1. Introduction

1.1 Research Problem

Over the past two decades, but more acutely in the 1990s, the cocoa industry in PNG has been suffering from a decline in production levels. Yields and output have fallen in a climate of low world cocoa prices, drought, civil unrest and crop diseases. Profits to plantation owners have declined with the unexpected drop in yields of high-yielding varieties (HYVs) planted in the 1980s and increased costs of production following the devaluation of the kina.[1] For smallholders, ineffective extension services, with the exception of ENB, have also contributed to a decrease in cocoa production and minimal growth in the sector (World Bank 1995).

Government policies and projects have had limited success in improving incomes and output of cocoa producers. Pricing policies, in place since 1974, are being phased out by the end of 1997 due to their ineffectiveness (King and Sudgeon 1996). Research and extension activities to date have had a significant impact only in ENB province. The high-yielding varieties, SG1 and SG2,[2] have failed to create the expected increase in cocoa output.

The floating of the exchange rate in 1994 increased costs of imported inputs used in cocoa production as well as increased the domestic prices for cocoa. Various reports have noted that the devaluation of the kina has had a positive impact on agricultural income and exports where the increases in input prices have been more than offset by the increases in cocoa prices (Manning 1992; Zeitsch, Fallon and Welsh 1993; World Bank 1996). However, there is some confusion whether this has had a beneficial or detrimental impact on the cocoa industry. Ruhle and Fleming (1998) found that the devaluation of the kina had a positive and significant impact on smallholder supply and a positive but

[1] *The kina is the local currency of PNG. In January 1998 the rate was $A1.00 = K1.12*

[2] *SG1 was introduced in 1981 and did not yield as highly and for as long as predicted by the Cocoa and Coconut Research Institute (CCRI). The SG2, introduced in 1989, was also not as high-yielding nor disease-tolerant as expected, leading the CCRI to distribute only cloned material, referred to as the SG2-mod.*

less significant impact on largeholders. Yet both groups of producers displayed negative supply response to producer prices.

This confusion exemplifies the absence of a sound analytical framework of the cocoa industry on which policy makers can base policy decisions. Insufficient data on the areas under tree crops, producers' supply and investment behaviour and the influence of agro-ecological and socio-economic factors on producers in the cocoa-growing regions constrain any meaningful assessment of policy changes in the industry.

1.2 Objectives of the Study

The main purpose of the study is to develop a dynamic simulation model of the cocoa industry, that can be used to analyse quantitatively the impacts of policy changes on output and producer returns. An analytical framework of cocoa supply response is developed that accounts for sectoral, regional and soil variations in PNG. In light of limited data, the model has minimal data requirements and does not rely on time series data.

Two specific objectives of the study are to predict the impact on annual, and the net present value (NPV) of output in the cocoa industry of the:

(1) disbandonment of the price support scheme;
(2) the devaluation of the local currency;
(3) introduction of the high-yielding varieties; and
(4) expansion of the smallholder sector.

Achievement of these objectives should provide an indication of the usefulness of the simulation model in analysing a range of other policy options.

1.3 Scenarios to be Analysed

The model is simulated over a 20-year period (1996-2015) under different scenarios and comparing changes annual output and the NPV of total output by sectors and provinces. A scenario is defined as a set of internally consistent and plausible assumptions concerning the future development of exogenous factors (Bossel 1994). The input parameters and scenarios are changed over a broad range of conditions to compute the resulting development paths and to compare and evaluate the outcomes. Given the nature of simulation in exploring alternative outcomes, scenarios are chosen over hypothesis testing.

The scenarios to be analysed are:

- a 5 per cent devaluation of the kina with and without price support;
- a 10 per cent devaluation of the kina with and without price support;
- a 15 per cent devaluation of the kina with and without price support;
- the removal of price support;
- increasing export prices; and
- doubling of yields.

1.4 Justification of the Study

The medium-term development strategy for the agricultural sector proposed strategies for accelerated growth to the year 2000, particularly through investment in export tree crops (DAL 1995). Research and extension activities have been stepped up with the introduction of the high-yielding variety, SG2-mod. However, there has been little research carried out on the potential impacts of policy changes on the cocoa industry. This study seeks to provide a framework by which policy makers can simulate the effects of alternative policies. It also helps to identify the additional data required to determine the impacts of policy decisions.

The study provides a basis for further policy analysis such as the impact of the new HYV on the cocoa industry. As more data are collected from research trials and survey work, parameters in the model can be added and modified to improve the accuracy of the projections.

1.5 Organisation of the Study

The dissertation is organised into eight chapters. In Chapter 2, the cocoa industry in PNG is described, covering the production trends, sector structure and geographic location of major cocoa-producing areas. Chapter 3 is an outline of the status of exchange rate and pricing policies and the impact on the cocoa industry of proposed policy changes, drawing on empirical case studies. In Chapter 4 the choice of the appropriate theoretical model for the study is discussed. Chapter 5 describes the formulation of the simulation model used in the study while Chapter 6 contains a discussion of the data sources, variable selection and constraints. Chapter 7 contains the empirical results, their interpretation and a discussion of the policy and research implications. Finally, in Chapter 8, a summary of the findings is made, followed by a review of the main limitations of the study and suggestions on future areas of research. The chapter is closed with an outline of the major contributions of the study.

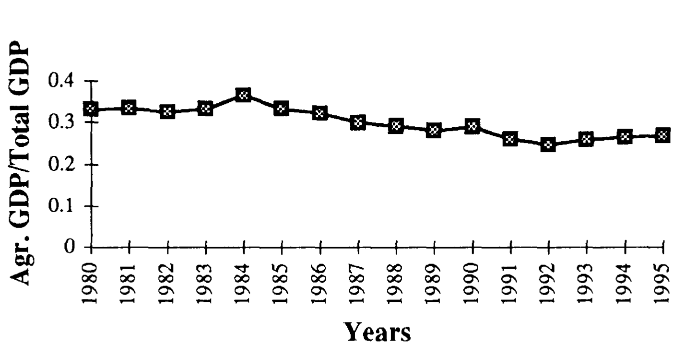
2. The Cocoa Industry in PNG

2.1 Agriculture and Tree Crops Production in PNG

PNG, situated just south of the equator, is heavily reliant on its agricultural sector. Currently it supports 85 per cent of the population and provides employment for 25 per cent of the workforce in the formal sector (DAL 1995). Cash cropping constitutes about 55 per cent of total agriculture with the remainder being in subsistence agriculture (Fallon 1992).

Between 1985 and 1995, agriculture's contribution to GDP declined steadily from 33 per cent to 26 per cent, exacerbated by low world commodity prices (see Figure 2.1). During the 1980s, agricultural GDP grew below the population growth rate, at an average of 1.7 per cent per annum. In 1991, the sector grew by only one per cent (AOD 1992). Cocoa's share of gross domestic product has followed a similar pattern, declining steadily from 1984 (2.9 per cent) to 1993 (0.5 per cent). In 1994, in light of the devaluation of the kina and its subsequent float, cocoa increased its share to 0.8 per cent of GDP. The declining share of agriculture is a common trend, given the rise in importance of the mining and petroleum sub-sector (Peter 1997b).

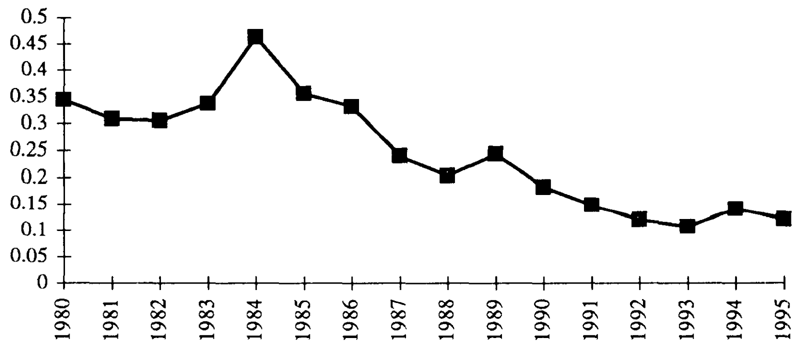
Figure 2.1 Proportion of GDP from Agriculture



Sources: National Statistics Office (1991); Parliament of Papua New Guinea (1994).

A sharper trend has occurred in agriculture's share of export value (see Figure 2.2). In 1984 agricultural exports accounted for 46 per cent of total exports but this proportion had fallen to 14 per cent by 1994 (DAL 1995a). Note that this is primarily due to the growth of the mineral sector in recent years.

Figure 2.2 Agricultural export value as a percentage of total exports



Sources: Bank of Papua New Guinea (1992); Bank of Papua New Guinea (1995); Parliament of Papua New Guinea (1993).

Despite the fall in the share of agriculture in GDP and exports, the government remains committed to the agricultural sector, particularly through investment in export tree crops. Tree crops account for one third of rural output in PNG and the major cash income activity for rural populations. In 1995 coffee, coconut, cocoa, spices, palm oil and rubber accounted for K235 million or 26 per cent of the value of agricultural output per year and 90 per cent of the value of export crops (see Table 2.1) (DAL 1995b; World Bank 1988a).

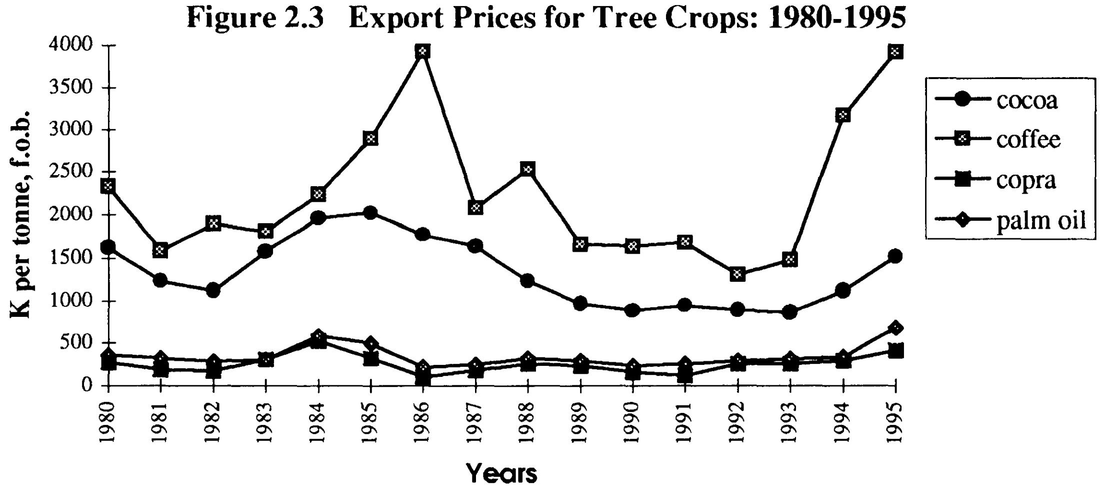
Table 2.1 Value of tree crops (million kina, FOB), 1985-1995

Year	Coffee	Cocoa	Palm oil	Copra	Coconut oil
1985	118	63	62	33	24
1986	209	56	28	10	10
1987	135	56	24	15	15
1988	114	46	33	19	17
1989	140	45	38	14	15
1990	103	30	33	9	12
1991	80	34	53	5	13
1992	68	34	64	12	24
1993	101	33	79	14	20
1994	205	29	778	15	20
1995	215	48	142	27	30

Source: Bank of Papua New Guinea (1996).

In October 1994, the depreciation of the kina improved the cash tree crops' international competitiveness, aided by both the increased government price support and more favourable international commodity prices (DAL 1995a) (see Figure 2.3).

Figure 2.3 Export Prices for Tree Crops: 1980-1995



Sources: Bank of Papua New Guinea (1992); Bank of Papua New Guinea (1995); Parliament of Papua New Guinea (1993).

2.2 Cocoa Production in PNG

Papua New Guinea's agro-climatic conditions, fertile soils and abundant family labour gives it a comparative advantage over large cocoa-producing countries such as Cameroon and Nigeria (see Table 2.2) (Peter 1997b).

Table 2.2 Yield comparison between cocoa-producing countries

Year	2	3	4	5	6	7	8-9	10-15	>15
PNG (SG1)	436	548	791	1068	1337	1169	1255	647	440
Ghana	-	660	883	1278	1885	-	-	-	-
Cameroon	-	117	234	430	836	838	-	-	-
Trinidad	-	173	328	882	834	1020	-	-	-
Sabah	338	720	1283	1053	1911	-	-	-	-
Malaysia	-	352	722	834	1315	-	-	-	-
Brazil	-	300	1400	2000	2500	2250	-	-	-

Sources: Wood and Lass (1985); CCRI (1981-1992).

Cocoa, currently the third most profitable export crop in PNG, is grown by approximately 93 000 households on islands and in coastal provinces. In 1990, 16 per cent of households growing cash tree crops grew cocoa, excluding North Solomons Province (National Statistical Office 1990). In PNG, cocoa is predominantly intercropped. Smallholders tend to intercrop with coconut palms and other food crops while estates commonly intercrop with just coconut palms (World Bank 1988b).

On a provincial level, the estimated number of households growing cocoa is approximately 60 per cent in ENB, 41 per cent in Madang, 48 per cent in East Sepik and 41 per cent in New Ireland. Before the Bougainville crisis, 77.5 per cent of households were growing cocoa in North Solomons with 40 per cent of the total cocoa export coming from the province (Peter 1997b).

2.2.1 Historic trends in cocoa production

The Germans are believed to have introduced cocoa into PNG from Samoa in the late 1900s, recording the first cocoa exports in 1905. Before World War Two, cocoa grew predominantly on plantations, with production reaching no more than 320 tonnes per annum (Densley and Barker 1987). It began developing as a smallholder's crop in the early 1950s, especially in ENB and North Solomons, through the promotion of smallholder cocoa production by the Department of Agriculture.

Total production increased rapidly through the 1960s and 1970s, helped by high world prices (Gimbol 1993). In 1960/61 PNG was exporting 7400 tonnes of cocoa and this had expanded to 30 400 tonnes by 1975/76 (Densley and Barker 1987). Smallholders were responsible for much of the growth, increasing their output from 1000 tonnes in the mid 1960s to 12 000 tonnes in the mid 1970s (Densley and Barker 1987).

The industry stagnated from 1980 to 1985 with low world cocoa prices and dry conditions in 1982 and 1983. In 1986, production increased slowly with an improvement in world prices, reaching peak levels in 1988/89 with the yielding of the SG1 hybrids, planted in the mid 1980s. However, total production declined dramatically in the early 1990s with the Bougainville crisis and Phytophthora pod rot in ENB brought on by a bad wet season. Production levels continued to decline, exacerbated by the 1994 volcanic eruptions in ENB.

In 1995, production increased by 26 per cent and reached 35 000 tonnes in 1996. Despite production forecasts of increases in the next five to 10 years, given expected increases in world prices and plantings of HYVs, 1997 production is likely to drop substantially. Strong winds and heavy rainfall experienced nationwide during the flowering and pod-setting period means the production in the cocoa year to June 1997 was down by 23 per cent on the previous year (Fripp 1996; Peter 1997b).

Until 1990, cocoa was PNG's second most profitable export crop but has now been surpassed by palm oil. In 1994 it made up eight per cent of the agricultural export earnings compared with 23 per cent in 1980 (Bank of PNG 1995). Total export earnings from cocoa declined from K67 million in 1984 to approximately K33 million in 1993. However, with improved world prices, annual earnings had recovered to K66 million by 1994. Devaluation and the subsequent float of the kina in October 1994 have contributed to the increase in cocoa export earnings (Peter 1997b).

2.2.2 History of high-yielding varieties

The introduction of high-yielding varieties has been partly responsible for the expansion of the industry. The first crossing programme took place in 1958 but was hampered by an outbreak of vascular-streak dieback disease (VSD) in early 1960. In the early 1970s, DAL expanded their planting material programme with the distribution of nine Trinitario clones and nine hybrid varieties (Densley and Barker 1987).

In 1980, the Cocoa Industry Company (which became the Cocoa and Coconut Research Institute) continued the hybrid breeding programme established by DAL, developing what became known as SG1. The hybrid was expected to bear higher yields of 2.5 to 3 tonnes of dry bean per year (Yong Tan, n.d.) and be more disease-resistant than the Trinitario. Production was expected to begin two years after planting and reach maximum yields by year six. Yields would then remain constant until year nine and slowly begin to decline after year 10. The early yields of SG1 exceeded predictions, leading to increased grower and lender confidence in the crop. Resulting from the introduction of HYVs, as well as the extensive rehabilitation of senile plantations, output peaked in 1988/89 at a record 47 831 tonnes. However, after peaking early, hybrid yields fell rapidly after six years. The SG1, released in 1981, also proved susceptible to *Phytophthora* pod rot and VSD. Crop losses of 30 to 80 per cent were recorded in ENB and Madang (Benton and Belfield 1995).

The Cocoa and Coconut Research Institute (CCRI) was established in 1986 to develop new technologies capable of improving productivity at different levels of management, through the introduction of disease-resistant varieties and better management practices. Initial research concentrated on yield maximisation trials on experimental plots. In 1989, the SG2 hybrid variety was commercially released and distributed to farmers for planting. It was initially estimated that the SG2 hybrids would produce, on average, 42 per cent more than the SG1 (Yong Tan, n.d.). Largeholder yields were estimated at 1.3 to 1.4 tonnes of dry beans per hectare after three to four years and 1.2 tonnes per hectare on smallholder farms after four years of planting. However, on-farm trials were not carried out and, subsequently, the SG2 hybrid did not perform as well as expected on either the plantations or smallholdings. Yields were variable and not as high as experienced on the experimental plots. Results of research trials found yields increased in the first three to six years and then decreased quite sharply. In addition, many plants suffered from *Phytophthora* pod rot.

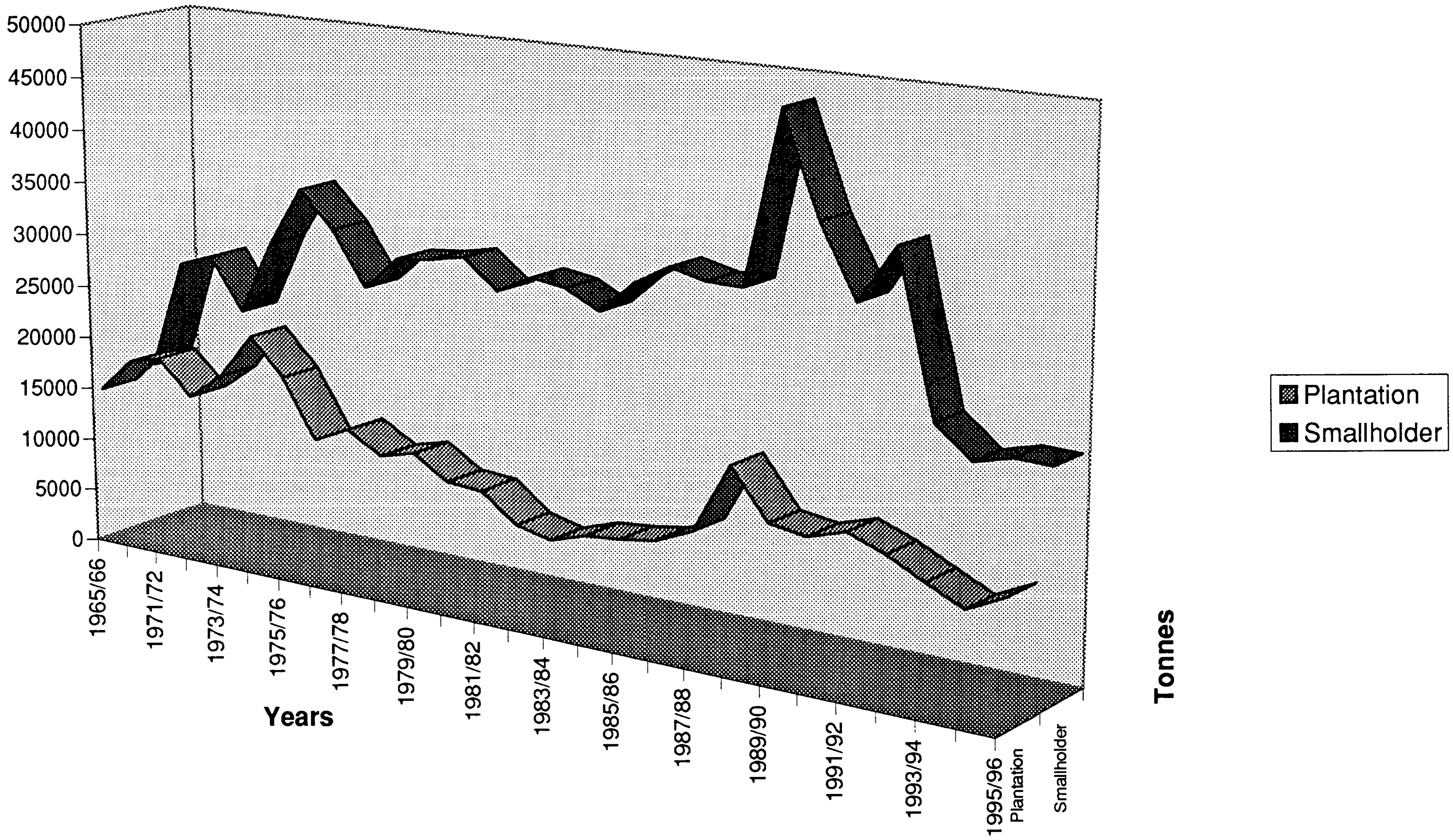
CCRI now only distributes the hand-pollinated and clonal planting material. To avoid further problems, on-farm trials are now carried out across different agro-ecological zones before distribution of planting material (Peter 1997b).

2.1.3 Cocoa prices

Low cocoa prices have had an adverse impact on the industry. Fripp (1996) found that with decreasing prices for cocoa, producers tended to decrease labour on the maintenance of the crop, hence lowering the quality of the cocoa and yields. Over the period 1986-1992, cocoa prices fell to an all-time low (in real terms) as a result of the volatility of world cocoa trade, raising concern of lower quality cocoa in the future (Grey 1993; Peter 1997b).

Since 1993, cocoa prices have improved, especially following the kina devaluation. From May 1995 bounty payments have not been paid out to producers as prices have exceeded the target support price of K1300 per tonne. In May 1997 the delivered-in-store (DIS) price rose above the trigger price of K1644.50 per tonne, forcing growers to pay out levies. Levies were collected in May and June 1997 at K17 and K49 per tonne, respectively, and cocoa prices are forecasted to continue to increase over the next few years (Peter 1997a). In response to growers' objections, the trigger price for levies on tree crops was raised by 20 per cent in August 1997. The new trigger price for cocoa is K1973.40 per tonne (DIS) (Peter 1997).

Figure 2.4 Cocoa Production 1970-1996



Sources: Cocoa Industry Board (1991); CBPNG (1997).

2.3.1 Smallholders

Smallholders can be classified as either village growers or blockholders. Manning (1992) defined village growers as customary land owners who 'own a number of small plots and have around 50 to 100 trees', and blockholders as those 'on a government resettlement block of two to ten hectares', maintaining their cocoa more intensively than the village grower. Many of the blockholdings have been abandoned or neglected due to the low world prices and land disputes (World Bank 1996).

Given the licensing powers of the Cocoa Board, smallholders have tended not to own a fermentary, instead selling lower priced wet beans to licensed dealers (Omuru 1997). In the past five years, extension services, in ENB particularly, have encouraged blockholders to invest in fermentaries, thereby increasing their profit margins (Manning 1992; Woruba 1997).

Smallholdings are characterised by relatively low levels of technology, yields and income, despite climate and agronomic endowments (DAL 1995b). Maintenance is of a low standard with limited weed control, routine pruning, pest and disease control and fertiliser inputs (Manning 1992). Smallholders tend to produce lower quality crops than largeholders and are slower in adopting new technology (Goldthorpe 1985). This is partly due to the high-cost structure from government intervention in the factor markets which has at times discouraged production (Fallon 1992). Recently, smallholder production has also been subject to adverse conditions including low prices, prolonged drought, lack of marketing structure, extension services, disease and the effects of the Bougainville (DAL 1995a).

Smallholders use family labour that is valued at or below the opportunity cost and may continue to apply labour until it marginal product approaches zero (Tiffen and Mortimore 1990). Smallholders rely heavily on family labour, hiring labour rarely. The amount of cocoa harvested will predominantly depend on the availability of labour. Hence, in the cocoa flush period (April to July), labour shortages can occur especially for smaller households, reducing the amount of wet bean harvested (Gimbol 1993).

The average smallholder yields have been estimated at 0.2 tonnes per hectare on poorly maintained plots and 1.2 metric tonnes per hectare in well maintained hybrid planting areas (Opa 1991). Potential yields are high by international standards, even with low levels of fertiliser use. Where smallholders have had access to new technology and management, such as through CCRI or a smallholder project, their yields have been higher. Moreover, there is still scope for increased production through expansion in area and productivity as well as through the adoption of more favourable agricultural policies.

Government programmes in the smallholder sector may have partially distorted producers' planting and supply responses. The ENB rural development project's (ENBRDP) subsidised replanting programmes and encouragement of smallholder fermentaries through subsidised credit schemes have influenced the planting investment decisions by smallholders (Jolly 1987; Omuru 1997). Further, production is also subject to levies and bounties. It is unknown, however, how much of the bounty is transmitted to growers from the export level.

2.3.2 Plantations

A plantation is classified by the National Statistics Office as an area of freehold or alienated land greater than 10 hectares. PNG plantations range from 10 hectares to 100 hectares, which is small compared with the estate sectors in Malaysia and Indonesia of up to 1000 hectares (Manning 1992). The plantation sector is recognised as a well organised and managed sector, renowned for the highest level of adoption of new research output and ability to influence government policies such as price support (Fripp 1996).

Plantation owners tend not to diversify their cropping systems that are characterised by large overheads, making them more vulnerable to decreasing world prices than smallholders (World Bank 1996). It has been estimated that if a plantation fully maintains its asset base, yields should be at least one tonne per hectare (Fripp 1996). Hired labour is usually employed from the rural sector. In regard to wage rates, largeholders tend to employ labour at wages above its opportunity cost and cease to employ labour when the value of the marginal product falls below the wage level. Most plantations have their own fermentaries, and hence ferment and dry their own beans and sell them to licensed dealers or directly to overseas buyers.

Plantations tend to have a higher ratio of capital to cultivated land than smallholders which often creates an incentive to increase productivity per planted hectare (Tiffen and Mortimore 1990). If the capital-land ratio is high enough to ensure research and development and management of the latest technology, yields may be expected to be higher than on smallholdings with a lower capital-land ratio. Where estates have been short of capital, yields have been lower. According to Tiffen and Mortimore (1990), high yields are associated with high capital-cultivated land ratios rather than with size of holdings.

Over the past 30 years, the plantation sector has suffered several depressed periods of production. The decline in sector growth in the 1970s was attributed to the increasing number of senile trees and a loss of confidence by expatriate plantation owners brought on by the Land Acquisition and Redistribution Scheme (Jolly 1987).[1] Significant redevelopment in the plantation sector in the 1980s, the introduction of the Export Tree Crop Loan Scheme and the availability of new hybrid planting material improved production levels but the recovery was slowed down by the lack of plantation maintenance during the 1970s (Jolly 1987).

From 1981 until the price collapse in early 1989, new plantings expanded rapidly, especially on abandoned and run-down plantations (Manning 1992). With the redevelopment of cocoa plantations, plantation labourers were retrained in chemical use, planting and nursery techniques, husbandry, and pest disease identification and control (Manning 1992).

The depressed cocoa prices in the 1990s forced plantations to reduce their costs of maintenance and pest and disease management. With reduced husbandry standards and severe pod rot, future yields were expected to fall. In the 1980s and early 1990s, yields

[1] The Land Acquisition and Redistribution Scheme offered low levels of equity to Nationals to increase national plantation ownership over foreign ownership (World Bank 1992).

were around 0.9 tonnes per hectare. However, by 1993 cocoa yields had declined to 0.53 tonnes per hectare and continued to fall to 0.49 tonnes per hectare by 1995 (Fripp 1995).

In 1995 and 1996 it was demonstrated that, with and without price support, the average plantation was operating at a negative net margin (see Table 2.4) (Fripp 1996; Omuru 1997). However, in reality, some plantation owners are able to produce higher quality cocoa, thereby receiving a premium of at least K100 to K200 per tonne higher than the average market price for cocoa (Omuru 1997; AOD 1992).

Table 2.4 Plantation margins, 1993-1996

Plantation average	1993 (K/tonne)	1995 (K/tonne)	1996 (K/tonne)
Net margin - with bounty	-87.78	-193.28	*
Net margin - without bounty	-636.78	-221.28	-106.84

*No support price was paid out in 1996 due to prices exceeding K1300/tonne.
Sources: Fripp (1996), Omuru (1997).

Despite receiving higher prices, the largeholder sector is constrained by finance and land availability. In June 1995, the commercial loan repayments of cocoa plantation owners was K84.3 million (World Bank 1996). Obviously, this has restricted their access to investment funds for expansion and capital investment growth. In addition, the price support scheme still requires plantations to repay their outstanding debt repayments. When the world price exceeds K1645 per tonne, government levies are enforced on the industry. Plantations argue that the high world prices are needed for the sector to recover. Hence, by losing 50 per cent of the additional revenue from prices over the levy enforcement price, it may restrict the sector's ability to reinvest and re-establish their yields and asset base (Peter 1997a).

The devaluation of the kina has increased the cost of imported goods by up to 30 per cent but this is believed to have been more than offset by the increases in producer prices (Fripp 1996). With increased producer prices, the plantation sector has begun replanting programmes, using hybrid clones from CCRI, and reinvesting in pest and disease programmes. Plantations experienced a 20 per cent increase in yields from 1995 to 1996 (Omuru 1997). This was mostly due to improved weather conditions.

2.3.3 Exporters

The marketing and export of cocoa is private sector-based and is considered well organised and competitive (World Bank 1996). Cocoa is directly exported by either larger plantation companies or licensed exporters. To be issued with an export licence by the Cocoa Board, exporters require a minimum of 1000 tonnes export grade cocoa (Manning 1992). There are currently 13 licensed exporters, of which ten are active (Peter 1997b). Agmark Pacific holds around 90 per cent of the market share, running agencies in most of the cocoa-growing areas (Peter 1997b).

PNG's major export markets have changed over the past three decades. In the 1970s, USA, Australia, France and West Germany were the major importers. By the 1980s West Germany had become the major importer, buying approximately 50 per cent of the total exportable cocoa production (Densley and Barker 1987). In the 1990s, Singapore has taken over the market, importing about 45 per cent of total output with Germany importing only seven per cent (Peter 1997b).

2.4 Major Cocoa-Producing Areas

2.4.1 Overview

Cocoa production is concentrated predominantly in the coastal areas of PNG. North Solomons, ENB (over 50 per cent), New Ireland (10 per cent), Madang (9 per cent) and East Sepik (8.5 per cent) are the major cocoa-producing provinces (see Table 2.5). Until the Bougainville crisis began in 1989, ENB and North Solomons accounted for 80 per cent of supply.

Table 2.5 Share of total cocoa production by province, 1992-1996

Province	1992/93 %	1993/94 %	1994/95 %	1995/96 %
ENB	52	50	49	60
North Solomons	15	15	17	11
New Ireland	8	8	9	9
Madang	8	9	5	7
East Sepik	7	9	7	6

Source: Peter (1997a).

Considerable yield variation has been found between provinces and within regions of individual provinces (Yarbro and Noble 1989) (see Table 2.6). High yields in ENB correlated with higher planting densities and younger trees. East Sepik's lower yields were attributed to lower planting densities and the older age of tree stock.

Table 2.6 Average smallholder yields by province

Province	Per hectare (kg)	Per bearing tree (kg)
East New Britain	320	0.9
East Sepik	170	0.7
Madang (NCR)	100	0.7
Madang (Karkar)	80	1.0

Source: Yarbro and Noble (1989).

In the 1980s new plantings of hybrids were predominantly in ENB, where over 80 per cent of the surveyed blocks were under 10 years old (Yarbro and Noble 1989). Plantings in East Sepik and Madang North Coast Road area tended to be older with some blocks exceeding 30 years since first planting, attributed to the unavailability of hybrid planting material (Yarbro and Noble 1989).

2.4.2 East New Britain

Situated on an island to the north-east of mainland PNG, ENB was one of the first provinces to grow cocoa in the early 1950s. The cocoa industry is a major income source for the province, earning 47 per cent of the total provincial income in 1996 (World Bank 1996). ENB has become the largest provincial supplier of cocoa, with a major proportion of the production coming from the highly fertile western region of Gazelle Peninsula. With smallholder cocoa developments spreading to other areas of the province, ENB is expected to remain a major producer of cocoa (Woruba 1997).

Plantations have dominated the industry in ENB but smallholdings have expanded with increased access to extension services, credit facilities, good road infrastructure and aid from government-owned management agencies (National Plantation Management Agencies). The ENBRDP has been partially successful in increasing the yields and incomes of smallholders. A total of 2745 hectares of cocoa trees were planted between 1990 to 1996 and still remain relatively healthy, although general lack of pruning has increased the incidence of black pod (Ryan 1997).

The Gazelle Peninsula, in the northern part of ENB, is rich in volcanic ash soils. Climatically, the province is prone to long dry spells of up to eight months which can severely reduce cocoa production (Bleeker and Freyne 1981). Of ENB's 18550 km^2, Bleeker and Freyne (1981) classified 4.1 per cent of the province as very high potential for cocoa production, 0.65 per cent of high potential and 1.7 per cent of moderate suitability. By 1975/76, 62.2 per cent of the area classified by Bleeker and Freyne as suitable for cocoa had been planted. With one of the most densely populated lowland areas, soil degradation on Gazelle Peninsula, in particular, has begun to become a problem. DAL (1996) included more land in the moderately suitable category (14.8 per cent) and classified 70 per cent of the province as marginally suitable.

2.4.3 East Sepik

East Sepik's smallholder cocoa industry produces six to ten per cent of the national production. With the introduction of the Smallholder Cocoa/Coconut Rehabilitation and Expansion Programme (SCCREP) in 1987, more smallholders entered the industry and the new extension service, Cocoa and Coconut Extension Agency (CCEA), is expected to encourage more households into the market.

With high rainfall and fertile soils, East Sepik's agro-climatic conditions are highly suitable for cocoa production. However, the province is constrained by a lack of good marketing facilities, especially roads to market, thereby reducing the profitability of cocoa production (Gimbol 1989). Further, a large portion of the moderately suitable land is relatively inaccessible or prone to flooding (Bleeker and Freyne 1981).

East Sepik covers an area of 41 720 km^2, of which Bleeker and Freyne (1981) considered 2.9 per cent was moderately suitable, 0.6 per cent was of low suitability and 2.6 per cent of very low potential for cocoa cultivation. In contrast, DAL (1996) saw greater potential for the province, classifying 2.6 per cent of the province as highly suitable for cocoa production, 8.7 per cent moderately suitable and 20.6 marginally suitable.

2.4.4 Madang

In Madang, cocoa is grown by both smallholders and largeholders, situated predominantly on Karkar Island and North Coast Road. In 1996, cocoa represented 14 per cent of income in the Madang province, behind the major income earner, copra which earnt 42 per cent of total income (World Bank 1996). Cocoa was first produced commercially in Madang in the late 1950s as a plantation crop, but rapidly expanded as a smallholder crop in the 1960s (Bleeker and Freyne 1981). In the 1990s, largeholders and smallholders have produced 55 and 45 per cent, respectively (Peter 1997a). Access to extension services, marketing information and credit facilities are constraints faced by smallholders in Madang but government efforts to improve extension services are encouraging more smallholders into the industry (Woruba 1997).

Madang's high rainfall and volcanic soils make it conducive for large-scale cocoa growing. Potential for expansion in this province is particularly on the Rai Coast, south-east of Madang (Bleeker and Freyne 1981). Bleeker and Freyne (1981) estimated that 1.8 per cent of Madang province was highly suitable for cocoa, 1.3 percent was suitable, 3.5 per cent was moderate and 6.4 per cent had a low potential for cocoa cultivation. DAL (1996) rated a higher amount of land suitable for cocoa production, classifying 3.6 per cent of the province highly suitable for cocoa production, 12.8 per cent moderately suitable and 31.8 per cent marginally suitable.

2.5 The International Cocoa Market

Cocoa is grown in over 50 countries but only 12 countries produce more than one per cent of the total world production. Seventy nine per cent of the world production is grown in Côte d'Ivoire, Brazil, Ghana, Malaysia, Nigeria and Cameroon (Densley and Barker 1987). Indonesia has recently become a major producer, increasing the Asia-Pacific share of world production to 21 per cent in 1993/94 (Benton and Belfield 1995). PNG cocoa exports currently make up only one per cent of the world cocoa export volume. They peaked at two per cent of the world share in the early 1980s (Peter 1997b).

The 1980s was a period of growth in world production of cocoa. However, the 1990s showed no upward trend until 1995/96 when Indonesia became a larger supplier and favourable weather conditions occurred in African cocoa-producing countries (Peter 1997b). The concentration of production increases the variability of world supply, where seasonal conditions in a major producing country can have a significant impact on the world market.

In the 1990s, world consumption has exceeded world production, causing a decline in the cocoa bean stock levels (Peter 1997b). The rate of world cocoa consumption, measured by total grindings of cocoa beans, increased by 7.75 per cent in the 1995/96 cocoa year (Peter 1997b). World production is forecast to increase over the next few years but world demand is also expected to rise, creating only a small production surplus (Fripp 1996).

During the 1990s, the average annual International Cocoa Organisation (ICCO) daily price has shown no consistent trend. Prices were down at the beginning of the decade, due to seven consecutive years of production surpluses, but since then prices have not reflected movements in world cocoa stocks (Peter 1997b).

2.6 Summary

This chapter has provided a background on the characteristics of the cocoa industry in PNG, in regard to the sub-sectors and regions. It has focused on the variations in output and output responses between the largeholders and smallholders and between the three provinces; Madang, ENB and East Sepik. A discussion on the policies which are most likely to impact on the industry is presented in the next chapter. Empirical studies covering policy impacts on the agricultural and the tree crop sector in PNG and in other countries are reviewed, and the relevant results reported.

3. Policy Impacts on the Tree Crops Industry

3.1 Introduction

In 1994, the DAL updated its medium-term development strategy for the agricultural sector, proposing strategies for accelerated agricultural growth to the year 2000 (DAL 1995). As part of its strategy in achieving these development objectives, the government prioritised the tree crop sub-sector in its budget allocation. The strategy emphasised the need to expand agricultural production and export earnings through predominantly non-price policies such as research and extension, smallholder public investment projects, diversification and production subsidies to specific industries (DAL 1995). Financial problems and low world commodity prices in the 1990s have made these goals somewhat difficult to achieve. Government measures to encourage agricultural production seem not to have been sufficient to overcome the adverse effects of current policy and constraints (Fallon et al. 1994).

Discussed below are the PNG government policies which are likely to have the greatest impact in revitalising the cocoa industry. A brief history is given of pricing policy, exchange rate policy and extension and research, followed by a review of the literature on the impacts of these policies on the agricultural and tree crop sub-sectors. Other empirical studies on the impact of policy changes on agricultural production are then discussed.

3.2 Pricing Policies

3.2.1 History of pricing policies in PNG

Since 1974, pricing policies have been implemented by the government to increase and stabilise production and incomes of tree crop producers, in the face of unstable terms of trade. Efficiency and welfare have been of prime importance to the smallholders while output growth of the particular tree crop has been the primary aim at industry level

(Brogan and Remenyi 1987). However, the effectiveness of pricing policies has been limited and the Agricultural Guaranteed Price Support (AGPS) scheme, currently in place, was due to be phased out by November 1997 (King and Sudgeon 1996).

A price stabilisation scheme for cocoa began operation in 1974 (AOD 1992). The commodity price schemes employed buffer funds that imposed levies on exports at high price levels and retained the funds to pay bounties when prices fell below a threshold price. However, with farm-gate prices continuing above the FOB export prices, together with consistently low world prices prevailing for major commodity exports, the stabilisation funds were eventually exhausted. All funds were depleted between mid 1988 and mid 1991, and the tree crop industries have since been dependent on loans and price support from the PNG Banking Corporation and STABEX-backed loans (AOD 1992). The cocoa industry was the first to draw upon loan funds in 1989, followed by the copra and palm oil industries in 1990 and the coffee industry in 1991 (DAL 1995).

The price support scheme was introduced in 1989, with recommendations to phase it out over three to five years (Opa 1991). In the 1993 budget, it was formalised into the AGPS scheme, a deficiency payments scheme, run by the Bank of PNG (DFP 1995). Initially, the support prices were based on the perceived costs of production of the 'efficient producer' and were to decline to zero over an adjustment period. However, in November 1992 the new government raised the support prices and fixed them for a five-year period at K1300 per tonne for cocoa (Fairbairn 1993). After the five-year period, following an adjustment phase, government price support was expected to fall to zero.

At the end of 1992, the scheme was thought to have increased the output of export crops significantly but at a cost of K271 million in guarantee loan drawdowns (DAL 1995). The policy was revised in the 1994 budget and several problems identified, including pressure on finances, creation of vested interests, rent-seeking activities and over-reliance on the government (Fallon et al. 1994). The rise in world prices since 1994 has reduced the need for price support and levies are now imposed when prices rise above the trigger price. In July 1997, the National Executive Council converted the Stabex component of the outstanding debt for price support into a grant, reducing the cocoa debt by K42.2 million.

3.2.2 Pricing policy effects on agricultural producers

Uncertainty surrounds the level of benefits that have resulted from pricing policies attempting to counter the negative impacts of price fluctuations and depressed world prices. Most studies have assessed the benefits and costs in terms of welfare effects. The welfare argument assumes that:

(1) tree crop producers are risk averse;

(2) export earnings make up a significant proportion of the producers' income;

(3) export prices are transmitted through the market chain to the producers;

(4) external market forces are responsible for the variability in tree crop export earnings; and

(5) price stability translates into income stability.

Some studies suggest that the assumptions do not all hold for PNG tree crop producers. In regard to assumption one, little work has been done on the level of risk aversion of tree crop producers, but it is assumed that farmers are moderately risk averse. Mwesigye (1988) estimated the supply responsiveness of smallholder and largeholder coffee farmers, concluding that both groups responded positively to price changes but that the supply response was highly inelastic.

Assumption two holds for largeholders but is less realistic for smallholders. Fleming and Piggott (1989) argued that for smallholders, domestic markets and off-farm employment still provided the bulk of the family income and living requirements, thereby limiting their reliance on tree crop export earnings. Additionally, smallholders are quite diversified and flexible in their production of crops and livestock. If world prices fell for tree crops they would have the ability to move into other forms of market and subsistence farming. In contrast, Yarbro and Noble (1989) suggest that a high percentage of households in the cocoa-producing provinces depend predominantly on their income from cocoa to supplement their subsistence produce.

Regarding assumption three, Gumoi (1992) found that the evidence was inconclusive concerning the extent of the pass-through of bounties and subsidies from export level to producer level. However, in relation to the coffee marketing chain, Overfield (1991) found that the level of support did pass through to coffee producers, despite the existence of three intermediaries between the grower and the point of export. In addition, Guest (1989), using export prices and local supplier prices, found a significant degree of pass-through in the marketing chain for the tree crops sub-sector. In regard to assumption four, Onchoke, Fleming and In (1993) estimated that domestic supply factors were as significant in determining variations in revenue as external demand factors.

One of the major aims of the price stabilisation schemes has been the stabilisation and growth of producer prices and income. Gumoi (1992) found that the copra scheme was the most effective in reducing export price variability, followed by cocoa and coffee and finally oil palm. However, stabilisation of producers' incomes only had a small but positive effect on growers' income (Gumoi 1992; Jarrett and Anderson 1989; Overfield 1991).

It is thought that the stabilisation schemes have created sizeable distortionary effects which have dampened the level of export receipts. Prices have been separated from short-run marginal costs, thereby removing the incentive to produce more in periods of high prices and less in the periods of lower prices (Claessens and Duncan 1993). In addition, with uncertainty surrounding export prices, conservative estimates have often been made to keep producer prices at a lower than average rate. Concern has also been raised over the tendency for producer contributions to stabilisation funds to be lower than their receipts, hence reducing their net income. In his review of price stabilisation, Jolly (1990) suggested that the price stabilisation schemes created very small net economic benefits and that their justification depended on political considerations.

In regard to the welfare effects of the current price support schemes in PNG, little research has been carried out to date. However, in theory, unlike traditional trade protection instruments, the deficiency payments are paid by the taxpayers rather than the consumers; hence, consumer surplus is not reduced. As a direct payment, no trade policy mechanisms, such as tariffs or quotas, are required, therefore no restrictions are put on trade. However, there is a problem in neutralising market forces, thereby constraining efficient resource allocation and diversification.

There is uncertainty surrounding the supply responsiveness of producers to price support schemes. Gerritsen (1985) suggested that copra producers in Milne Bay were increasing output when world prices were falling. Ruhle and Fleming's (1998) empirical work on the effect of price support on cocoa supply found that smallholder cocoa producers had a negative supply response to price (the case of the perverse supply response is discussed in Appendix A). This suggested that the price support fund had been ineffective in achieving increases in supply of cocoa for export. The tentative conclusion was drawn that the price support fund was targeting the wrong price indicator. However, the authors were aware of shortcomings with their econometric model and suggested that poor data may also have caused the unexpected result.

3.3 Exchange Rate Policy

3.3.1 History of exchange rate policy in PNG

From independence in 1975, PNG followed a 'hard kina strategy' to constrain domestic expenditure in order to avoid large budget deficits and high levels of foreign borrowing (Duncan 1995). Despite maintaining a convertible currency and relatively low inflation as well as artificially holding up the value of the kina throughout the 1970s, the policy put pressure on tree crop producers. It lowered prices in kina terms for primary commodity exports on top of already low world commodity prices. With a deterioration in the terms of trade from 1980 to 1982, it was necessary to revise the strategy (Duncan 1995).

From 1983, real depreciations were allowed but due to further deterioration in the terms of trade during the early 1980s and the mounting foreign debt, further depreciations were required in 1985. The policy became unsustainable with a breakdown in fiscal discipline and higher wage levels unsupported by productivity growth.

A Structural Adjustment Programme was put in place in 1989/90 as a consequence of diminishing government funds and closeness to default on World Bank loans. In 1990, under this program, the PNG government agreed to devalue the currency by 10 per cent (Semel 1995). Speculation against the currency increased in August 1994, forcing a 12 per cent devaluation of the kina, followed by suspension of foreign exchange trading in early October and a decision to float the kina two weeks later.

3.3.2 Exchange rate effects on agricultural producers

The devaluation and the subsequent float of the kina have been found to have both positive and negative impacts on the agricultural sector. First, the agricultural sector has gained a greater level of international competitiveness and subsequently increased agricultural export earnings. Zeitsch, Fallon and Welsh (1993) estimated that a seven per cent fall in the real exchange rate (via a 10 per cent reduction in real wages) led to a six to eight per cent increase in the volume of agricultural exports.

However, the government support prices have been set significantly above world prices, insulating growers' revenue from exchange rate effects. With the rise of mining exports likely to continue, the kina is expected to appreciate, reducing the competitiveness of the agricultural sector (Grey 1993). The efficacy of exchange rate policy in developing tree crop exports is also under question. The World Bank (1988a) considered that the key to long-term growth and profitability lay in improving productivity and reducing costs, rather than through exchange rate policy.

3.3.3 Exchange rate effects on the cocoa industry

In their analysis of the 1990 devaluation, the World Bank (1992) assumed fixed input coefficients (i.e. producers do not change their production techniques after the change in the exchange rate). They found that most of the devaluation passed through to the export tree crop producers to increase their international competitiveness. Since smallholders used few imported inputs, the gains from the devaluation were expected to be considerable and much higher than in the plantation sector where there was greater use of imported inputs. However, for cocoa producers, the 10 per cent devaluation, in conjunction with effective wage constraints, increased smallholder incomes by 7.0 per cent and plantation incomes by 7.6 per cent.

Fallon, King and Zeitsch (1995) measured the effects of a 20 per cent devaluation of the kina, using a general equilibrium model of the PNG economy. In the short run, they found that plantation output increased by 1.1 per cent but had no effect on smallholder cocoa. The smallholder outcome was explained by the constraining assumptions and the operation of the price support scheme which prevented the full benefits of the devaluation from being passed on.

Omuru, Fraser and Burton (1996) studied the welfare effects on cocoa producers of price support policy and the devaluation of the kina in the 1990s. They concluded that the policies both had a positive welfare effect on producers although the devaluation had lessened the effectiveness of the price support policy, thereby reducing the negative impacts of the policy's removal in 1997. In addition, more risk-averse producers were found to receive greater benefits from the introduction of the price support system than the devaluation of the kina.

Ruhle (1996) and Ruhle and Fleming (1998) assessed the effect of exchange rates on cocoa supply and smallholder incomes. Ruhle (1996) found that the real effective exchange rate variable appeared to have an insignificant effect on smallholder supply response. Ruhle (1996) also demonstrated that smallholders experienced an increased income after devaluation, given that producers responded positively to increases in world prices. Ruhle and Fleming (1998) found that supply elasticities were high and positive in response to a devaluation which was contradictory to a negative response to world price changes.

3.3.4 Other studies of the effects of devaluation on output

There is no generally accepted relationship between aggregate output and devaluation. However, in the short run, many studies point to a contractionary output effect from a devaluation (Siamwalla and Setboonsarg 1989; Rouis, Razzark and Mollinedo 1994; Boccara and Nsengiyumva 1995; Edwards 1989; Krugman and Taylor 1978).

Rouis, Razzark and Mollinedo (1994) summarised the results of 22 sub-Saharan African country studies of the effects of devaluation on output. They found that not all countries experienced contractionary effects and, where it was evident, it was short-lived; in the long run, devaluation was neutral.

Boccara and Nsengiyumva (1995) evaluated whether in the short run, a devaluation could have a contractionary effect on primary commodity exporters in less developed countries. They found that for devaluation to a have a positive impact on output, wage indexation must be kept to a minimum. They also demonstrated the importance of the timing of producer responses. It was suggested that if producers based their production decisions on the pre-devaluation prices, the devaluation would have a contractionary effect on output.

3.4 Agricultural Research and Extension

3.4.1 History of research and extension in PNG

In 1977, under the Organic Law, extension services were devolved to the provinces while research remained at the national level. Along with the emigration of many ex-patriate staff after independence (1975), the quality and quantity of extension services fell, forcing remaining staff to spread themselves over a broad range of duties (Stein 1991).

Since 1980 the PNG national agricultural research system (NARS) and extension services have been transformed in terms of organisation, structure and management (Sitapai 1994). Research and extension functions have been transferred to corporatised crop organisations. Research into tree crops has been the responsibility of semi-autonomous organisations such as the Coffee Research Institute (CRI), Cocoa and Coconut Research Institute (CCRI) and the Oil Palm Research Association (OPRA) which are gradually being absorbed into the Corporations. However, the linkages between the government and corporations are minimal. The commodity corporations and NGOs are tending to carry out specific crop research in isolation (Bakani 1994).

Extension services have been primarily the responsibility of the provincial governments. However, the national government has been involved through public investment projects

(PIPs), aimed at servicing farmers in the remote areas. Government funding is concentrated in the export crop sector, particularly in expanding areas of oil palm, although the allocation has been steadily decreasing for the PIPs. Programmes in the export crop sector have focused on expansion and rehabilitation but, due to funding shortages, most of them have ended or been taken over by the Corporations (DAL 1995). In the cocoa industry the Smallholder Cocoa and Coconut Rehabilitation and Expansion Programme (SCCREP) and the ENBRDP have been implemented with varying degrees of success.

SCCREP, introduced in 1987, aimed to rehabilitate senile trees, expand blocks and improve extension in order to increase productivity and ultimately producer incomes (DAL 1992). The project targeted smallholders with less than one hectare of cocoa and planned to cover over 6000 hectares of cocoa and nine provinces, with the aid of both DAL and DPI. The Project fell severely behind schedule and was disbanded before the completion date. Many smallholders considered the project a failure because the investment in fertilisers and mechanised inputs was not accompanied with the appropriate management information required to bring about the expected benefits from the new technology (Gimbol 1989).

The ENBSDP, established in 1989, ran until 1996. Despite a delayed start, it was more successful than SCCREP, reaching its goal of setting up 887 smallholders on 2 300 hectares of cocoa and coconut on government land in ENB province (Ryan 1997). However, black pod disease is threatening to lower production levels, especially on poorly maintained blocks.

Given the poor performance of the DPI, the government decided in 1997 to transfer cocoa extension from the provincial DPI staff to the recently created CCEA. Branches are being located in the major cocoa-producing provinces and have been set up to work with CCRI. The ENBSDP extension services model will be adopted and staff from the project are likely to be employed (Ryan 1997).

3.4.2 Studies on effects of extension policies

No economic studies were found on the impact of extension services on the cocoa industry in PNG. Some literature has been written on the engagement of extension services in regeneration schemes in several cocoa-producing countries. In many cases, the adoption of regenerative techniques have been well below agronomists' expectations. Petithuguenin (1995) illustrated this phenomenon with two examples from Brazil and Togo. He emphasised the insufficient attention paid to the economic costs and benefits of the different replanting techniques and underestimation of the difficulties in some techniques developed in research stations.

3.5 Other Studies on the Effects of Policies on Agricultural Producers

Trivedi and Akiyama (1992) analysed the effects of government policies on the cocoa and coffee industries of Côte d'Ivoire. By specifying a time path of identified variables, from 1987 to the year 2000, they were able to study the potential impacts of policies on production levels, quantity of exports, new plantings, removals and tax revenues.

In Côte d'Ivoire, producer prices for cocoa and coffee were set above the world prices to encourage production and export revenue. Due to extended periods of depressed world prices, the price stabilisation program suffered from substantial financial deficits. With producer cocoa and coffee prices fixed at 47 per cent and 36 per cent above the world price, the cocoa sector expanded more rapidly than the coffee sector.

Simulations showed that with an unchanged exchange rate, a 40 per cent price cut for cocoa and a 10 per cent price cut for coffee would generate a CFAF 113 million surplus compared with a CFAF 1 957 million deficit without the price cuts. The trade-off would be a fall in cocoa production by 38 per cent by the year 2000, thus causing world prices to increase, while coffee production would increase by 5 per cent. A 50 per cent devaluation in the exchange rate, given unchanged producer prices, was predicted to generate a surplus of CFAF 1 098 million after an initial decline in 1987.

Akiyama and Coleman (1993) used a production function simulation approach to assess the likely impacts of policy changes on coffee farmers in Nicaragua. Their findings suggest that a 10 per cent real devaluation would have a positive effect on the coffee sector, despite the increased prices of imported fertiliser. Output and exports both would increase by 10 per cent, indicating an elasticity of unity between production and the exchange rate. An increase in labour efficiency of 10 per cent would cause yields to increase for all technologies and exports to increase by 10 per cent over the 10-year period. Finally, a fall in coffee prices of 10 per cent would have the opposite effect, decreasing the demand for inputs, reducing yields and investment in improved technology and ultimately reducing exports by 27 per cent.

Huang (1992) assessed the impacts of adjustment costs on the implementation of government price support and crop-switching programs. Adjustment costs were incorporated in the response function through the profit maximisation equation. Those costs associated with the adoption of new technology slowed down the adjustment of rice output to increased prices as well as hindering the movement from rice production to other enterprises.

In summary, this chapter has provided a background on the policies that are most likely to impact on the cocoa industry in PNG and a review of the findings from empirical studies of policy impacts on agricultural output. The following chapter is a more detailed discussion on the theoretical frameworks and models applicable to the study of the impacts of policy changes on the cocoa industry in PNG.

4. Choice of Model

4.1 Introduction

A majority of the perennial crop supply studies to date have adopted an econometric approach, with few examples of simulation approaches. This chapter opens with a discussion of the advantages and disadvantages of different approaches—simulation, econometric and mathematical programming—with respect to the study objectives. This is followed by a discussion on the unique features of perennial crop production critical to modelling the supply response of the cocoa producers to changes in policy. Perennial crop supply studies are mentioned in relation to their approaches in modelling the planting, harvesting and yield responses.

4.2 Approaches

4.2.1 Econometric approach

Perennial crop supply models have predominantly followed an econometric approach. An econometric approach has been defined as 'a study of empirical data by statistical methods of estimation and hypothesis testing' (Chiang 1984). Many data are required although, more recently, econometric perennial crop models have been developed in the light of limited data (see section 4.6.2). In addition, econometric models assume that variable relationships remain stable over time. These models are therefore not appropriate where structural changes have taken place in the industry, such as the exchange rate liberalisation and expected abandonment of commodity price schemes in PNG. Even in the case of reliable data, econometric modelling would be limited in predicting responses to changes in prices and policy variables.

Knapp (1987) criticised econometric models for their inadequacies in catering for the changes in yield, input requirements and age composition of perennial crops over the life span of the crop, in the light of data limitations. He believed that these influences on new plantings, replantings, removals, quantity produced and subsequently producer prices were not fully accounted for.

Econometric approaches are adopted in the proposed study to estimate some key parameters. Ordinary least squares regression is used for estimating smallholder production function parameters and a state-space model is used to obtain coefficients for the replanting and new planting responses. However, it is apparent that price is not the most significant factor in determining planting responses in an industry recently supported by smallholder cocoa projects and suffering from natural disasters such as volcanoes and cyclones. Hence, the estimates are modified to account for these factors.

4.2.2 Mathematical programming approach

There are several perennial crop supply response models that have adopted a mathematical programming approach (Knapp 1987; Bellman and Hartley 1985; Trivedi 1986). Mathematical programming models have tended to be deterministic, optimising and empirical, allocating resources, which are restricted in some way, with respect to some objective function (France and Thornley 1984).

Knapp's (1987) dynamic equilibrium model for the Californian alfalfa market attempted to determine the optimal rotation endogenously in the model. The competitive equilibrium was determined by solving the optimisation problem of maximising net benefits. This approach was believed to be superior to an econometric approach where time-series data on plantings, removals, area and production were not available. In addition, it could be used where changes in economic conditions or policies resulted in values of explanatory variables being significantly different from their historical values.

As a normative approach, mathematical programming and optimisation have been most useful in the area of farm management rather than for policy impact analysis, which requires a positive approach.

4.2.3 Simulation approach

Simulation has been described as 'the process of defining, creating and studying a model in order to develop conclusions that provide insight as to the behaviour of the real system' (McHaney 1991). It includes not only the model development but also the model experimentation (McHaney 1991; Korn 1989).

Simulation has been used extensively in policy planning and analysis by social scientists (Whicker and Sigelman 1991). Through sensitivity testing, it is a powerful tool for retrospective, contemporary or prospective policy testing. In its prospective capacity, it facilitates the systematic exploration of policies that are yet to be implemented or for which empirical data are scarce (Whicker and Sigelman 1991). In so doing, potential problems can be identified and analysed in less time and at a lower cost than by real experiments. Simulation models require less data than econometric models which is an advantage for studies on developing countries where problems of insufficient data usually arise. In addition, it reduces the risk of implementing and modifying a system by its ability to conduct 'what if' scenarios (McHaney 1991).

Obviously there are some shortfalls in using a simulation approach. They include the difficulties in verifying a system which is not known with certainty, the lengthy amount of time required in the development phase and the estimation of coefficients which may have to be determined with limited data (McHaney 1991; Whicker and Sigelman 1991).

4.3 Characteristics of Perennial Tree Crop Production

In building a cocoa supply response model, the unique characteristics of perennial crops need to be considered. Perennial tree crop production can be distinguished from the production of annual crops by: the long gestation period between planting and harvesting; the longer time horizon; the heterogeneity of capital stock with respect to yield in terms of both the varietal differences and the age distribution of stock; the decline in productive capacity in the later years of the plant's life; qualitatively different investment decisions; new plantings; replantings; removals and harvesting; adjustment lags and costs of different planting decisions; lagged impact of management strategies on yields; and technological advances over the life span of the crop (French and Matthews

1971; Knapp 1987). Discussed below are the approaches to modelling investment, supply and yield responses.

4.4 Planting and Harvesting Responses

Since the 1960s, attempts have been made to depict separately the short- and long-run decisions in perennial crop production. The short-term period is representative of the harvest response, dependent on cocoa prices, weather, pests and diseases, variable costs of harvesting and marketing (weather and diseases are also critical factors in the growth stages of the cocoa pods). The long term captures the variations in the age stock of trees, and planting and removal decisions. It is suggested that producers' planting decisions are made in response to long-run profitability of growing cocoa relative to other crops competing for the use of land. Jolly (1987) included a third time period: the medium term. The medium-term response is influenced by the levels of management and their subsequent impact on yields of current stock. Changes in maintenance will have a lagged effect on cocoa production and supply.

A chronological review follows of the attempts to capture the planting and harvesting responses. Of interest are the early modelling efforts because of their concentration on cocoa supply response. Given that the study proposes to use simulation (see section 4.10), the methodology adopted in the reviewed econometric studies is not discussed in depth. The focus is more on the choice of variables, findings and changes in modelling approaches.

4.4.1 Early cocoa supply models

In the 1960s, cocoa was the most researched perennial tree crop (Lim 1975). The supply response models were based on an estimated single reduced-form output function based on the Nerlovian adaptive expectations model developed for annual crops (Bateman 1965; Ady 1968; Behrman 1968). The long-term investment decisions—new plantings, replantings and removals—and the short-term harvest decision were combined, thereby not accounting for separate long-run and short-run producer supply responses. Some of the early studies recognised the need to separate the investment decisions form the harvest response, but lack of data forced many to estimate variables using the standard Nerlovian model.

Stern (1965) attempted to quantify the short- and long-run price responsiveness of cocoa farmers for the major cocoa-producing countries of the world: Ghana, Nigeria, Côte d'Ivoire, Cameroon Republic, Brazil and Ecuador. The new planting equation was simply a function of lagged prices (Lim 1975). Lack of data on new plantings and area for most countries limited the study to Ghana and Nigeria.

Bateman's (1965) cocoa supply response model was applied to five cocoa-growing regions in Ghana, accounting for soil and climatic differences. It assumed that yield and cost per acre remained relatively stable over the period and that growers maximised their present value of expected profits with respect to planted area. Assuming adaptive price expectations, output was expressed as a function of lagged own- and cross-prices, lagged rainfall, humidity and lagged output.

Findings showed that the total elasticity of output with respect to cocoa price was inversely related to the length of time cocoa had been grown in the region. In addition, the elasticities of output with respect to rainfall were relatively large, showing the importance of climatic factors in the cultivation of cocoa (Lim 1975).

Several weaknesses were identified with the Bateman model. The model did not include a removal decision, and hence the life span of the crop was assumed to be infinite (French and Matthews 1971). Ady (1968) criticised it for depicting the planting decision equation for cocoa as that of an annual crop. Finally, the model contained an implicit positive relationship between price and crop investment, which meant it was not responsive to downward shifts in the price level (Lim 1975). However, Olayemi and Oni's (1972) study on the asymmetry in area response to prices amongst Western Nigerian cocoa farmers found an elastic area response to increasing producer prices (1.16 to 14.42), but an inelastic area response to falling prices.

In her cocoa supply response model, Ady (1968) used area planted as the dependent variable and focused on the importance of the size of existing stock in deciding the area of new plantings. She included a price expectations model to account for the divergence between world prices and producer prices of cocoa created by the Cocoa Marketing Boards. The relative price was the only determinant of long-run supply of cocoa as other factors were considered negligible. She believed that cocoa was not competing with other crops for scarce resources and that prices did not affect the levels of planting. Climate was also considered an important determinant of short-run supply but data were not available.

Behrman's (1968) cocoa model initially specified the supply response according to *desired area* as a function of own- and cross-prices. In his study on monopolistic pricing in eight cocoa-producing countries, Behrman found the short-run response in Ghana, Nigeria, Cameroon and Ecuador to be negligible. Possible explanations were the high opportunity cost in the short run for neglecting the cocoa trees and the low marginal cost of harvesting the pods (Lim 1975). Similar to findings by Bateman for Ghanaian cocoa producers, the long-run price elasticities of supply were lower for the older producing countries than the newer entrants.

Despite attempts to separate the long- and short-run planting decisions, data constraints transformed the supply response to an output equation based on a Nerlovian model of area adjustment (Akiyama and Trivedi 1987).

4.4.2 Structural models

From the 1970s, the Nerlovian adjustment model was deemed unsuitable for perennial crops (Wickens and Greenfield 1973). It was accepted that perennial crop supply responses were influenced by decisions made that year as well as investment decisions from previous years (French and Matthews 1971; Wickens and Greenfield 1973; Hartley, Nerlove and Peters 1987; Akiyama and Trivedi 1987; Kalaitzandonakes and Shonkwiler 1992). It was recognised that reduced-form supply functions failed to capture the structural features of the supply response and the heterogeneity of capital stock because the equations could not separate the short-run and long-run supply responses (Hartley et al. 1987).

Wickens and Greenfield (1973) developed a decision-theoretic vintage model in which investment was treated as a derived demand for capital. Their supply response model of coffee producers in Brazil consisted of three equations specifying production potential, actual production and investment. It solved for output by estimating a reduced-form output equation based on a distributed lag model. The investment function was derived from a neoclassical adjustment cost model, equating marginal cost and the expected discounted marginal revenue of investment. The neo-classical view was that replanting (replacement investment) and new planting (net addition to the capital stock) responses were equal in terms of the derived demand for the stock of capital as a factor of production. The net revenue from continuing cultivation of the stand depended on its age and age-yield profile for the variety to be replanted, and the costs of uprooting and replanting. When a constant density of planting was assumed, net investment became the change in area under cultivation minus the area uprooted or abandoned and not replanted in the same period. Thus, the change in area was a linear function of net marginal revenues at expected prices and costs with a disturbance term representing the area uprooted or abandoned and not replanted in the same period. The estimated general distributed lag relationship between changes in area and past prices assumed adaptive expectations (Hartley et al. 1987).

The vintage production function related potential output to past investment in trees by a set of constant coefficients. The yield term measured the present yield of the past plantings. The function reflected the age-yield profile under the assumptions that:

(1) past inputs and harvesting decisions did not affect the maximum output currently obtainable;
(2) current factors were used in fixed proportions to the stock of trees in each age class;
(3) supplies of land and labour were unlimited;
(4) no technical change occurred; and
(5) all potential output was harvested.

The weaknesses of the model were: (1) its inability to derive coefficients of the three structural equations from the reduced form, (2) difficulties in including non-price variables in the planting equation, and (3) using a polynomial form to approximate yield curves (Akiyama and Trivedi 1987). An Almon lag was adopted to create a lag shape similar to the age-yield profile. However, Hartley et al. (1987) attempted to incorporate the lag for their study on rubber in Sri Lanka but it did not create the shape of the age-yield profile.

The inclusion in the investment equation of the cost of replanting and uprooting would be useful in the proposed study. It may help to explain why smallholders are more prone to plant on new land than replant on existing land. However, there are no data available in PNG on the cost of separate investment decisions.

4.4.3 Supply cycle model

Unlike the standard supply response studies where prices are treated as exogenous, Ruf's (1995) qualitative cocoa supply model regarded them as endogenous to the model, postulating that cocoa production is supply-driven. Based on the theory of production dynamics, the qualitative model was designed to demonstrate that the price cycles last about 25 years and are predetermined largely by the 'laws' of cocoa supply, related closely to environmental, ecological, social and institutional factors. Ruf argued that even with increasing prices, some countries had not increased cocoa supply due to supply constraints such as political factors, and availability of land and labour. He depicted the role of price as a catalyst in 'a pre-programmed natural process', exacerbating supply recessions and triggering a replanting reflex (Ruf 1995).

Ruf considered three cycles: family life; cocoa tree capital; and the market. He explained how the 'triple crisis'—ecological (deforestation), social (access to land) and economic (reduced prices)—triggered a planting response, representing a true innovation. Environmental factors, such as deforestation, were crucial factors in determining cocoa production. Deforestation and the increased incidence of disease were believed to hinder replanting activities, resulting in geographic shifts in production centres, which in turn brought about a boom in supply and the international market price.

Ruf's theory on cocoa supply was discussed in relation to growers in South-East Asia, West Africa and South America where geographic shifts in cocoa-producing areas and an influx of immigrant labour supply were experienced in boom periods. The applicability of this theory to PNG is limited since there is little evidence of these geographic shifts in production areas or significant migration patterns. In addition, the idea of an endogenous price variable is difficult to accept since PNG is a price taker in the world cocoa market. However, it is recognised that social factors may play an important role in the determination of cocoa supply such as the age of the farmers, but limited data prevent their incorporation in the proposed model.

4.5 Age-Yield Profiles

As a perennial crop, the yields of cocoa vary over the age of the tree. Bateman's (1968) early attempt to include the changes in yield over the life cycle of the tree involved defining two stages of rapid growth. Bateman (1968) included variables for the gestation period between planting and first bearing and varying yields over the tree life. Hence, output per year was the summation of the area under cultivation across all mature vintages of a given age multiplied by the average yield for each age group.

Age-yield profiles have been used in numerous perennial supply response studies to capture the changes in yield over the life span of the crop. Hartley et al. (1987) and Akiyama and Trivedi (1987) incorporated an expected age-yield profile to represent new technology. Akiyama and Trivedi used an age-yield profile to calculate the productive capacity of the tree stock generated by replantings and new plantings of tea in India. The potential yield for trees of each age cohort was calculated for a given year by summing the production potential of all trees planted in the past. The productivity of new plantings was found to increase exponentially due to the more intensive use of inputs and better application of cultural practices.

4.6 Qualitatively Different Investment Decisions

4.6.1 Structural models

French and Matthews (1971) and Wickens and Greenfield (1973) were among the early economists who attempted to model the qualitative difference amongst investment decisions: replantings, new plantings and removals. Many perennial crop response models have since been based on the French and Matthews model (e.g. Alston et al. 1980; Rae and Carman 1975). However, in their empirical work, data limitations prevented them from recovering the structural parameters.

French and Matthews' (1971) area response structural model assumed that producer output decisions were made in terms of the area planted and area removed. Subsequently, equations for both these variables were used to explain changes in bearing age. Total new plantings were expressed as a function of the time interval between initial plantings and the bearing age, the area expected to be removed, the non-bearing area in the previous year, and input and establishment costs. Removals were expressed as a function of the short-run profit expectations, area of a particular age group in the current year, long-run expected normal profitability, short-run profit expectations for alternative land uses, institutional factors and the current bearing yield. A third relationship was defined to explain yield variation. Yield levels were determined by the initial bearing age, maximum age of plants and the effects of technology change, captured through a trend variable. Changes in yields and area were then summed to give changes in output, resulting in a single reduced-form equation for output. Since the estimated coefficients could not be used to recover the structural parameters, the harvest and investment decisions could not be separately identified (Akiyama and Trivedi 1987).

Bellman and Hartley (1985) developed a theoretical framework on the qualitative differences among planting decisions which was explored further through the empirical work by French, King and Minami (1985) and Akiyama and Trivedi (1987). Hartley et al. (1987) recognised that the age distribution of perennials impacted on new plantings, replantings, removals and subsequently the investment in new stock. They noted that the qualitatively different planting decisions in perennial crop production impacted on the age composition of the stock, the total stock of trees and hence the total area under crop. In addition, they noted the interaction between different planting decisions.

Hartley et al. (1987) treated new plantings and replantings as separate investment decisions in their supply response study of rubber in Sri Lanka. They realised that with new technology, such as the introduction of HYVs, reduced-form equations would not depict the increasing yields of a given age class over time. Thus, the new planting and replanting decisions and the age and clonal composition of the stock were required in understanding the supply response (Hartley et al. 1987).

Since there were few new planting activities in Sri Lanka, replanting was the major part of the supply response. In the output equation, the trend coefficient which captured weather, labour inputs and fertiliser use was found to be the most significant variable. Technological advancement was found to account for the changing age composition of the tree stocks by motivating replantings (Mutunga 1994). The inclusion of the age-yield profile allowed for differentiation between short- and long-run decisions.

Akiyama and Trivedi (1987) adopted a vintage capital approach to production and investment to evaluate the effects of new plantings and replantings on the long-run supply response of tea producers in Kenya, Sri Lanka and India. The framework distinguished between long- and short-run elasticities and accounted for the heterogeneity of capital stock with respect to yield. The magnitude and direction of the responses were used to indicate the impacts of government policies, such as taxes and subsidies, on producers.

Separately estimated new plantings and replantings equations were incorporated into the planned output equation through the vintage production function. It was assumed that an increase in expected future product price would raise the desired output capacity and thereby stimulate new plantings. Analogously, an increase in production costs would reduce new planting activities. Planting and uprooting decisions were determined by expected future profitability and past investment decisions.

Country-specific variations were included in terms of differences in rates of planting and subsidies. Well established tea producers in India and Sri Lanka were subsidised for both new planting and replantings. Their rate of planting as a proportion of total planted area was below two per cent compared with the new and fast-growing smallholder sector in Kenya which grew at 17 per cent between 1963 and 1983.

Akiyama and Trivedi (1987) found that uprootings in Sri Lanka and replantings in India showed little price responsiveness while new plantings in all three countries were significantly price-responsive. It was expected that the short-run elasticity of new plantings would be greater in countries relatively unconstrained by the availability of suitable land (i.e. the cost of the adjustment factor). New producers were expected to have larger price elasticities than established producers who had used up most of the suitable land, but the contrary situation was found. Producers in Kenya had a lower short-run price elasticity than those in Sri Lanka and India.

The limited availability of detailed and continuous data on the age-group distribution of tree stocks and plantings in many countries restricts use of the models developed by Hartley et al. (1987) and Akiyama and Trivedi (1993) for empirical work. This is certainly the case in regard to their usefulness in modelling the cocoa industry in PNG.

4.6.2 Data limitation models

Since structural approaches require significant amounts of data, econometric approaches have been developed in the absence of continuous and detailed data (Knapp and Konyar 1991; Dorfman and Havenner 1991; Kalaitzandonakes and Shonkwiler 1992; Elgnagheeb and Florkowski 1993; Mutunga 1994).

Kalaitzandonakes and Shonkwiler (1992) adopted a state-space approach in their study of the Florida grapefruit industry. They represented new plantings and replantings as qualitatively separate investment decisions in terms of adjustment costs and lags, and direct costs. Replanting adjustment costs included the removal of non-productive trees and the special application of cultural practices, resulting in replanting delays—costs not incurred in new planting activities. Credit constraints, adoption of technology and shortages of planting material were also calculated as adjustment costs. Hence, the total adjustment of the firm's future productive capacity in any given year was the net effect of all planting decisions that modified both the total cultivated area and the age composition of the tree stock. Further, they developed an empirical model to incorporate specifications of unobserved expectations and 'desired' levels of area, the estimation of which are the inherent difficulties in perennial area and supply response analyses.

The study found that expected prices positively influenced new plantings and that opportunity costs and taxes negatively affected new plantings and replantings, but that the coefficients were insignificant. Significant coefficients were found for the interaction between replantings and new plantings. New plantings had a positive effect on replantings but increased replanting activity tended to crowd out new plantings.

Using a state-space model, Mutunga (1994) found that increased prices led to a decline in replantings for coffee producers in Kenya. She suggested that high prices delayed the uprooting of coffee since producers were not willing to uproot partially productive trees, which could earn some income, and replace them with initially non-productive trees, which would earn them no income.

4.6.3 Supply cycle model

Similar to the state-space model, Ruf's (1995) supply cycle model differentiated between replanting and new planting decisions in terms of the different adjustment costs. It was found that replantings were much greater than new plantings in terms of labour cost. Given the availability of forests in Indonesia, farmers were more likely to abandon their pest-infested plantations and move to a newly cleared area, saving money on treatment and drawing money on new cocoa by exploiting available forest rent. In Côte d'Ivoire, where weeding problems were rife, farmers preferred to clear new land than replant on existing land. In the first year after new planting, it was estimated that 86 days of labour were required per hectare, in contrast with 168 days for replanting activities (Ruf 1988). In addition, replanting yields have been found to be much lower than those for trees planted after land clearance (Voelker 1955; Card 1983).

Ruf (1995) examined the delay in the replanting decision of cocoa farmers. Like Mutunga (1994), he attributed it to the reluctance of producers to fell trees and face an immediate fall in income, and reduction in the economic optimum of an established plantation. Hence, he suggested that the delayed decision to remove trees lengthened the economic life of the tree capital. Supported by empirical evidence, he showed that farmers would remove trees when no alternative existed and output was at a minimum (i.e. no forest to clear).

Barlow and Jayasuriya's (1986) three-stage plantation model showed that replanting only succeeded where the state had intervened through funding research and extension, and through direct aid. They identified access to credit as a major constraint in the adoption phase and spread of crop; this is a similar conclusion to Ruf (1995) but a different explanation. Ruf explained it in terms of exhaustion of forest rent which must be replaced with labour, inputs and new techniques while Barlow and Jayasuriya related it to the new and expensive planting material that requires increased inputs.

There are a number of issues surrounding the qualitatively different investment decisions which are relevant to PNG, especially in relation to the new planting and replanting responses. Largeholders, constrained by land availability, tend to replant more than clear new land while smallholders, with the ability to expand their area under cocoa, have cleared more land. Ruf's (1995) discussion on the higher cost of replantings to new plantings may be very relevant for PNG. However, the lack of time series data on establishment costs and levels of new plantings and replantings, as well as the history of subsidisation of planting material which would distort the planting response with respect to costs, restricts this type of analysis.

4.7 Yield Determination

In a perennial crop model, output is influenced by both the stock of trees and the yields. Given that there are a number of physical, socio-economic and institutional processes that determine the technical possibilities for agricultural output in a region, there are a number of approaches to obtain yield estimates. Physical scientists, such as agronomists and crop physiologists, have used crop growth models (see Appendix B), GIS, remote sensing and field experiments which estimate yields according to the climatic and soil conditions in the area. In contrast, economists have tended to estimate yield through a production function, which considers the relationship between inputs—capital, labour and land—and output. Economists and physical scientists also hold different views on producer behaviour. Agronomists and physiologists tend to assume producers are output maximisers while economists assume they are either cost minimisers or profit maximisers.

An example of a pure scientific approach is van Keulen and Wolf's (1986) hierarchical procedure approach which allowed for quantitative estimates of yield levels of the crop under differing constraints and input levels (see Appendix H). In contrast, the economic approach does not attempt to define potential yield levels. Yield levels are treated as a dependent variable and determined by actual observations and the relationship between the inputs and outputs. Maximum obtainable yields are usually representative of the most efficient producer. Frontier production functions can be used to obtain these levels (see Gimbol 1993). For this study, we are more interested in the average actual yield levels of smallholders and largeholders. The production function may include climatic and soil data, but it is required as a continuous data set rather than cardinal numbers. The production function may also account for different management practices such as pruning, spacing and pest and disease control, if data are available.

4.7.1 Bio-economic models

Given the lack of economic information in the crop growth models, they are not useful for measuring the impacts of policy changes on producers' output. However, a biological model, which describes the production system, can be incorporated with an economic model, which links the production system to market prices and resource constraints (Cacho 1997). Such models, called bio-economic models, can improve the accuracy of crop modelling. They have been defined by Allen, Botsford, Schuur and Johnston (1984) as mathematical models which relate the biological performance of a production system to its economic and technical constraints. Once the biological model is established, it can be made to interact with the economic model at different levels of aggregation, depending on the objective of the study. The economic model can be used as an 'outer layer' which controls the operation of the biological model for its own purposes (Cacho 1997).

There are limited examples of bio-economic models in relation to perennial tree crops (Hester and Cacho 1997). Most of the studies have been carried out in the areas of livestock and aquaculture (Cacho 1995, 1997). The models are used more for management problems than assessment of policy impacts at a regional or national level. The approach has not been adopted for this study because of the significant data requirements, especially at a regional level, and the time required in building the model.

4.7.2 Production function models

Akiyama and Trivedi (1987) included a vintage production function to determine yield in their study on tea producers. It consisted of two factors, capital and labour, where capital was defined as homogeneous land planted with trees at a specified density and requiring fixed levels of inputs. Output was assumed to be homogeneous and produced by only mature vintages. Total planned output was the profit-maximising level of output, given the price expectations of product and input prices in the following year.

Akiyama and Coleman's (1993) production function simulation model for coffee producers in Nicaragua specified the yield equations for three technologies using a Cobb-Douglas production function. They specified two inputs—labour and fertiliser—which were assumed to be used in a profit-maximising way.

The yield elasticities with respect to labour and fertiliser were derived by cost of production data for each technology. However, there is an inconsistency in Akiyama and Coleman's approach. By using factor shares to estimate elasticities, constant returns to scale should have been assumed. However, decreasing returns to scale were stipulated, presumably because their simulation results became unstable when the sum of the partial elasticities of output was close or equal to unity.

4.8 Land Suitability

To account for the differing suitability of land for the expansion of cocoa production, land quality across the regions under cocoa can be assessed. Indicators of the quality of the resource base reflect the productivity of the system over a long period of time. Some of the more broadly used categories are soil organic matter, soil water quality, soil structure, soil micro-organisms, pH, soil temperature, pests and beneficial organisms (Barnet et al. 1995).

4.8.1 Physiology models

A physiology model, like Gerritsma and Wessel's (1996) CASE model, is able to assess the suitability of areas under cocoa (see Appendix H). Plantgro, a site-specific yield prediction and land suitability software package, which identifies both soil and climatic limitations, has been used for predicting yields of cocoa in PNG (Hackett 1991). Its inclusion of climate factors is relevant to cocoa, where lack of, and excess, rainfall are major determinants of yield. Plantgro can also be used to assess the best time to plant, fertiliser application programmes and timing of preventative spraying against pests and diseases for different soil and climatic conditions. It can predict the yields for high- and low-input management strategies through adjustments of soil input data to match management input levels (eg. fertiliser, drainage, irrigation). However, Plantgro is not used in this study because it does not include economic variables and its site-specific nature and high data requirements would make it time-consuming at a regional and/or national level.

4.8.2 Land and crop evaluation systems

Although less accurate than the physiology models, land evaluation systems can assess the suitability of land for particular crops and estimate yield figures for similar climate and soil conditions. In PNG, land/crop evaluation systems have been developed since the 1960s due to population pressure, the expansion of commercial agriculture and a requirement for increased production. Land qualities and characteristics are identified, measured and rated according to a suitability rating.

The first cocoa evaluation system was developed by Bleeker and Freyne (1981), based on the relative severity of nine types of physical limitations. Wayi (1987) also developed a cocoa evaluation system, which defined three levels of management based on the FAO a cocoa evaluation system, which defined three levels of management based on the FAO framework to determine cocoa production. Both methodologies allowed for regional and site-specific assessment of the potential of land for specific crops (Freyne, Bleeker, Wayi and Jeffrey 1996).

The Land Use Unit of DAL uses the Papua New Guinea Land Evaluation System (PNGLES) to compute land suitability ratings for smallholder crops in each province. The information is imported from the Papua New Guinea Resource Information System (PNGRIS)[1] in order to assess the temperature, erosion hazard, moisture conditions, nutrient availability, rooting conditions and soil drainage for areas under cocoa.

A disadvantage of using the land and crop evaluation systems is that systems can vary greatly, according to the designers' criteria and ratings used to determine the suitability of the area for a particular crop. However, given the scale of the study and the availability of data, PNGLES seems an appropriate tool by which to account for land quality across the three main cocoa producing provinces: Madang, ENB and East Sepik.

4.9 Sectoral Differences

Very few perennial crop supply studies have accounted for sectoral differences. Akiyama and Trivedi (1987) modelled Kenyan tea smallholders and estates separately because the smallholder sector accounted for two-thirds of the area and most of the growth in area whilst the estates dominated the growth in production through rapid increases in yields. The growth of the smallholder sector was attributed chiefly to the involvement of the Kenya Tea Development Authority (KTDA) in providing extension services and infrastructure. It was assumed that the Kenyan smallholder did not have land constraints in the study period and that critical limitations arose from access to planting material, credit facilities, processing factories and marketing information. KTDA expenditure in

1. PNGRIS is a computer-based geo-referenced database on the natural resources, population distribution, current land use and smallholder economic activity of PNG. At 1:500 000 scale, it provides information on 4600 resource mapping units (RMUs) for resource use planning purposes. RMUs can be aggregated into agro-ecological zones for provincial and national resource use planning.

smallholder production was postulated to enable smallholders to maintain a steady growth in new plantings.

Since the level of new plantings on Kenyan estates was very small in comparison with smallholders, it was hypothesised that the estates were producing at the intensive margin and the smallholders at the extensive margin. Hence, an improvement in expected profitability from a rise in the product price would increase the number of smallholder producers in the industry but expand the use of yield-increasing agricultural practices by the estates. Although these issues are relevant to PNG cocoa producers, data was not available on the number of smallholder producers in the industry or the adoption rates of HYVs.

Ruf (1995) differentiated between smallholders and largeholders on the basis of monocropping versus intercropping. Monoculture was assumed to be practised by plantation owners while smallholders would intercrop with food crops to optimise the exploitation of forest rent. Monocropping was depicted as an exploitative farming practice, rapidly reducing forest rent at the cost of permanently destroying such rent. Plantation owners were assumed to be migrants whose prime concern was to make quick cash rents rather than sustain resources.

4.10 Assessment of Suitable Methods

After reviewing the various approaches to determining planting, harvesting and yield functions, a combination of approaches are selected to measure the impacts of policy changes on the cocoa industry in PNG. From the early cocoa models, Ady highlighted a couple of relevant issues: the modification of producer prices due to the marketing boards and the non-inclusion of competing crops in her planting equation. In PNG, producer prices for cocoa also differ from world prices due to the price support system; and cocoa tends to have no major competing crop except coconuts which are often intercropped with cocoa.

The structural modellers developed separate equations for the investment decisions. The inclusion of more variables in the investment equations would obviously improve the predictability and structure of the model; however, in the PNG case, data limitations prevent it. The inclusion of a bio-physical model would be useful for measuring the impacts of changes in management practices recommended through extension and research policies (see section 8.3). Again data requirements restrict quantitative analysis.

Akiyama and Coleman's production function simulation approach is appropriate, considering the problems of insufficient data and structural changes taking place in PNG. Kalaitzandonakes and Shonkwiler's (1992) state-space model is useful for the estimation of short-run price elasticities in the planting equations, in the absence of replanting and new planting data. Given the availability of yield profiles for the varieties of cocoa, a yield profile can be used to determine the area in full-bearing equivalent (FBE) hectares.

5. Model Formulation

5.1 Introduction

A modification of the production function-based simulation model of perennial crop supply (Akiyama and Coleman 1993) is chosen for the economic analysis of the cocoa industry in PNG. The model used by Akiyama and Coleman (1993) was designed for the coffee sector in Nicaragua but is applicable to other perennial crops and industries in developing countries. It is consistent with the vintage-capital production approach (Akiyama and Trivedi 1987) where past investment decisions and other dynamics of supply response are incorporated. But, unlike the vintage-capital approach, time series data are not required. Hence, problems of inconsistent and lack of data faced by many developing countries are minimised.

The chapter begins with an overview of the construction of the simulation model. The framework and individual modules and sub-modules are then discussed and finally an outline is given of the scenarios to be simulated.

5.2 Simulation Approach

5.2.1 Modelling steps

The development of the simulation model requires four stages:

1. development of the model concept;
2. development of the simulation model;
3. simulation of system behaviour; and
4. policy analysis and system design.

1. Model concept

In the first stage, the model purpose is clearly defined in response to the objectives of the study and used to define the system boundaries. The expected influences from the system environment are determined and their points of influence on the system structure specified (Bossel 1994).

2. Developing the simulation model

Secondly, the influence structure—a qualitative description of influences in the system—is established. The influence diagram focuses on the influence structure of the system, not on the exact function of its elements (see Figure 5.1). In the figure, circles represent policies which are likely to influence the cocoa industry and the boxes represent other key variables which make up the cocoa production system. Shaded circles denote the policies relevant to the proposed study: price support policy and exchange rate policy. Black and/or shaded boxes are the chosen variables to describe the cocoa system. Shaded boxes are also sub-models and consist of the variables connected to them in the diagram. Variables in the grey boxes are equally significant as those in black boxes but, due to data limitations, they could not be quantified and hence are not included in the model.

Properties of the system elements—input elements, state variables and intermediate variables—are specified for the simulation model (Table 5.1). Input elements—parameters, initial values of state variables and exogenous inputs from the system environment—do not influence the system development. They can only change as a function of time or otherwise they remain constant. State variables are expected to change by their rates of change. Intermediate variables—auxiliary or converters—are algebraic or logical functions of input elements and state variables and/or other intermediate variables.

Figure 5.1 Influence diagram

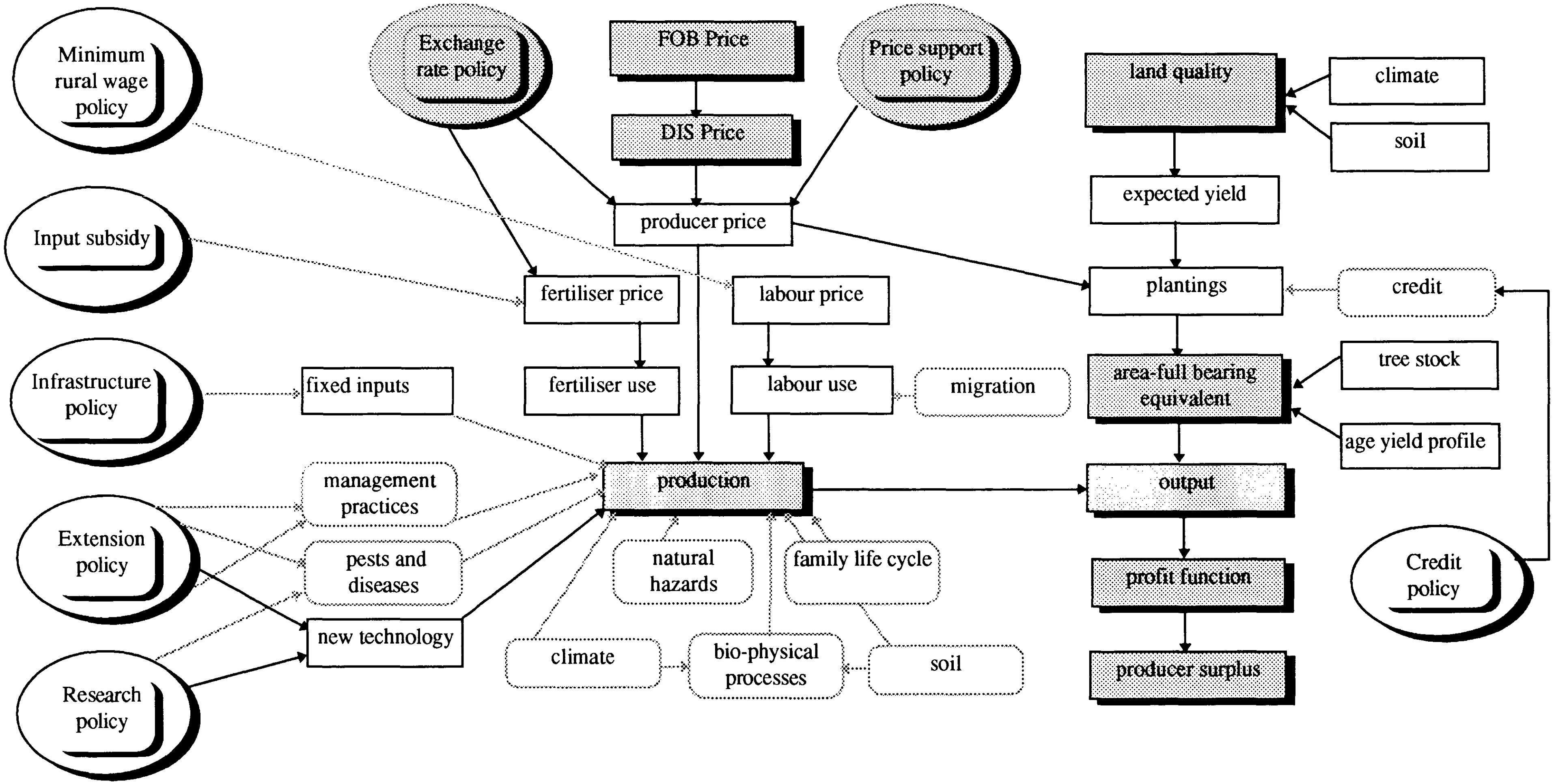


Table 5.1 Description of variables

Input	State	Intermediate
world price of cocoa	area	planting response
yield profiles	new plantings	removal rate
suitability of land	replantings	factor demand
elasticities	yield	production function
domestic price of fertiliser	quantity and value of output	supply response
domestic price of labour	exports	harvest decision
exchange rate		producer price
		profit function

For the simulation, relationships are specified by algebraic and logical functions. Parameter values are estimated from available information and data on the system so the relationships can be quantified.

3. Simulation of system behaviour

After validating the model, it is used for simulations of alternative policies and development paths. In historical investigations or for validating the model, the influence of the system environment is known. In computing future paths, 'scenarios' of expected exogenous inputs have to be assumed. The development of exogenous variables, time frame, initial values of state variables and choice of system parameters are then decided on. Sensitivity tests are used to test the strengths and types of influences on variables.

4. Policy analysis and system design

Path analysis—the comparison of outputs under different scenarios—is then undertaken. The constant or time-dependent inputs are known or assumed as scenarios, and specified to investigate the behaviour of the system under given conditions. The input parameters and scenarios are changed over a broad range of conditions to compute the resulting development paths and to compare and evaluate the outcomes.

5.2.2 Choice of software

STELLA, a dynamic simulation modelling software package, has been chosen for this study. There are several more sophisticated simulation packages on the market—Simulink, Atsim, Dynamo—but Stella is considered adequate for the purposes of the research.

The notation used for structural blocks in STELLA is developed from Forrester's (1961, 1968) systems dynamics method. It uses flows (rates of change) of the stocks (state variables), regulated by 'valves' (rates), where the valve setting is changed by inputs from other system elements.

The software uses three simulation algorithms by which to solve the system of finite difference equations in the model: Euler's theorem, and second-order and fourth-order Runge-Kutta methods. Euler's theorem is the simplest algorithm and the one chosen for this analysis because it handles discrete event simulation and the model contains some of the software's built-in functions which do not allow for continuously varying systems. Runge-Kutta methods are more useful for continuous simulation and systems that have inherent oscillatory tendencies (Peterson and Richmond 1994).

Problems with STELLA have been noted by Bossel (1994). The diagrams show two processes: (1) the inflows and outflows of state variables, and (2) the influence relationships in the system that change the inflow and outflow rates. Hence, the direction of the flows has no relation to the direction of the influences. There is also no distinction between the exogenous parameters or functions and the intermediate variables—both are represented by circles. Further, STELLA models can become cumbersome when indexed variables (vectors, rays) are used.

5.3 Model Framework

Production function simulation models are constructed for the three major cocoa-producing provinces: ENB, East Sepik and Madang. The framework is an adaptation of Akiyama and Coleman's model, extended to account for two groups of producers—

smallholders and largeholders—and the different land qualities under cocoa production. The producers are treated as a group, based on assumptions about individual producer behaviour. The groups are assumed to be profit maximisers and have similar production functions and investment decisions.

Sectoral differences are identified by the level and cost of input use and the different planting responses. To simplify the model, risk, uncertainty and variations in management strategies, such as pruning, shade, spacing and their impacts on yields, are not considered. Despite recent literature on the importance of social factors in the cocoa system (Ruf 1995), they are not addressed explicitly.

The technological change and credit blocks specified in the model by Akiyama and Coleman are not included in this model due to lack of data. The study model is based on only one technology so the area figures are not calculated in light of conversion calculations. Instead, area figures are established for age-groups and converted, applying an age-yield profile, into full-bearing equivalent hectares.

With difficulties in distilling the long-run price responsiveness of producers from the many other factors affecting production, the model is developed using a short-run supply elasticity, determined by the harvest decision, and a series of long-run supply elasticities associated with planting decisions from previous years.

The model consists of five blocks: area of cocoa and a sub-sector on age and variety of trees; land suitability; output and a yield sub-sector; break-even price; and export (see Table 5.2).

Table 5.2 Description of modules

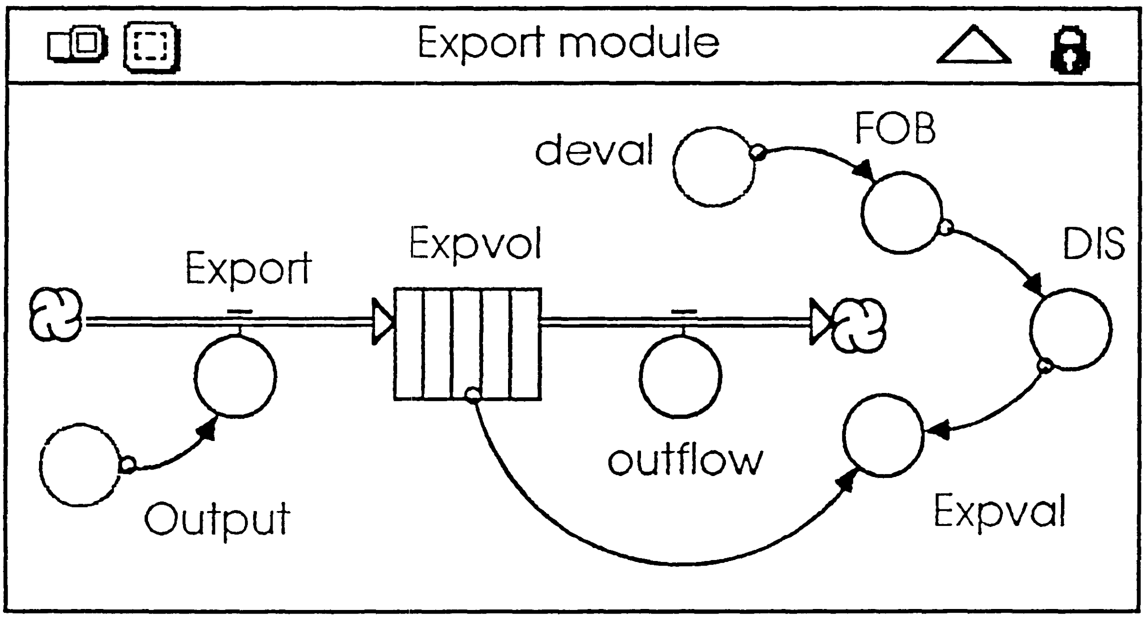
Name of module	Key variables calculated	Comments
Assumptions	exchange rate, world cocoa prices, wages	assumptions on impact of key exogenous variables
Export	FOB price, DIS price, export quantity and value	uses mainly variables from the assumptions block; calculates FOB, DIS and producer prices and export value based on output and export prices
Area	planting responses and area under cocoa	calculates FBE area based on planting responses and yield profiles
Area sub-sector	area by age group and variety	calculates area under each variety and age group
Output	total annual and NPV output for each sector	FBE area is multiplied by production to estimate output
Output sub-sector		yield calculated by Cobb-Douglas production function using cocoa and input prices; calculates factor demand (labour and fertiliser) for cocoa production
Yield	yield per hectare	
Factor demand	required labour and fertiliser	
Break-even	expected annual and long-term profits	calculates expected profits based on outputs from the output module

Source: Modified from Akiyama and Coleman (1993).

5.4 Export Module

Figure 5.2 is the export module where the FOB and DIS prices are determined and the effects of devaluations are initially introduced to the system through changes in the FOB price for cocoa. The DIS price is then used to determine levels of bounties and levies and the producer prices (see Figure 5.3). The module equations and values of variables are given in Appendix C1.

Figure 5.2 Export module



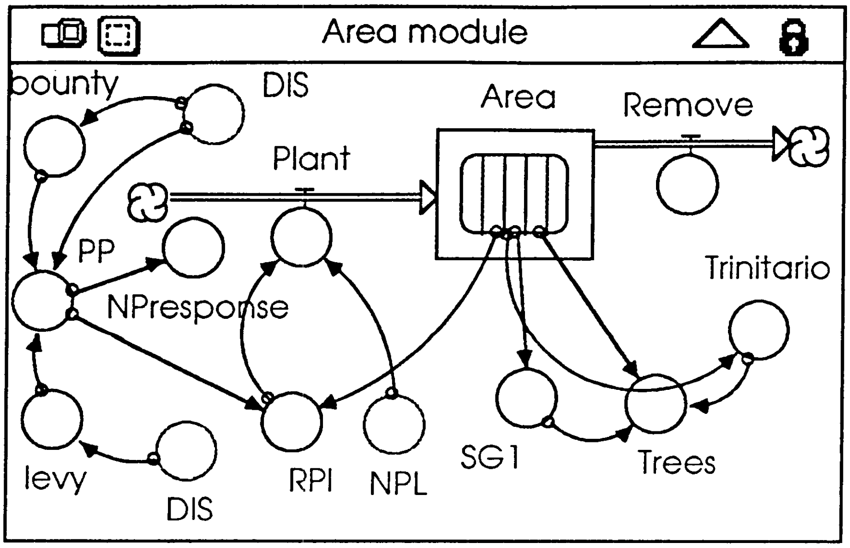
The FOB price is derived by estimating the average FOB price and the standard deviation over the period 1990 to 1996 and then applying the normal distribution function in STELLA to simulate prices for a 20-year period. The DIS price function was estimated by regressing the FOB price from the last six years on the DIS price (see Appendix D). The prices received for cocoa are assumed to be the same across all provinces and between sectors.

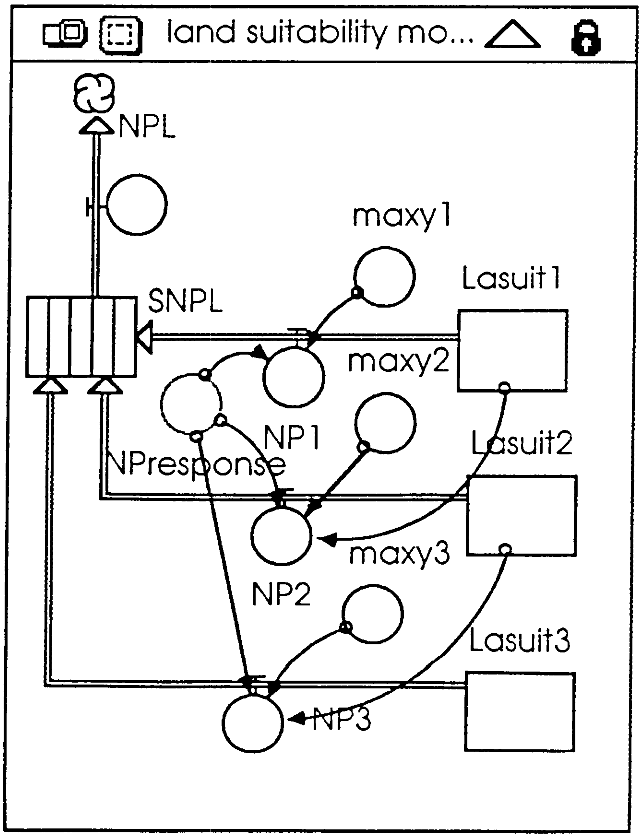
Bounties and levies are calculated according to the AGPS. A bounty is equal to the difference between the support price (K1300 per tonne) and the delivered-in-store (DIS) price. A levy is paid by producers at the rate of 50 per cent of the difference between the trigger price (K1645 per tonne) and the DIS price (Peter 1997). It is assumed that the full values of the bounties and levies are passed onto the producers.

5.5 Area Module

The area module calculates the number of hectares in FBE under cocoa, determined by the stock of trees, rate of planting and age of trees (see Figure 5.3). The planting responses—new plantings (NPresponse) and replantings (RPL)—are a function of the producer price (PP) which together make up the total planting response (Plant). The planting response quantifies the number of hectares planted each year. The area module sub-sector determines the annual area of cocoa according to the age of the stock and variety: Trinitario, SG1 and SG2-mod. (see area sub-sector equations in Appendix C2). These are then converted to FBE area by multiplying the age cohorts by an age-yield profile. By giving the tree stock in FBE, different production functions of each age group of cocoa are not required in the output module. In other words, the same production function is assumed to exist across all age groups of trees.

Figure 5.3 Area and land suitability modules





5.5.1 Planting decisions

The planting responses are given as a function of future price expectations. Naive price expectations are assumed whereby producers base their expectations of future prices on the price in the period before planting (Ruhle and Fleming 1998). A one-period time lag is incorporated into the planting decision to model this type of expected response to price.

Many supply studies tend to include a variable to account for alternative opportunities for land use. The alternative crop for cocoa would tend to be coconuts but in most places cocoa and coconut are intercropped and are not considered substitutes.

The planting decisions for both sectors are expected to be positive but relatively inelastic in response to price in the short run (Ruhle and Fleming 1998). Future expansion of the smallholder sector is predicted under the newly established Cocoa and Coconut Extension Agency and the introduction of the SG2 clones (CCRI 1997). It is also noted that smallholders find it less costly to clear new land than regenerate old blocks and hence will be more price-responsive in their new planting decisions than replanting (Ruf 1987; Jarrige and Ruf 1990). This is reflected in the new plantings and replanting equations for smallholders in the state-space model (see Appendix E for the model description). The real producer price coefficient in the replantings equation is very small (0.0027) while in the new plantings equation, the price coefficient is significantly larger (0.4889) (see Appendix F for empirical results).

Coefficients were also estimated for the dynamic interrelationships between the rate of new plantings and replantings (see Appendix F). As expected, there was interaction between the planting decisions for smallholders. An increased rate of new plantings in one year is followed by a period of increased but lower rate of replanting (Φ_{12} = 0.29). Similarly, in periods of increased rates of replanting the future levels of new plantings are increased but at a lower rate (Φ_{21} = 0.3).

In the largeholder sector, debt repayments and land constraints have curbed the expansion of area under cocoa (Manning 1997; Woruba 1997). It is therefore expected that all future planting response will be in the form of replantings rather than new plantings. Hence, it is reasonable to assume that the price coefficient will be zero in the new plantings equation for largeholders. With the aid of the state-space model, a real producer price coefficient was estimated in the replantings equation (1.03) (see Appendix F). As expected, the estimated coefficients for the interrelationship between replantings and new plantings were very small ($\Phi_{12} = 0.0036$, $\Phi_{21} = 0.0029$).

Due to a lack of data on removals, it is impossible to estimate the relationship between the level of removals and producer price. However, it has rarely been the practice for cocoa producers to remove cocoa trees unless they are replanting. Instead, the trees that are removed are considered to be either those that die before reaching the bearing stage or senile trees that are left unattended. Removals have been estimated at one per cent in the first three years, and ten per cent from year ten onwards (Woruba 1997). The impacts of pests and diseases are not accounted for.

5.5.2 Area sub-sector

To estimate FBE area, the total area figures for province and sector were disaggregated by variety and then by age group and incorporated into the yield profiles (see section 6.2).

In calculating the area figures, a strong assumption was made that all new plantings of cocoa were HYVs. This was made on the grounds that the distribution of HYVs—SG1 and SG2—has been heavily subsidised and well marketed by CCRI. Largeholders were believed to have uprooted most of their traditional cocoa in the 1980s with the expectation of high yields from the SG1 variety (Manning 1997). Extension services, particularly in ENB, have encouraged smallholders to grow HYVs and, as a result, the adoption rates were estimated at close to 100 per cent (Woruba 1997; Gore 1997). However, in less accessible cocoa-growing areas where extension services are limited, the traditional Trinitario is most likely still grown by smallholders.

5.5.3 Yield profiles

As a perennial crop, cocoa has yields that vary according to the age of the tree. Age-yield profiles are incorporated into the model to depict the yields of the tree over time whereby biological, varietal and technological factors will vary its shape and position.

A cocoa tree can produce for up to 50 years but it is economically productive for 15 to 30 years, depending on the level of management and pest and disease problems (Gimbol 1989). Traditional varieties start producing at three to four years and reach maturity at seven to 10 years where yields remain fairly constant for a number of years before gradually declining. Hybrids can begin producing at two years and reach their full capacity production earlier than traditional varieties, at about six years. Yield profiles are included for the Trinitario, SG1 and SG2-mod. varieties (see section 6.2.3).

5.6 Land Suitability Module

In an attempt to capture the quality of land under cocoa, a land suitability module is included in the model (see Figure 5.3). The land suitability module contains the areas of three categories of land suitability—Lasuit1 (highly suitable), Lasuit2 (suitable) and Lasuit3 (marginally suitable)—and their yield potentials (maxy1, maxy2 and maxy3) (see section 6.3 for area figures and Appendix C3 for equations). New plantings on the most suitable land are given a weighting of one. The yield potential for the other two classes is expressed as a percentage of the most suitable class and the area under new plantings weighted accordingly (see Table 5.3). Although producers will plant cocoa on land not necessarily the most suitable for cocoa, the simplifying assumption is made that the most suitable land is cleared first before moving to more marginal areas. The annual amount of new plantings under each category is calculated by the converters: NP1, NP2 and NP3.

Table 5.3 Land suitability and potential yield

Classification	Yield	Weighting
Highly suitable	1 tonne/ha	1
Suitable	850 kgs/ha	0.85
Marginally suitable	350 kgs/ha	0.35

Source: Venema (1992).

5.7 Output Module

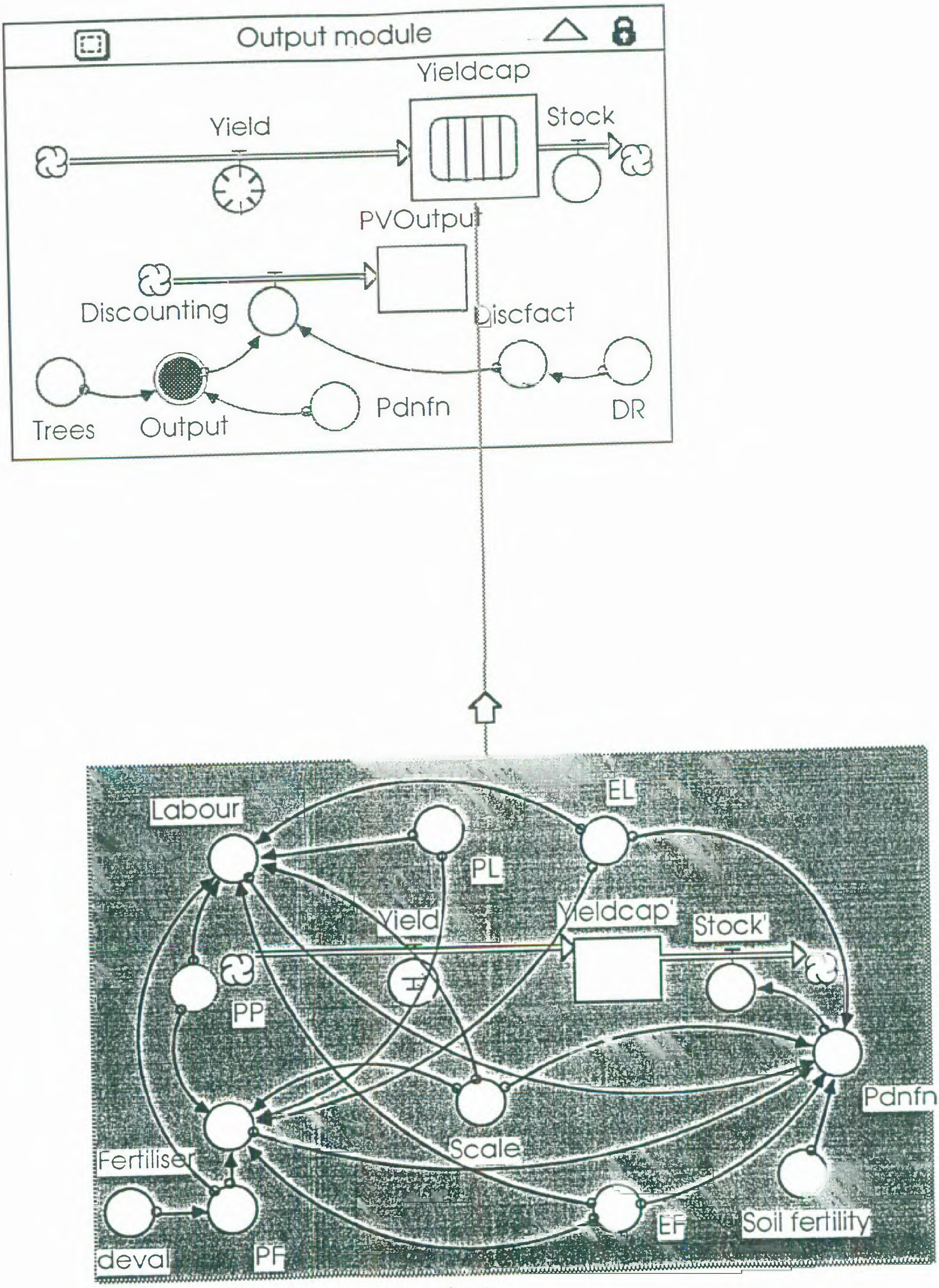
5.7.1 Description of module

The output module calculates the total annual output and the NPV of output for the sub-sector over the 20-year period. Total annual output is calculated by a multiplication of the area in FBE with the output per tonne, as given by the Cobb-Douglas production function in the output sub-module. A 10 per cent discount rate is used to convert the annual output to net present value (NPV) of output (see Figure 5.4 and equations in Appendix C4).

Given that most largeholders are growing cocoa continuously on the same area of land, it would also be useful to account for changes in soil fertility in the model. A study of Nigerian smallholder plots showed that soil degradation is significant in plantations over 25 years old (Eskanade 1988), and other studies have suggested that soils become poorer under cocoa than under forest (Wessel 1971; Ayanlaja 1983).

A soil fertility index is included in the largeholder production function for illustrative purposes. With data collected on the impact of replantings on yields under typical cocoa soils, the accuracy of the model could be improved. The collection of fertiliser-yield response data would also help to improve the accuracy of the input parameter values. Labour constraints, diseases and pests could be built into the model, given the availability of data (see section 8.3).

Figure 5.4 Output and sub-sector output module



5.7.2 Production function

The Cobb-Douglas production function is chosen to calculate cocoa yields 'because of its simplicity and ease with which its parameters can be obtained' (Akiyama and Coleman 1993, p. 4). The function allows for the substitutability between inputs and thus is less restrictive than the fixed proportions functions. The Cobb-Douglas is constructed under the assumptions of perfect certainty and unchanging levels of technology. Hence, producers will use the technology that produces the maximum output from a given set of inputs (Doll and Orazem 1984).

It is assumed that the only inputs are labour and fertiliser which are used in a profit-maximising way at the levels given by estimated production costs. It is assumed that producers in each sub-sector have the same levels of technical efficiency and the cost of labour is the same for all producers in each sub-sector. Since the study is only concerned with the short run, establishment costs such as shade trees are not included. The inclusion of shade trees is also complex, given the different varieties—glericidia, leucaena and coconuts—and the benefits of shade varying over the life span of the cocoa tree (see section 8.3 for further research on shade trees). The input demand equations are therefore derived in terms of prices of cocoa and two inputs. It is assumed that yields increase with the amount of fertiliser and labour used. Further, it is assumed that the cocoa is produced by profit-maximising producers who maximise their net revenue from their output, subject to technical constraints imposed on them by the production function (see Figure 5.4 and Appendix C4 for the equations).

Neither cross-sectional nor time-series data were available on production, labour and fertiliser use for largeholders so the elasticities could not be estimated econometrically. Following Akiyama and Coleman (1993), the calculated elasticities correspond to the shares of total revenues paid to factors of production. The elasticities for the smallholders' production function were estimated with an econometric model using cross-sectional data. The inputs and yield change with prices of cocoa and inputs, allowing for analysis of the effects on yield of policies that cause changes in cocoa and input prices. However, the effect of current management practices on future crop yields is not accounted for. If producers decrease their levels of maintenance in the current year, this would not reduce yield potential, and hence output levels, in the following years in the model.

The Cobb-Douglas production function is given as:

$$\mathbf{Y=\alpha F^{\beta f} L^{\beta l}} \qquad (1)$$

where:

Y = output per hectare
F,L = units of fertiliser and labour, respectively
β_f, β_l = elasticity of yield with respect to fertiliser and labour, respectively, and
α = constant term.

Properties of the function are:

(1) β_i = percentage change in output for a one per cent change in the unit of input i.

(2) The sum of the β_is gives the degree of homogeneity or returns to scale, and

$\Sigma\beta_i < 1$: decreasing returns to scale

$\Sigma\beta_i = 1$: constant returns to scale

$\Sigma\beta_i > 1$: increasing returns to scale.

(3) The elasticity of substitution between inputs is one.

(4) The production function infers declining marginal product of the inputs.

(5) β_i s represent the ratio between the total cost of factor i and total revenue, thereby assuming that $\Sigma\beta_i \leq 1$ (Akiyama and Coleman 1993).

For profit maximisation:

$$\mathbf{P_y \alpha \beta_f F^{\beta f-1} L^{\beta l} = P_f} \qquad (2)$$

$$\mathbf{P_y \alpha \beta_l F^{\beta} L^{\beta l-1} = P_l} \qquad (3)$$

where:

P_{y} = price of cocoa

P_f = price of fertiliser

P_l = price of labour.

Rearranging the two equations gives the input demand functions:

$$\mathbf{F = (Rp_f\ \alpha\ \beta_f\ L^{\beta l})^{1/(1-\beta f)}} \tag{4}$$

$$\mathbf{L = (RP_l\ \alpha\beta_l\ F^{\beta f})^{1/(1-\beta l)}} \tag{5}$$

where:

$\mathbf{RP_f}$ = price of coffee relative to the price of fertiliser (P_y/ P_f), and

$\mathbf{RP_l}$ = price of coffee relative to the price of labour (P_y/ P_l).

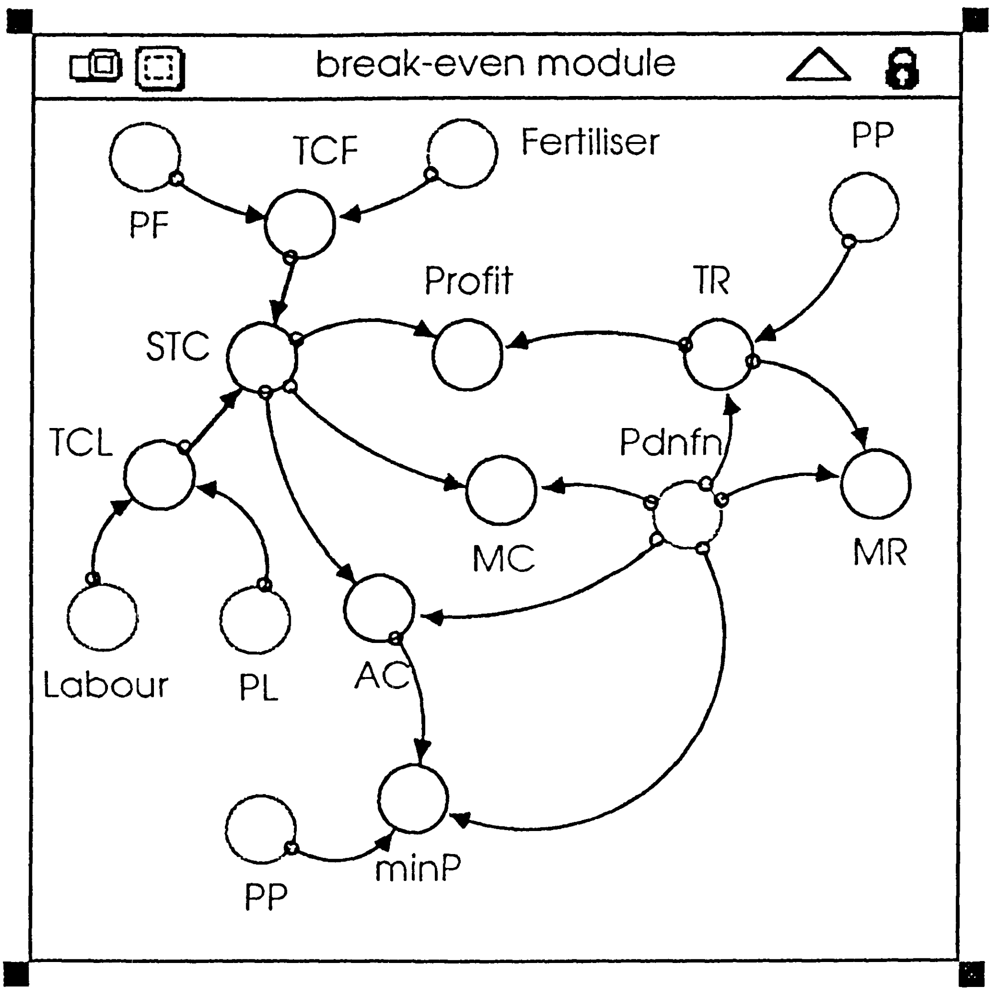
By substituting (5) into (4), labour demand is expressed in terms of product and factor prices and production function parameters. The labour demand equation, using logs to simplify the expression, is:

$$\mathbf{lnL = (1/\beta_l - 1(-lnRP_l - ln\alpha - ln\beta_l) - \beta_f/(\beta_l - 1)(\beta_f\ - 1)(- lnRP_f - ln\alpha - ln\beta_f).}$$

5.8 Break-Even Price Module

The break-even price module is included to calculate the break-even price for the average producer or, in other words, where the average variable cost per tonne is equal to the producer price per tonne. The quantity and price variables depicted in Figure 5.5 are taken from the output sub-sector module and used to calculate total revenue, total cost, profit, average cost, minimum price, marginal cost and marginal revenue (see Figure 5.5 and Appendix C5 for the equations). In considering the removal of the price support scheme, it is important to assess whether the average producer will be still able to break even in the short run. Alternatively, given the increasing cocoa prices, the removal of the levy may have a more beneficial impact on the industry.

Figure 5.5 **Break-even module**



5.9 Policy Simulation Runs

To capture the effects of the devaluation, the cocoa price and prices of imported inputs are devalued by 5 per cent, 10 per cent and 15 per cent, under the support price scheme.

For the removal of the price support, the bounties and levies are removed, allowing the producer price to fall below the support price of K1 300 per tonne. The same levels of devaluation are then simulated with the removal of price support.

To assess whether an increasing FOB price has a different impact on the industry for the removal of the price support scenario, FOB price projections from the ADB review of the ENBRDP are used (Ryan 1997).

Although no input-output data are available for the new technology, SG2-mod., a scenario is run for the impact of the SG2-mod. on output, measured by a change in the scale factor (also see section 8.3 on further research).