by cocoa producers in 1998.

Comparing the price-output relations with empirical estimates of the short-run price elasticity of supply

A significant problem of simulation modelling using empirical estimates is in knowing the shape of the short-run supply response function for cocoa below the minimum observed price in the data used for estimation. It is an important problem when using the simulation models to measure the industry effects of specific price policies. These simulations require knowledge about what happens to industry supply when prices fall below levels unobserved in the past because price stabilization or support programs have been in place to ensure minimum producer prices.

It is highly unlikely that the extrapolations at low prices provided by the models are accurate. This is because of the way the supply response functions are estimated as industry-wide models, entailing the horizontal summation of individual farm supply functions. In practice, in virtually every situation there is a reservation price below which it would not pay a producer to supply the market (below the point where short-run average cost equals output price), implying that the supply function intersects the price axis at a point above zero. This is especially a problem for the double-log Cobb-Douglas model, which dictates that a supply response function should emanate from the origin.

In the presence of technical inefficiencies, the relevant reservation price would vary from one producer to another according to different levels of technical inefficiencies. Two extreme reservation prices should be identifiable:

- The *frontier producer price*, at which point a producer situated on the production frontier (that is, a perfectly technical efficient one) just breaks even, represents the lowest price at which any quantity would be supplied.
- The *least efficient producer price*, at which the least technically efficient producer would just break even, represents the price at which all producers would be willing to supply.

As the producer price increases from the frontier producer price, quantity supplied would increase as more producers find it profitable to supply. Producers would enter the market in descending order of technical efficiency, with the least efficient producer the last to enter. Technical efficiency is typically measured as an index between zero and unity. An index of unity implies perfect efficiency while an index of zero implies perfect inefficiency.

Assuming all producers have similar-shaped individual short-run supply response functions, it is possible to estimate that section of the aggregate supply function between the frontier producer price and the least efficient producer price using information about the distribution of technical efficiency indices across the population of cocoa producers. Given that the short-run marginal cost curve above the short-run average cost curve represents the supply curve in a single-product situation, the supply curve can be related to the production function applying duality theory. For every Cobb-Douglas production function, an equivalent Cobb-Douglas supply function can be specified using the dual relationship between Cobb-Douglas production and cost functions.

The steps to specify the industry supply function between the frontier producer price and the least efficient producer price are outlined by Fleming and Milne (1999, p. 24-25). By following this procedure, it is possible to retain the first-order conditions for profit maximization by individual producers that underlie the short-run marginal cost function. The total area of cocoa beans harvested to supply the market at different prices depends on the proportion of producers who can still at least break even at each price given their technical efficiency index.

Data on cocoa areas, input prices and output quantities for sample smallholders and estates were obtained from Fleming (1999a), and identification of the most efficient and least efficient producers was based on the estimation of technical efficiency indices. Gimbol, Battese and Fleming (1995, p. 352) estimated a range of technical efficiency indices between 0.152 and 0.955

for a sample of 30 cocoa smallholders in Madang province while Aku (2000, p. 67) estimated a range of mean technical efficiency indices between 0.491 and 0.938 for a sample of 26 cocoa estates. These data were used to estimate the reservation prices for the most efficient and least efficient cocoa producers by sector, which define the range of output prices in which the number of producers supplying the market varies.

Fleming and Milne (1999, pp. 26-27) compared the econometric estimates of the short-run price elasticity of supply for cocoa with the price elasticities of output estimated in the base simulation run of the bioeconomic models for estates and smallholders. They considered the two sets of estimates sufficiently compatible to justify the use of the Cobb-Douglas production functions.

Break-even module

Apart from providing estimates of profit per hectare to compare with estimates of economic surplus per hectare, the break-even module furnishes the minimum price (equals average variable cost) below which it is presumed cocoa producers would not supply to the market. A description is now given of each variable that primarily originates in this module.

Total revenue per hectare is calculated as the product of the producer price times the yield, or output per hectare, derived from the production function. Marginal revenue is calculated from changes in the total revenue.

Labour cost per hectare is calculated as the total cost of labour inputs, measured as the price of labour multiplied by the quantity of labour inputs used in production. Fertilizer cost per hectare is calculated as the total cost of fertilizer inputs, measured as the price of fertilizer multiplied by the quantity of fertilizer inputs used in production. A subsidy on fertilizers used in production is introduced by reducing fertilizer price. The total cost of inputs per hectare is calculated as the sum of the costs of all inputs. Marginal cost is calculated from changes in the total cost. Average cost is calculated as total cost per hectare divided by yield derived from the production function (because all figures are expressed on a per hectare basis).

Profit per hectare is calculated as total revenue minus total cost, and is expressed in kina.

Export volumes and values module

The purpose of the export volumes and values module is to convert annual output into volume of annual exports, and derive the value of annual exports in domestic currency. The annual output of cocoa is expressed in its common export form, namely dry beans, and is converted into the annual volume of exports in tonnes. The value of cocoa exports is calculated as the export volume in tonnes multiplied by the average annual free-on-board (f.o.b.) price in kina per tonne of exports of cocoa beans (see next section).

Export prices module

In this module, the average f.o.b. export price of cocoa beans is specified assuming various types of world price fluctuations in order to account for the price uncertainty facing exporters. Export prices are allowed to vary in two main ways. The first is via a price cycle that comprises long periods of low prices and short periods of price peaks, typical of world price changes for perennial crops such as cocoa and coffee in the past few decades. Second, export prices can trend upwards or downwards. Both deterministic and stochastic price series can be derived depending on the purpose of the analysis, with standard deviations used to provide normal distributions from which prices are randomly selected. A description is now given of each variable that primarily originates in this module.

The f.o.b. export price is in kina per tonne of dried cocoa beans. It is calculated from the f.o.b. price in US dollars by applying the exchange rate. Quality differences are not expected to influence export price greatly, and so it was not considered necessary to introduce quality differences according to the mode of production. (This contrasts with an analogous approach by Fleming and Milne (1999) in modelling coffee production and export where separate export prices were specified for different qualities of exports.) The export price in US dollars is converted into kina using the exchange rate, which is expressed in kina per US dollar. The rate chosen (2.2) is a forecast of the likely long-term rate rather than the actual rate prevailing at the start of the study period.

For analyses reported in this paper, the minimum f.o.b. export price is used in conjunction with price spikes to simulate export price fluctuations in a cyclical manner. Its value in US dollars at the beginning of the study period is estimated as the mean of the lowest two-thirds of actual prices for the period from 1984 to 1998. The price per tonne used is US$1036. The minimum f.o.b. export price in US dollars is adjusted by introducing either an upward or downward trend in this price series of 0.5 per cent per year over the study period. This is a fairly conservative estimate given that Ramirez and Somarriba (2000, p. 658) forecast a downward trend in real cocoa prices from 2000 to 2020 of around 1 per cent per annum.

Where the f.o.b. export price is to be estimated as a stochastic variable, the NORMAL option in *Stella* (HPS 1997, p. 7-17) is used. This requires an estimate of the standard deviation of f.o.b. export prices. Annual observations for the 15-year period from 1984 to 1998 were used to make this estimate.

A price cycle is introduced by incorporating spikes from a minimum f.o.b. export price level in US dollars. The use of spikes for f.o.b. export price increases requires an estimate of pulses to represent these spikes. Annual observations for the 15-year period from 1984 to 1998 were used to make them. Pulses from minimum prices are assumed to occur every 10 years over a three-year period. The first pulse is assumed to be 80 per cent of the maximum range, the second is 100 per cent, and the third is 70 per cent.

The year in which the first pulse, or f.o.b. export price rise, occurs is based on an estimate of where the cocoa market cycle is at the beginning of the study period. It is set to occur in year 7. A variable for the magnitude of the pulse is set according to the range from the minimum export price to the peak price.

Note that Ramirez and Sosa (2000) followed a different approach in dealing with the kurtotic and right-skewed distribution of world coffee prices (similar to that for world cocoa prices) caused by this cyclical nature of price movements. They specified a non-normal distribution for generating stochastic prices. The problem with this approach is that it ignores the important influence on long-term profitability of the chronological structure of world commodity price cycles. For this reason, it was decided to mimic past cyclical tends in cocoa export prices in this study.

Domestic prices module

The purpose of the domestic prices module is to specify price transmission between the export level and producers, accounting for bounties and levies associated with price stabilization schemes where required. The delivered-in-store (d.i.s.) price in kina per tonne for producers is estimated before any adjustment is made for stabilization bounties or levies. It is calculated as a function of the f.o.b. export price using simple regression analysis on past f.o.b. and d.i.s. prices. This relationship comprises two parts. The first part is an intercept term, which is a fixed component of the marketing margin reflecting the fixed nature of some of the inputs used in marketing and processing. The second part is a variable component, reflecting the use of inputs in processing and marketing that vary with prices.

Producer price is meant to denote the price received by the producer. In fact, a lack of information on marketing margins between the factory door and the farm gate means that this is really the price received at the factory door, more often by roadside buyers than producers themselves. It is denoted in kina per tonne, and is net of bounties and levies.

A moving average of past d.i.s. prices is used in the calculation of bounties and levies, measured in kina per tonne. Bounties paid out to producers as part of a commodity price stabilization scheme are calculated according to a formula embedded in the model. Various formulae could be used. For the purposes of this study, a five-year moving average of past d.i.s. prices (the reference price) is compared with the actual d.i.s. price in a particular year. If the actual price is a specified amount below that reference price, a bounty is paid to producers to the extent of the difference. If it is not below the reference price, no bounty is paid. Bounties are measured in kina per tonne.

Levies paid by producers as part of a commodity price stabilization scheme are also calculated according to a formula embedded in the model by comparing a five-year moving average of past d.i.s. prices with the actual d.i.s. price. If the actual price is a specified amount above that reference price, producers pay a levy to the extent of one-half the difference between the actual price and reference price. No levy is paid if the actual price is not above the reference price. Levies are measured in kina per tonne.

It is assumed in the model that the bounties are paid directly to producers, when in fact they are paid to exporters who are required to pass them back to the producers, and levies are collected directly from producers and put into the stabilization fund, when in fact they are deducted from exporters who are to redeem them from producers. The model would accurately portray reality so long as the full bounty and levy reach the producers within the particular year. Evidence surveyed by Fleming and Milne (1999) suggests this is a reasonable assumption.

Domestic prices module for the assessment of past price support

Simulation models for smallholders were run separately to show the impact of a tree crops price support scheme, termed the Agriculture Guaranteed Price Support (AGPS) scheme, on output and economic surplus between 1990 and 1994. The period of analysis was from 1984 to 1998.

Additional and revised building blocks were required to assess the impacts of the AGPS, to account for the annual values of price support in the domestic prices module.

The total bounty for the period of operation of the AGPS scheme is redefined, being subdivided into bounties for individual years from 1990 to 1994. The producer price is redefined to include separate variables for bounties for each year of operation of the AGPS scheme.

ASSESSMENT OF PRICING POLICIES USING A DETERMINISTIC MODEL

The impacts of selected input and output price policies are assessed for the smallholder and estate sectors of the cocoa industry in Papua New Guinea. Fleming and Yala (1999) provide a background to the choice of policies for assessment, which is based on runs of the bioeconomic simulation models described above. The models were used to assess the economic impacts of the following price policies: short-term output price support; price stabilization; exchange rate manipulation; counter-cyclical planting subsidies; subsidies on purchased fertilizer inputs; and policies influencing the opportunity cost of rural labour.

In this section, results of the deterministic simulation models are presented and discussed for all price policies in terms of their impact on industry profitability, measured by the discounted economic surplus. Separate commentaries are provided for each price policy option, and the results are discussed and compared for smallholders and estates. In all cases except past price support, results are reported for 30-year simulation runs. For past price support, simulation models were constructed for the 15-year period from 1984 to 1998. In the next section, a stochastic element is introduced in the smallholder models by allowing the cocoa export price to vary in a normal distribution around its mean, specified in this section.

Short-term price support

Two analyses are reported for short-term price support. First, an assessment is made of the short-term price support provided by the government to cocoa smallholders (the targeted beneficiaries of the scheme) between 1990 and 1994. This support was provided as part of the AGPS scheme during a period of low world cocoa prices.

Second, data were developed for a 30-year period to assess any future modified price support scheme. Export prices of cocoa beans were assumed to fluctuate in a manner similar to that over the past 30 years. This provided the basis for calculating the revenues and economic surpluses if price support were to be reintroduced in periods of extended low prices in the future. Two triggers were used for providing price support: where prices fell below 95 per cent and 90 per cent of a five-year moving average of d.i.s. prices. The method of analysis used in assessing a modified AGPS scheme is similar to that described above for the existing AGPS scheme except that separate models were estimated for estate and smallholder cocoa production.

The results presented here do not cover all possible options. The AGPS scheme could be modified to a variety of forms in terms of length of time of support and level of support, and under different scenarios about future world market conditions. Another important issue in respect of long-term benefits is the extent to which price support helps avoid long-term damage to the cocoa export industry caused by prolonged periods of low export prices. Hence, a number of 'one-off' simulation runs, not reported here, were made under a variety of conditions to demonstrate how different results could occur. Runs were modified according to what happened in the world cocoa market, changes to the criterion used for providing price support, or assumptions about the likely damage of neglect of cocoa plantations through lack of maintenance during periods of low prices.

Simulation of price support to tree crop industries from 1990 to 1994

The policy of short-term price support during the period from 1990 to 1994 under the AGPS scheme was tested by simulating the actual value of support to smallholders in each of the years of the scheme. Annual average export prices in 1998 US dollars were used in this simulation. Data were collected on amounts spent on price support, and the main empirical work undertaken was the estimation of supply responsiveness in the cocoa industry. This provided the basis for calculating the revenues that would have been earned had the AGPS scheme not been in operation.

The result reported in Figure 1 shows that the impact of the AGPS on cocoa smallholders was quite strongly negative. The cost in reduced surplus is estimated to be K14.7 mn. This contrasts with the negligible economic impact of the AGPS scheme on the other major export tree crop producers in Papua New Guinea, namely coffee and oil palm smallholders (Fleming 1999b).

Simulation of future price support

A future policy of short-term price support was tested by increasing all d.i.s. prices to within 90 per cent and 95 per cent of a five-year moving average of d.i.s. prices. Funds are assumed to come from the government budget. Separate simulation runs were made for short commodity cycles (10 years) and long commodity cycles (15 years).

Elasticity estimates reported in Figure 1 are for a 10-year cycle based on a threshold for intervention of a 90 per cent moving average. Economic surplus response to price support is inelastic. Substantial negative impacts (K7.7 mn) are evident for cocoa smallholders which, as expected, get larger as cocoa price trends move from positive to negative (a function of substantial increases in government costs). With no price trend, smallholders gain K17.4 while the government cost is K25.1 mn. A more active support program with intervention at 95 per cent of the moving average price would slightly reduce the loss in economic surplus, to K6.7 mn. Longer commodity cycles appear to have little impact on economic surplus, with lower government contributions and slightly higher loss of economic surplus.

In contrast, a slight positive impact on discounted economic surplus occurs for estates, which tends to decrease with decreases in the product price trend. With no price trend, the government transfers K6.1 mn to the estates, which gain an additional K0.4 mn. Intervention at 95 per cent of the moving average price would yield a slightly higher economic surplus, but at a higher cost to the government of K4.2 mn. Longer commodity cycles appear to have little impact on economic surplus, with changes of similar direction and order as for smallholders.

Even if the impact of short-term price support had been positive in the smallholder sector, large amounts of public funds would be needed to bring about a significant impact on economic surplus. Given the doubts about achieving the desired impacts of short-term price support, it is a risky venture for government to provide this support. Furthermore, the introduction of stochasticity into price movements demonstrates how easy it is for losses in economic surplus to occur as a result of changes in timing and levels of support, misreading of price trends and variations in the length of commodity cycles.

Government intervention to provide short-term price support demands a very high quality of management and capability to resist pressures for higher and extended levels of support. Allocative inefficiency is also likely to occur because of the distortions in price signals to producers. This can be high in the case of smallholders who have considerable flexibility in varying their labour use during extended periods of low prices.

Manipulation of the exchange rate

Devaluation of the kina is a policy decision recently taken by the government of Papua New Guinea that provides an excellent opportunity to observe its effects on the cocoa industry. The expected outcome of the devaluation was that it would make cocoa exports cheaper and more competitive in world markets.

Exchange rate impacts were analysed within the separate simulation models for cocoa estates and smallholders. Simulation runs were made with and without simultaneous short-term price support at 90 per cent of a 5-year moving average of the d.i.s. price.

Elasticity estimates presented in Figure 1 are for the situation without price support. They show a high elasticity of economic surplus in response to changes in the exchange rate, thus demonstrating the potentially powerful positive impact of a devaluation on industry profitability. Elasticities are similar for smallholders and estates, with gains of K51.6 mn and K40.6 mn, respectively. Interestingly, impacts are slightly greater as product price trends change from price growth to price decline.

In times when cocoa exports were sufficiently important to have a profound influence on the exchange rate, devaluation in times of low tree crop export prices would have a stabilizing impact on industry revenue. The ‘hard kina’ policy of maintaining a high value of the kina against foreign currencies, however, limited this impact. Such an impact is of limited potential now that the kina has been floated because of the decline in macroeconomic importance of the tree crops sub-sector.

When devaluation is combined with short-term price support, the impact of the devaluation is muted from the industry viewpoint although it remains similar from an overall economic viewpoint in that the devaluation saves the government funds that otherwise would have gone into support. A comparison of the combined impact of devaluation and price support with the independent effects of the two policies shows that the dissipation of surplus increases as the cocoa price trend moves from positive to negative, as expected. At an upward price trend of 0.5 per cent per annum, the difference is a mere K1.1mn, increasing to K3.0 mn with no price trend and K6.1 mn with a price decline of 0.5 per cent per annum. The latter represents a 13 per cent decline in the gain in economic surplus.

Counter-cyclical planting subsidies

A policy of counter-cyclical planting subsidies is tested by introducing into the simulation models a government payment for all costs of planting and early maintenance of cocoa trees where there is a shortfall of planting below 90 per cent of a 5-year moving average of areas of planting. The planting subsidies were tested only for cocoa smallholders who, in contrast to estates, exhibit a positive planting response as discerned in an empirical analysis by Milne et al. (1999).

Elasticity estimates of economic surplus in respect of the area planted, presented in Figure 1, are positive but low. With no price trend, the gain in economic surplus is just K0.58 mn. The elasticities increase with trends to higher cocoa prices. Elasticity estimates of economic surplus in respect of public funds committed to the subsidy present a different picture, with an 88 per cent return in economic surplus for the government investment. These returns also increase markedly with a shift from negative to positive cocoa price trends.

Subsidization of fertilizer inputs in cocoa production

Subsidization of inputs in cocoa production has been used in the past by the government of Papua New Guinea as an alternative to output price support to producers. Subsidies have often been provided on one of the main inputs used by producers, namely fertilizer. The welfare effects of a fertilizer subsidy were examined by accommodating changes in the price of fertilizer in the simulation models. The prices of fertilizer inputs to cocoa producers were reduced by 10 per cent, with funds come from the government budget.

Elasticity estimates presented in Figure 1 are negligible for smallholders and substantially negative for estates. The output effects of subsidies on fertilizer inputs by smallholders are small (K0.63 mn), and only slightly outweigh the opportunity costs of the funds used by the government in subsidizing fertilizer use (K0.52 mn). This result is perhaps not so surprising given the limited use made of fertilizers by cocoa smallholders in Papua New Guinea. The negative elasticities are substantial for cocoa estates, which are fairly large users of fertilizers. As would be expected, losses increase with the change from increases to decreases in cocoa price trends. With no price trend, the gain to the estates of K18.0 mn from the subsidy is offset by the large cost to the Treasury of K31.4 mn.

An important caveat here is the assumption of a static environmental state in which cocoa production occurs. Historical data have been used to estimate the production relations on which the simulation runs are based. To the extent that the production environment is degrading over time and external inputs begin to have much greater marginal output effects, these results will underestimate the impacts of inputs on industry surplus. Empirical evidence on the extent to which fertilizer application (and other conservation measures) can assist in sustaining cocoa tree yields is lacking, but an idea of its potential impact can be gauged from simulation experiments to increase the yield capacity of mature cocoa trees. The impact on the economic surplus is quite substantial: a 10 per cent increase in the yield capacity of these trees on smallholdings and estates results in 7 per cent and 9 per cent increases in economic surplus, respectively. The greater responsiveness for estates reflects the considerable scope for yield improvement caused by the rapid decline in productivity of an initially higher-yielding variety of cocoa tree planted by almost all estates in the 1980s (Fleming 1999b).

Allen, Bourke and Hide (1995, p. 297) argued persuasively that intensification of production 'brings about changes that must be overcome by innovation … intensification without innovation is likely to lead to land degradation'. These observations on intensification, innovation and stress suggest that there is a major research and extension effort needed in future to monitor the sustainability of cocoa production systems and the contributions by external inputs such as fertiliser to this sustainability.

Changing the opportunity cost of labour

Simulation runs were made for a 5 per cent decrease in the opportunity cost of labour. Estimated elasticities of economic surplus to wage presented in Figure 1 are high for both smallholders and estates. This result is hardly surprising given that labour is the most important input after land in cocoa production in Papua New Guinea. The elasticities tend to increase slightly with lower trends in output prices for both sectors. With no price change, a decline in the opportunity cost of labour would increase economic surplus by K18.2 mn and 18.1 mn, respectively, in the smallholder and estate sectors.

In the past, the government has had in place a minimum wage policy for both rural and urban workers. Inverse estimates of the above elasticities for an increase in the opportunity cost of labour suggest that reimposition of such a policy, if effective, would have a major adverse impact on profitability in the cocoa industry. By increasing wages in the estate sector and indirectly raising the opportunity cost of labour used in cocoa production by smallholder households, economic surplus in both sectors would decline substantially.

STOCHASTIC ANALYSES

The stochastic analyses are confined to the smallholder sector because policy makers consider smallholders to be much more vulnerable than estates to fluctuating export prices. A total of 4000 iterations of the cocoa smallholder model were run for each policy option, assuming no trend in cocoa prices over the study period and a coefficient of variation of cocoa prices of 29.5 per cent around its cyclical movement. This coefficient was estimated from 15 years of data on cocoa export prices for Papua New Guinea between 1984 and 1998. The exchange rate was made stochastic in addition to export price in order to compare the base model with the devaluation option. The base option was simulated using the standard deviation of the exchange rate prevailing in the period from 1976 to 1993, when the 'hard kina' policy was in place. The standard deviation of the exchange rate for the period from 1994 to 1998 was used for the devaluation option, representing the period when a floating exchange rate policy was followed during which the kina was substantially devalued. Stochastic dominance analysis is undertaken to compare policy options by a visual assessment of cumulative density functions of present values of economic surplus of policy options and by the application of second and third degree stochastic dominance using *RISKROOT* (McCarl 1988). The range of the risk aversion coefficient considered was between plus and minus 0.1.

Cumulative density functions

Figure 2 shows the cumulative density functions for the base policy option and the policy options of stabilization, short-term price support, planting subsidy, 10 per cent fertilizer subsidy and 5 per cent decrease in the opportunity cost of labour. Cocoa export price is assumed to be the only stochastic variable. Five results are of particular interest.

The first point to note about the results of the stochastic analysis is that the mean present value of economic surplus for the base run (K213.63 mn, with a standard deviation of K24.30 mn) is substantially higher than the present value of economic surplus in the deterministic model (K191.59 mn). This result suggests that export price fluctuations encourage higher rates of investment in cocoa plantations by smallholders, thereby increasing economic surplus in the long run.

Second, a decrease in the opportunity cost of labour gives the greatest possible gain in present value of economic surplus among the policy options considered, consistent with the findings of the deterministic analysis. Its mean value is K232.65 mn, almost K20 mn higher than the mean of the base option, with a higher standard deviation of K26.20 mn.

Third, and again consistent with the results of the deterministic analysis, the price stabilization policy option (mean of K205.61 mn and standard deviation of K23.93 mn) and short-term price support policy option (mean of K207.16 mn and standard deviation of K23.90 mn) appear inferior to the base option. As expected, the standard deviations of these two options are lower than that for the base option, but not greatly so.

Fourth, it is difficult to differentiate between the results of the price stabilization, short-term price support and fertilizer subsidy policy options from Figure 2. On the basis of means and standard deviations, short-term price support seems preferable to stabilization, but the cumulative density functions are difficult to distinguish.

Finally, it is similarly difficult to distinguish between the cumulative density functions of the base and planting subsidy policy options. Some of these results suggest it is worth examining second-degree and higher stochastic dominance through the *RISKROOT* results (next section).

Figure 3 shows the cumulative density functions for the base policy option and the policy option of devaluation, with stochastic exchange rates and cocoa export prices. Clearly, the wider dispersion of present values of economic surplus for the devaluation option means that first-degree stochastic dominance does not prevail. However, it is equally clear from Figure 3 that there is second-degree stochastic dominance favouring the devaluation option.

RISKROOT results

The *RISKROOT* results for all policy options except devaluation show that:

- First-degree stochastic dominance prevails for the base policy option over the stabilization, short-term price support and fertilizer subsidy options. Distributions do not cross.

- The distribution cumulative density functions for the base and planting subsidy options cross four times. The break-even risk aversion coefficient is very high, at 0.060, above which the base is dominant and below which the planting subsidy dominates. (See McCarl and Bessler (1989) for a discussion of the appropriate upper bound on the risk aversion coefficient when comparing risky choices.) This reflects the fact that there is a wider dispersion of values of economic surplus for the latter.

- The planting subsidy dominates all other policy options except a reduction in the opportunity cost of labour. Its distribution does not cross the distributions of other policy options except for that of the fertilizer subsidy, which it crosses twice. In this case, the planting subsidy has second-degree stochastic dominance at all risk aversion coefficients in the range considered.

- Short-term price support dominates stabilization in first-degree stochastic dominance, as the distributions do not cross. The distributions of price support and fertilizer subsidy cross once, with a very high break-even risk aversion coefficient of 0.052. Price support dominates above this figure and fertilizer subsidy below it, reflecting the lower volatility in economic surplus with price support.

- The distributions of planting subsidy and fertilizer subsidy cross twice, but the planting subsidy dominates the fertilizer subsidy at all levels of the risk aversion coefficient.

- The composite results show that reducing the opportunity cost of labour is the dominant policy option at all levels of risk aversion, despite the greater volatility of its values of economic surplus. First-degree stochastic dominance prevails in all pair-wise comparisons of options. This finding is in line with the results of the deterministic analysis.

The existence of second-degree stochastic dominance for devaluation over the base policy option is borne out by the results of the *RISKROOT* modelling, which show a break-even risk aversion coefficient of 0.020. Only above this quite high figure of risk aversion would the base policy option dominate the devaluation option.

CONCLUSION

A set of price policies is selected, and their impacts on smallholders and estates assessed, for the cocoa industry in Papua New Guinea. The assessments have been made by running bioeconomic simulation models for each policy option, based on specified scenarios. Most simulation runs were made for future scenarios, but one run was made for the period from 1984 to 1998, to assess the impact of past price support on cocoa smallholders.

Results of deterministic and stochastic analyses are presented and discussed for all policy options. As might be expected, they reveal a wide range of impacts, many of them positive. The most positive impacts on profitability clearly come from a devaluation of the local currency and reduction in the opportunity cost of labour inputs. While these changes do not have specific industry costs, their macroeconomic impacts are diverse and their desirability would need to be judged in the context of broader economic issues. Neither short-term price support nor price stabilization is preferred to the base policy option. Somewhat surprisingly, short-term price support appears to be a preferred option to a self-funding stabilization scheme. There is some support from the results for a planting subsidy, although the additional gains over the base policy option are small.

Information gleaned from the results should be useful in assisting policy makers to set priorities for policies that encourage the future development of the tree crop industries in Papua New Guinea.

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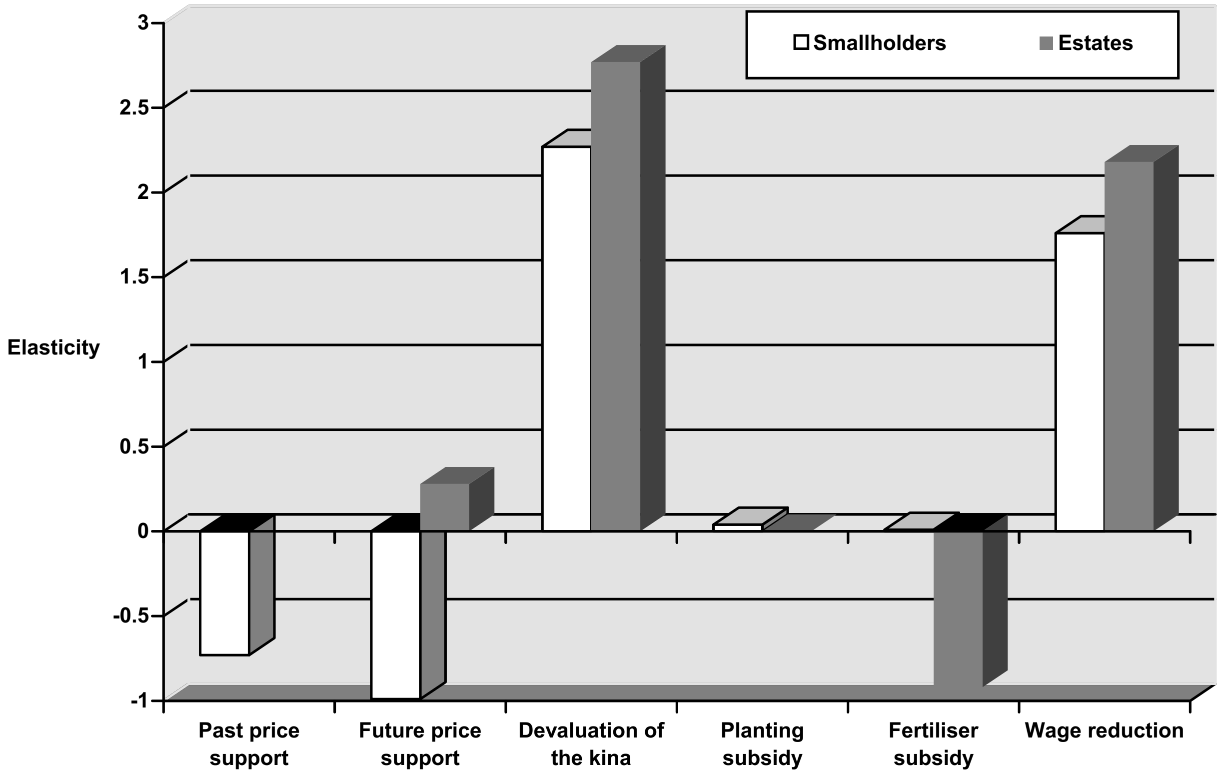

Fig. 1. Estimated elasticities of economic surplus in respect of price interventions.

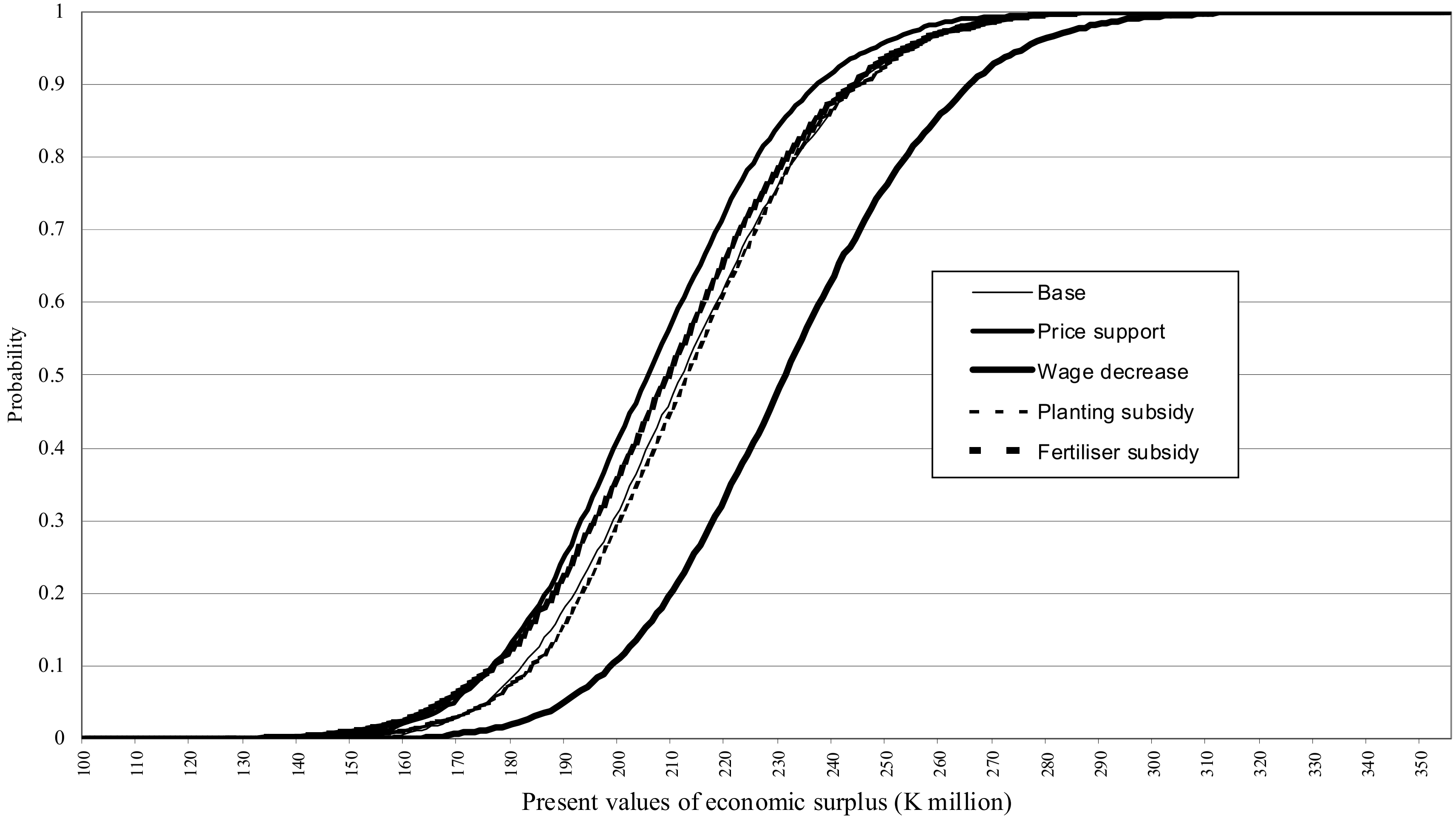

Fig. 2. CDFs of the present values of economic surplus of policy options.

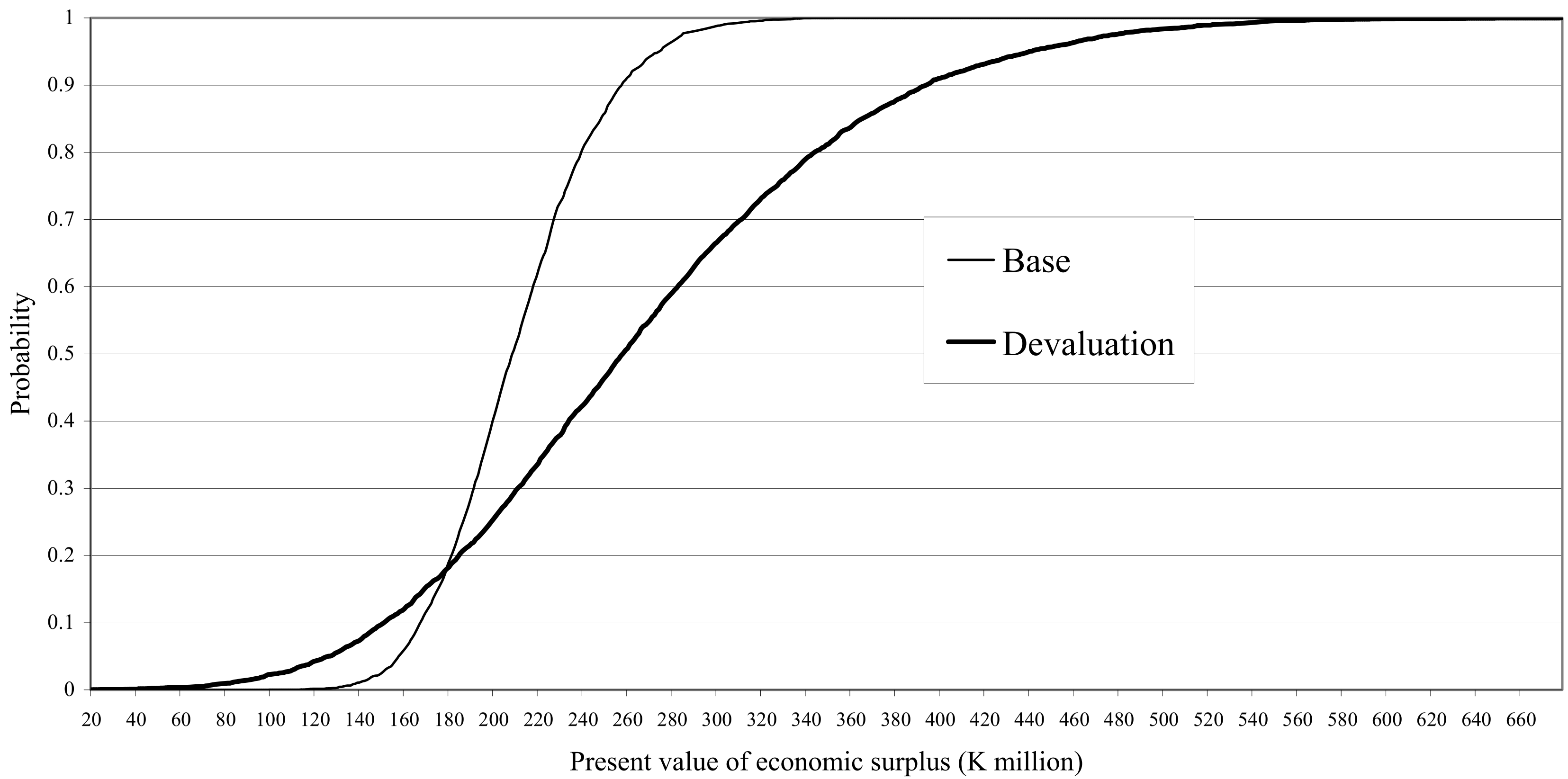

Fig. 3. CDFs of the present values of economic surplus of base and devaluation policy options.