DEPARTMENT OF ECONOMICS

RESEARCH MEMORANDUM

**CONTROL, COORDINATION AND CONFLICT ON
INTERNATIONAL COMMODITY MARKETS**

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ABSTRACT

The effects of price stabilisation policies have been investigated for both theoretical and empirical models. The institutional construct for international commodity markets is that a buffer stock manager employs a band width rule or a price adjustment rule to stabilise the world market price. In those investigations it is assumed that the other market participants do not react to the stabilisation activities of the buffer stock manager.

This paper describes an international commodity market as a difference game between buffer stock manager, producing countries and consuming countries and uses an empirical model for the world cocoa market to analyse the effects. The feedback Nash behavioural equilibrium for this game is compared with the optimal control outcome which ignores the strategic behaviour in producing countries and consuming countries. It is found that producers and consumers engage in storage activities which have a negative effect on the stabilisation efforts of the buffer stock manager but which decrease the operating costs of the buffer stock, decrease the revenues of the producers and decrease the costs of the consumers.

Key words: buffer stock price stabilisation, international cocoa market, optimal control, difference games

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1. Introduction

International commodity agreements aiming at price and revenue stabilisation are a major policy issue at the meetings of the UNCTAD. Especially during the last conferences the main if not only objective formulated in the agreements is price stabilisation around a long-term trend (see e.g. UNCTAD, 1986). The desirability of price stabilisation has been an important theoretical issue in the economic literature for a long time. Turnovsky (1978) surveys and extends the Waugh-Oi-Massell analysis. Prices are random due to stochastic fluctuations in demand and supply. The criteria for judging the desirability of price stabilisation are the expected producers surplus and the expected consumers surplus. The main conclusion of the Waugh-Oi-Massell-Turnovsky analysis is that the source of the fluctuations determines whether the surplus improves or deteriorates. In general the sum of the surplusses, that is total welfare, improves. Newbery and Stiglitz (1982) argue that the market is in fact competitive and complete, because future and risk markets are redundant. This implies that the market equilibrium is Pareto efficient, so that the optimal stabilising policy is to reproduce the storage decisions of risk neutral competitive speculators with rational price forecasts. Turnovsky (1978) and Newbery and Stiglitz (1982) emphasize that perfect price stability is either not feasible or infinitely costly. It is better to analyse partial adjustment policies or the optimal degree of price stabilisation. In the literature two types of stabilisation policies are distinguished. The first one is a band width rule, which means that the stabilising agency intervenes when the price moves above or below an a priori specified price band. This is the sort of rule that is suggested in the international commodity agreements and that is referred to by Newbery and Stiglitz (1982) as the pragmatic approach. The second one is a price adjustment rule, which means that the stabilising agency is constantly trying to keep the price as close as possible to an a priori specified target price path. This is the sort of rule that also results from an optimal control approach to the stabilisation problem. Lee and Blandford (1980) use empirical models for the world cocoa and copper markets and perform an optimal control analysis for price and revenue stabilisation. They stress the need

to take account of the systematic trend of the price in setting the target price path, because otherwise the attempts to stabilise are doomed to fail. Their conclusion is that it is likely to require substantial market intervention to produce a significant reduction in price instability, although price stability can have a favourable impact on the level and stability of producers revenues. Ghosh, Gilbert and Hughes Hallett (1982) construct a model of the world copper market in which the market clearing identity is replaced with an explicit price formation mechanism. They compare band width rules with optimal control results and conclude that band width rules are no match for optimal stabilisation schemes. Hughes Hallett (1986) explores the problem further. The conclusion is again that significant stabilisation of the copper market is possible but very expensive. However, in contrast with Lee and Blandford (1980) there now is no improvement of the level of producers earnings, although the variability can be reduced substantially. This is in line with the theoretical results that are reported in Turnovsky (1978).

Turnovsky (1978) and Newbery and Stiglitz (1982) raise the question what the impact might be of the actions of the stabilising authority on private speculative storage and whether the actions of private speculators might jeopardise the desired outcome. Lee and Blandford (1980) and Hughes Hallett (1986) also emphasize the assumption in their exercise that the behaviour of market participants is unaffected by buffer stock stabilisation. The Lucas' critique argues that this assumption is not realistic and might lead to the wrong policy advise. This paper therefore suggests to use a difference game approach in stead of an optimal control approach. In this way it is possible to study the effects, when producers and consumers can also employ storage activities in reaction to buffer stock activities and, moreover, when the buffer stock manager realises this. It must be stressed that the Lucas' critique is not completely resolved in this way, because other behaviour is kept fixed in the model. The storage behaviour of buffer stock manager, producers and consumers is modelled as an optimal control problem and the strategic interaction is modelled as a game. It is suggested to employ the feedback Nash or subgame perfect equilibrium concept for this difference game. An algorithm which leads to this equilibrium is given by de Zeeuw (1984). In this paper an empirical model for the world cocoa market is used which is based on a model developed in van

Groenendaal and Vingerhoets (1988). This model consists of estimated equations for production and consumption and for several price indices. The optimal stabilisation policy of the buffer stock manager based on an optimal control approach is compared with the Nash equilibrium between buffer stock manager, producing countries and consuming countries. The idea is that a country modelled as a strategic agent represents all strategic activities within that country. In this Nash equilibrium the producing countries aim at higher export prices and the consuming countries aim at lower import prices. In the attempt to stabilise the world market price the buffer stock manager is restricted by the available buffer stock, which can never become negative. In their attempt to get a better export price or import price the countries are restricted in their storage decisions by assumptions about a reasonable size of the stock. The conclusions are that both producing countries and consuming countries engage in storage activities which counteract the stabilising efforts of the buffer stock manager, although this effect is small. The buffer stock can be successful in stabilising world market prices and revenues, but there remains a conflict on the market which calls for further coordination. Interesting is that the operating costs of the buffer stock decrease in the game setting. Furthermore, when producing countries and consuming countries are both active, the producers are worse off whereas the consumers are better off.

This paper is organised as follows. Section 2 presents an empirical model for the world cocoa market. Section 3 gives algorithms for the optimal control solution and the feedback Nash behavioural equilibrium in a linear quadratic framework. In section 4 the price stabilisation problem is formulated as an optimal control problem, when there is no speculation, and as a Nash difference game, when there is speculation. The algorithms given in section 2 are applied to the model presented in section 1. The results for the optimal control formulation and the Nash difference game formulation are compared. Section 5 concludes the paper.

2. Cocoa Model

Cocoabeans are produced in underdeveloped and less developed countries and
cocoa products are mainly consumed in developed countries. This implies
that the trade between producers and consumers typically is international
trade between countries or regions. The structure of the model reflects
this observation. The exports and imports of intermediary cocoa products
are transformed into cocoabean equivalents, so that cocoabeans are in fact
the only traded goods. Suan Tan (1984, pp. 71-83) reviews the theory un-
derlying the construction of this type of models. The sampling period is
in principle 1960-1982 and most data originate from FAO Cocoa Statistics,
Gill & Duffus Market Reports and the ICCO Quarterly Bulletin (the attached
list of symbols contains a complete description of the data sources).
The producing countries or regions are Cameroon, Ghana, Nigeria, Ivory
Coast, Africa Rest, Brazil, Rest South America and Asia and Oceania. The
production of cocoabeans depends on the area planted and the average pro-
duction per acre of land. Akiyama and Duncan (1982) therefore use equa-
tions for acreage and for average production in their model. However,
since the data for acreage are not reliable (FAO, 1984), here only one
equation for production is used. Under fairly reasonable assumptions this
is anyway not a severe restriction (Ady, 1968; Bateman, 1965). The deci-
sion on a change in production is based on the development (or adaptive
expectation) of real producer prices PFI/PC as an indicator of expected
profits. The resulting specification is

$$(2.1) \quad \Delta QR_t = \beta_0 + \sum_{j=0}^{8} \beta_{j+1} (PFI/PC)_{t-j} + \beta_{10} QR_{t-1}.$$

Table 1 gives the estimation results.
The consuming regions are North America, Western Europe, Eastern Europe
(including the USSR) and Rest of developed World. Especially between North
America and Brazil there is a large trade in intermediary cocoa products.
Therefore the imports consist of cocoabeans for grindings as well as pow-
der, paste and butter transformed into cocoabean equivalents. Cocoa con-
sumption per capita CC/POP is based on real gross per capita income
GNPR/POP and on real cocoa prices. The real import price PI/PC is used to

represent the real cocoa price. The real price of sugar PS/PC is intro-
duced to account for possible substitution or complementary products. The
resulting specification is

$$(2.2) \quad (CC/POP)_t = \omega_0 + \omega_1(GNPR/POP)_t + \omega_2(PI/PC)_t + \omega_3(PS/PC)_t$$

$$+ \omega_4(CC/POP)_{t-1}.$$

Table 2 gives the estimation results.
The producer prices PFI are expressed in home-currency and the export
prices PE in US-dollars. Due to government policy and quality differences
these prices are not only related through the exchange rates RE. For the
same reason export prices PE and import prices PI are not equal to the
world market price PICCO. For all these price equations an autoregressive
distibuted lag model of the first order was introduced. The resulting
specifications are

$$(2.3) \quad PFI_t = \kappa_1 PE_t \times RE_t + \kappa_2 PE_{t-1} \times RE_{t-1} + \kappa_3 PFI_{t-1}$$

$$(2.4) \quad PE_t = \kappa_1 PICCO_t + \kappa_2 PICCO_{t-1} + \kappa_3 PE_{t-1}$$

$$(2.5) \quad PI_t = \kappa_1 PICCO_t + \kappa_2 PICCO_{t-1} + \kappa_3 PE_{t-1}.$$

Tables 3, 4 and 5 give the estimation results.
The world market cocoa price PICCO depends on the difference between world
supply and demand. Buffer stock operations ΔBST have a direct influence on
this difference. Supply ERWT sums up the production per country or region
minus a change ΔST in stocks, which is held for strategic reasons in that
country or region. Demand IRWT sums up the demand for grindings per region
plus the imports of cocoabean equivalents plus a strategically held change
ΔST in stocks. Apart from stocks held for strategic reasons it is also
assumed that the consuming regions keep a fraction of the demand for grin-
dings in stock for production of cocoa products. This desired level of
stocks is set equal to the average level of stocks over the period 1968-
1980 (.225×IRWT). The definitional equation for total demand IRWT also
includes an autonomous component CCRR to account for imports in countries

or regions, which are not modelled explicitly. Differences in world supply and demand will also create changes ΔSTWT in free stocks of cocoabean equivalents (the factor .99 accounts for transportation losses). These free stocks will influence the world market price in as far as they differ from the desired level of stocks. Changing demand will induce a change in the desired level of stocks (.225×ΔIRWT). This will lead to a change in the demand for stocks and therefore this term is added to demand IRWT in the specification for the world market cocoa price. Since markets are not independent the commodity price index CPI is included in the specification in order to separate the effect of differences in supply and demand on the cocoa market from the spill-over effects from other markets. Indicators for the instability of monetary variables did not have any significant influence. The relevant definitional equations and the resulting specification for the world market cocoa price are

$$(2.6) \quad \text{ERWT}_t = \sum_{j=1}^{8} [\text{QR}_{tj} - \Delta \text{ST}_{tj}] \qquad \text{(World Supply)}$$

$$(2.7) \quad \text{IRWT}_t = \sum_{i=1}^{4} [\text{CC}_{ti} + \Delta \text{ST}_{ti}] + \text{CCRR}_t \qquad \text{(World Demand)}$$

$$(2.8) \quad \text{STWT}_t = \text{STWT}_{t-1} + [.99 \times \text{ERWT}_t - \text{IRWT}_t - \Delta \text{BST}] \qquad \text{(World Stocks)}$$

$$(2.9) \quad \text{PICCO}_t = \alpha_1 \text{CPI}_t - \alpha_2 [\text{ERWT}_t - (\text{IRWT}_t + .225 \times \Delta \text{IRWT}_t) - \Delta \text{BST}_t]$$
$$- \alpha_3 [\text{STWT}_{t-1} - .225 \times \text{IRWT}_{t-1}] + \alpha_4 \text{PICCO}_{t-1}.$$

Table 6 gives the estimation result.

The global structure of the model is as follows. The non-controllable exogenous variables are the commodity price indices PC for each country or region, real income GNPR and population size POP for each consuming region, an autonomous import component CCRR, the general commodity price index CPI, the price index for sugar PS and the exchange rates RE. The instrumental variables are the change ΔBST in the buffer stock and the changes ΔST in stocks for each country or region. These instrumental variables were set equal to zero in the estimation procedures. The endogenous variables are production QR, the producer price index PFI and the export price index PE for each producing country or region, consumption CC and

the import price index PI for each consuming region, total exports ERWT, total imports IRWT, free stocks STWT and the world market price index PICCO. Given time paths for the non-controllable exogenous variables and for the instrumental variables the model generates time paths for the endogenous variables from an appropriate set of initial values. The model is linear in the endogenous and instrumental variables. Non-linearities such as the transformation from nominal to real variables or from US-dollars to home-currency are reflected in the time-varying coefficients of an essentially linear model.

In order to be able to apply control algorithms the model is rewritten in state-space form. This means that the set of higher-order difference equations is rewritten as a set of first-order difference equations by stacking lagged endogenous and instrumental variables into a state vector and by solving this set of equations for the state transition. The result is

$$(2.10) \quad x_{t+1} = A_t x_t + \sum_{i=1}^{13} B_t^i u_t^i + z_t,$$

where x is the state vector and u^i the instrumental vector for market participant i, $i=1,\ldots,13$, and where the exogenous influences are reflected in the time-varying parameters A, B and z. The state vector consists of all the endogenous variables with one lag and the producer price indices PFI up to their maximum lag, which adds up to 75 elements. The instrumental vectors have only one element. The objective variable of the buffer stock manager is the world market price. In the game exercises in sections 3 and 4 the producing countries or regions have as objective variable their export price index and the consuming regions their import price index. Since these objective variables form a subset of the state variables the vector y of objective variables can be written as

$$(2.11) \quad y = Cx.$$

In section 3 control and game algorithms are given for the abstract model (2.10)-(2.11). In section 4 these algorithms are applied to the underlying world cocoa model (2.1)-(2.9).

3. Difference Game Methodology

The objective of the buffer stock manager is to keep the world market price as close as possible to an a priori specified target price path by selling and buying on the world market. Therefore the basic part of the objective functional of the buffer stock manager consists of squared deviations of the world market price path PICCO from this target price path PICCO. The interventions of the buffer stock manager are restricted by the available buffer stock and/or the available budget. An optimal degree of price stabilisation can be found by using as objective functional the weighted sum of squares over a fixed planning horizon

$$(3.1) \quad \sum_{t=1}^{T}[q(PICCO_t - \underline{PICCO}_t)^2 + r(\Delta BST_t)^2].$$

A high value for the relative priority q/r will generally lead to a good stabilisation result with strong interventions, whereas a low value for q/r will generally lead to a bad stabilisation result with minor interventions. Given the restrictions on interventions there will generally be a best stabilisation result corresponding with an optimal value for the relative priority q/r.

The objective functionals of the other market participants are formulated in the same way with the world market price replaced by the export price for the producing countries or regions and by the import price for the consuming regions. These objective functionals reflect the idea that, although producing and consuming countries and regions participate in the buffer stock in order to stabilise prices, there may be additional storage activities in these countries and regions in order to try to get higher export prices or lower import prices. This leads to a strategic interaction between buffer stock manager, producers and consumers, which can be modelled as a difference game. In terms of the state-space form (2.10)-(2.11) of the model this difference game consists of the objective functionals

$$(3.2) \quad J_i(u^1,\ldots,u^{13}) := \sum_{t=1}^{T}[(y_t - \hat{y}_t^i)'Q_t^i(y_t - \hat{y}_t^i) + u_t^{i'}R_t^i u_t^i] ,$$
$$i=1,\ldots,13,$$

and the constraints (2.10)-(2.11), where $\hat{y}^i$ are the vectors of target price paths and where the diagonal matrices Q^i are semi-positive definite and the scalars R^i are positive. The quadratic form of the objective functionals implies that deviations above and below the target paths are equally punished. This is a suitable type of criterium for stabilisation purposes. However, in this game it is not the objective of producers and consumers to stabilise prices, but to get higher export prices or lower import prices. A way out is to set the target path of export (import) prices high (low) enough so that the resulting price path remains below (above) the target price path. The precise choice of the target paths as well as the relative priorities q/r must again be motivated by the desirability and the feasibility of the outcomes (see also section 4).

Suppose the buffer stock manager is labelled as player 1, the producing countries or regions are labelled as players 2,...,9 and the consuming regions are labelled as players 10,...,13. In case $Q^i=0$, i=2,...,13, the producing and consuming countries and regions do not act and there remains an optimal control problem for the buffer stock manager.

The behavioural equilibrium concept used to solve the difference game is the noncooperative Nash concept. It is important to distinguish between the Nash solution with only initial state information and with binding commitments and the Nash solution with current state information and without binding commitments (Başar and Olsder, 1982; de Zeeuw and van der Ploeg, 1987). The first one is called the open-loop Nash solution and the second one is called the feedback Nash or subgame-perfect solution. Since it seems more realistic to assume the use of current state information and no binding commitments, the feedback Nash solution is employed here. This behavioural equilibrium is found by solving static Nash games in a dynamic programming framework. The equilibrium strategies are given by (de Zeeuw, 1984)

(3.3) $\quad u_t^i(x) := G_t^i x + h_t^i$, i=1,...,13,

where

(3.4) $\quad G_t^i := -[R_t^i]^{-1} B_t^{i'} K_{t+1}^i [E_{t+1}]^{-1} A_t$

(3.5) $\quad h_t^i := -[R_t^i]^{-1}B_t^{i'}\{K_{t+1}^i[E_{t+1}]^{-1}(z_t - \sum_{j=1}^{13} B_t^j[R_t^j]^{-1}B_t^{j'}g_{t+1}^j) + g_{t+1}^i\}$

(3.6) $\quad E_{t+1} := I + \sum_{j=1}^{13} B_t^j[R_t^j]^{-1}B_t^{j'}K_{t+1}^j$

and where K^i satisfy the coupled backward recursive Riccati-type matrix equations

$$K_t^i = C'Q_t^iC + A_t'[E_{t+1}']^{-1}(I + K_{t+1}^iB_t^i[R_t^i]^{-1}B_t^{i'})K_{t+1}^i[E_{t+1}]^{-1}A_t,$$

(3.7)

$$K_{T+1}^i = 0$$

and g^i satisfy the coupled backward recursive tracking equations

$$g_t^i = -C'Q_t^i\hat{y}_t^i + A_t'[E_{t+1}']^{-1}(I + K_{t+1}^iB_t^i[R_t^i]^{-1}B_t^{i'})$$

(3.8)

$$\{K_{t+1}^i[E_{t+1}]^{-1}(z_t - \sum_{j=1}^{13} B_t^j[R_t^j]^{-1}B_t^{j'}g_{t+1}^j) + g_{t+1}^i\}$$

$$g_{T+1}^i = 0.$$

The variable x in the strategy representations (3.3) denotes the state information at time t. In a simulation it is assumed that the players observe the simulated state vector.

4. Cocoa Market as a Game

In this section two strategic interventions on the international cocoa market are compared. In the first one a buffer stock manager tries to stabilise the world market price by selling and buying on the world market from an available buffer stock. In the second one producers and consumers take account of these buffer stock activities and consider to intervene for themselves aiming at higher export prices or lower import prices. The buffer stock manager realizes this, so that the three market participants play a Nash game between them. In the first exercise the buffer stock manager employs the optimal control strategy u^1 given by equations (3.3)-(3.8) with $Q^i = 0$, $i = 2, \ldots, 13$. In the second exercise the players employ the

set of Nash strategies u^i, $i=1,\ldots,13$, also given by equations (3.3)-(3.8). Both control and Nash game algorithms start from the model parameters (A_t, B_t, z_t), the initial state vector x_1, the target paths $\hat{y}^i$ and the relative priorities (Q^i, R^i).

The target path for the world market price should reflect the idea that the buffer stock manager only tries to counter undesirable market forces on the international cocoa market and not the spill-over effects from other markets. Therefore this target path is constructed as follows (see for other ideas for the construction of target price paths Lee and Blandford, 1980; Ghosh, Gilbert and Hughes Hallett, 1982; Hughes Hallett, 1986). Firstly, the world market price PICCO is simulated with the cocoa model from section 2 and a trend is determined. Secondly, the world market price PICCO is simulated with equation (2.9) in which α_2 and α_3 are set equal to zero, which implies market equilibrium, and again a trend is determined. Finally, the deviations from trend in the second simulation are added to the trend found in the first simulation. The resulting price path is taken as target path for the world market cocoa price. It seems logical to use this target path and equations (2.4) and (2.5) to construct target paths for the export and import prices. However, this would typically lead to additional stabilisation efforts and not to the sort of conflict that is supposed to be analysed here. In that conflict producers and consumers are trying to get higher export prices and lower import prices, respectively, and not stable prices. They aim at a better result than what they would get when they do nothing. Therefore, the construction of these target paths is based on the resulting price paths from the control experiment. The target paths for export prices are set 10% higher than what comes out of the control experiment and the target paths for import prices are set 10% lower.

The control experiment is set up as follows. The buffer stock manager is given an initial buffer stock of 100,000 mt. The relative priority Q^1_{11}/R^1 is determined by experiment. The value of R^1 is arbitrarily set at 10. Starting at 0 the value of Q^1_{11} is gradually increased until the accumulated buffer stock changes just hit the ceiling of 100,000 mt somewhere in the sampling period, which happens for $Q^1_{11}=30$. This is the best stabilisation result the buffer stock manager can achieve with the available buffer stock. The results are presented in table 7.

The game experiment is essentially set up in the same way. The values of R^i, i=2,...,13, are also arbitrarily set at 10. The values of Q^i_{ii}, i=2,...,13, are also gradually increased starting at 0 until the accumulated interventions on the producers' side and the consumers' side unrealistically exceed a preset value of about 140,000 mt. From the experiments it is found that an increasing Q^i_{ii}, which must lead to higher export prices and lower import prices, respectively, also leads to more income for the producing countries and regions and less costs for the consuming regions. This implies that prices are a good indicator for revenues and costs, so that the experiment was set up realistically in that respect in the first place. It remains to be seen what happens when both producers and consumers try to improve their situation by speculative actions.

The results of the game experiment are presented in three steps. Firstly, there is only a game between buffer stock manager and producing countries and regions in which the consuming regions remain passive. This game is called game 1. Secondly, there is only a game between buffer stock manager and consuming regions in which the producing countries and regions remain passive. This game is called game 2. Finally, the game between the three market participants is called game 3. It is found that in the games with consuming regions there is some more room for the buffer stock manager to operate. In these games the value of Q^1_{11} can be increased to 35. In game 1 the preset boundary for the producing countries and regions is hit for Q^i_{ii}=6, i=2,...,9. In game 2 the preset boundary for the consuming regions is hit for Q^i_{ii}=10, i=10,...,13. In game 3 the preset boundaries are hit for Q^i_{ii}=5, i=2,...,9, and Q^i_{ii}=9, i=10,...,13. It is possible to vary the values of Q^i_{ii} over the different countries and regions and over time. An idea is to relate these values to the size of the trade of each country and region, so that the resulting interventions will also be related to the size of the trade. It proves that the market results remain essentially the same. The reason is that the interventions of the producers as a group and of the consumers as a group remain essentially the same. The results with these values for Q^i_{ii} are presented in table 8 for game 1, table 9 for game 2 and table 10 for game 3.

The first conclusion from the figures in tables 7-10 is that the pattern of the buffer stock interventions is the same in all four experiments. The buffer stock manager starts to sell for three periods, then buys for three

periods, then sells again for four or five periods and ends up buying. In total the buffer stock manager is a seller. The producing countries or regions are predominantly withholding to lower supply in order to increase prices and the consuming regions are predominantly using up their stocks to lower demand in order to decrease prices, which is to be expected.

As an indicator for the degree of stabilisation the sum of absolute differences between the values of the resulting price path and the corresponding values of the target price path is used. The optimal control solution leads to a good stabilisation result. This result is somewhat better than for the game solutions. However, the stabilisation indices for the games with consumers are almost as good as for the optimal control solution, whereas the stabilisation index for the game with only producers is quite a bit worse. This means that the destabilising effect is mainly due to the storage activities in the producing countries and regions.

The net sales from the buffer stock are the lowest in the game with only consumers and the highest in the game with only producers. However, this does not mean that the buffer stock manager is less active in game 2. On the contrary, the sum of interventions in absolute terms is the highest in game 2 and the lowest in game 1. What it does imply is that there will be less costs to replenish the buffer stock up to the initial level of 100,000 mt. These costs are calculated by multiplying the required quantity with a simulated world market price. In this simulation it is assumed that every market participant has to restore its initial endowment, which determines fictitious supply and demand, and that there are enough buyers or sellers.

In order to get an indicator for the costs of operating the buffer stock the net inward cash flow into the buffer stock has to be substracted from these replenishment costs. The costs of operating the buffer stock are the lowest for the game with only producers (game 1). The interventions of the producers induce an upward pressure on the world market price, which leads to a very high net inward cash flow into the buffer stock. These revenues outweigh the high replenishment costs for this game. The costs of operating the buffer stock are also very low for the game with producers and consumers (game 3). The interventions of the producers and consumers almost cancel out, so that the world market price path changes only slightly as compared to the price path in the optimal control solution. Therefore

the net inward cash flow into the buffer stock is almost the same. However, the replenishment costs are much lower. The costs of operating the buffer stock for the game with only consumers (game 2) are higher than for the other two games but still lower than for the optimal control solution. The interventions of the consumers induce a downward pressure on the world market price, which leads to a low net inward cash flow into the buffer stock. However, the replenishment costs are much lower, since there remains a large buffer stock at the end, and this outweighs the lower revenues.

The results of game 1 and game 2 show that the producers and consumers actually benefit from their actions. The pursuit of higher export prices and lower import prices leads to higher revenues and lower costs, respectively. The group that remains passive has a loss. The differences between the gains of the one group and the losses of the other are due to the way in which the market is modelled, when the market participants restore their initial endowments. The differences are a gain or a loss of fictitious traders. The results of game 3 show that when producers and consumers are both active the producers are worse off than in the optimal control solution. The reason is that the attempts of both groups to improve their situation approximately cancel out, so that withholding and dumping implies a loss. On the other hand, the consumers are better off, because they restore their used stocks at a favourable price. The values are, however, rather small.

These budget considerations are important to put the results with respect to the stabilisation issue in the right perspective. Although the general conclusion is that the buffer stock stabilisation activities are less successful when producing and consuming countries and regions also employ storage activities for their own sake, this conclusion is weakened by the fact that the operating costs of the buffer stock are much lower. Furthermore, the producers have lower revenues and the consumers have lower costs. A topic of further research will be to make an overall cost and benefit analysis and to see if the results are robust for reasonable variations in the target paths and the relative priorities. Finally, the issue of coordination through the buffer stock and conflict on the market afterwards could be analysed further with other noncooperative and cooperative game theoretic solution concepts.

5. Conclusion

This paper tries to answer the question what happens if agents in produ-
cing and consuming countries are still strategically active on the inter-
national cocoa market, although the countries coordinate their stabilising
efforts through a buffer stock manager. An empirical model for the world
cocoa market is constructed and the optimal control solution for the buf-
fer stock manager is compared with feedback Nash or subgame-perfect game
equilibria between buffer stock manager, producers and consumers. The
conclusion is that the stabilising efforts are partly offset by the stra-
tegic activities of the other market participants. However, the costs of
operating the buffer stock decrease and some other market participants are
better off. A further treatment of the trade-off between the stabilisation
result, on the one hand, and costs and revenues, on the other hand, and
the study of other game equilibria are left for further research.

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Table 1: Production

$$\Delta QR_t = \beta_0 + \sum_{j=0}^{8} \beta_{j+1}(PFI/PC)_{t-j} + \beta_{10}QR_{t-1} + \beta_{11}HY_{t-4} + \beta_{12}t + \beta_{13}DU65$$

country or region	CA	GH	NI	IC *)	AR	BR	RA	AO
β_0 t^0	. .	170.5 (4.5)	. .	115.0 (5.6)	. .	76.3 (2.2)	143.4 (3.6)	-46.0 (-3.4)
β_1 t^1	.36 (3.6)	. .	3.46 (7.4)	2.02 (5.7)	. .	. .	. .	. .
β_2 t^2	. .	1.97 (3.9)	. .	-2.02 (-.-)	. .	.38 (2.8)	.14 (2.4)	. .
β_3 t^3	. .	-.89 (-1.6)	1.05 .	. .	. .	. .	. .	. .
β_4 t^4	. .	. .	-1.48 .	. .	. .	. .	.18 (2.1)	. .
β_5 t^5	. .	. .	. .	. .	. .	. .	. .	. .
β_6 t^6	. .	1.17 (2.2)	-2.82 (-6.3)	1.61 (5.1)	. .	. .	.17 (2.7)	.05 (1.6)
β_7 t^7	. .	-2.18 (-3.3)	. .	-1.55 (-3.6)	. .	. .	. .	.06
β_8 t^8	. .	. .	. .	1.10 (2.4)	.13 (2.1)	. .	-.31 (-2.3)	. .
β_9 t^9	. .	.98 (3.2)	1.89 (6.3)	-1.16 (-.-)	. .	. .	. .	. .
β_{10} t^{10}	-.38 (-3.3)	-.75 (-6.4)	-.90 (-8.7)	-.59 (-5.1)	-.17 (-2.2)	-.57 (-2.7)	-.85 (-3.7)	-.48 (-2.2)
β_{11} t^{11}	. .	163.2 (4.5)	140.1 (4.9)	-46.8 (-2.1)	. .	. .	. .	. .
β_{12} t^{12}	. .	. .	. .	803.5 (6.0)	. .	197.0 (1.4)	. .	. .
β_{13} t^{13}	. .	. .	. .	. .	. .	. .	. .	2.52 (3.1)
R^2	.41	.87	.86	.93	.22	.45	.60	.57

*) The following restrictions were introduced: $\beta_1 = \beta_2$, and $\beta_9 = \beta_6 + \beta_7 + \beta_8$.

Remark: In addition to the variables of section 2, three other factors were introduced. Firstly, a dummy variable DU65 for the year 1965, in which year the weather conditions were extremely good. Secondly, a variable HY which represents a change in technology due to the introduction of hybrids. Thirdly, a time trend t for Asia and Oceania, which reflects the policy of increasing the acreage for cocoatrees by the local governments.

Table 2: Consumption

$$CC/POP_t = \omega_0 + \omega_1(GNPR/POP)_t + \omega_2(PI/PC)_t + \omega_3(PS/PC)_t + \omega_4(CC/POP)_{t-1}$$

country or region	NA	WE	EE	RW
ω_0	.	.70	.	.30
	.	(4.3)	.	(2.9)
ω_1	.10	.06	2.48	.08
	(2.6)	(2.6)	(4.3)	(2.8)
ω_2	-.17	-.08	-.38	-.11
	(-2.9)	(-3.2)	(-4.3)	(-2.8)
ω_3	-.35	-.13	.	.
	(-2.55)	(-1.8)	.	.
ω_4	.78	.49	.30	.51
	(7.1)	(3.9)	(1.6)	(3.1)
R^2	.78	.77	.78	.82

Remark: For Eastern Europe and the USSR there are no figures on the price of consumption. Therefore PI and PS were used instead of the relative prices.

Table 3: Producer prices

$$PFI_t = \kappa_1 PE_t \times RE_t + \kappa_2 PE_{t-1} \times RE_{t-1} + \kappa_3 PFI_{t-1}$$

country or region	CA	GH	NI	IC	AR	BR	RA	AO
κ_1 t^1	.05 (1.8)	.18 (5.7)	. .	.07 (1.1)	.12 (2.6)	.74 (20.3)	.	.
κ_2 t^2	.15 (3.6)	. .	.21 (2.6)	.16 (2.2)	.10 (1.2)	-.45 (-2.4)	.	.
κ_3 t^3	.63 (7.7)	.63 (6.6)	.79 (5.1)	.59 (4.4)	.65 (4.0)	.60 (2.1)	.	.
R^2	.99	.98	.98	.97	.98	.99		

Remark: For the Rest of South America (RA) and Asia and Oceania (AO) pro-
ducer prices are not known. It is assumed that for these regions producer
prices are equal to export prices in home-currency: PFI = PE×ER. For the
rest of Africa an index (1975 = 100) was used based on the sum of producer
prices in US-dollars, weighted with the production.

Table 6: The world market cocoa price

$$PICCO_t = \alpha_1 CPI_t - \alpha_2 [ERWT_t - (IRWT_t + .225 \times \Delta IRWT_t)]$$
$$- \alpha_3 [STWT_{t-1} - .225 \times IRWT_{t-1}] + \alpha_4 PICCO_{t-1} + \alpha_5 DU77$$

para-meter	α_1	α_2	α_3	α_4	α_5	R^2
value	.85	.22	.06	.71	145.29	.97
t	(3.1)	(3.6)	(2.0)	(6.5)	(6.4)	

Remark: A dummy variable DU77 for the year 1977 was introduced to account
for the extreme increase in PICCO in that year.

Table 4: Export prices

$$PE_t = \kappa_1 PICCO_t + \kappa_2 PICCO_{t-1} + \kappa_3 PE_{t-1}$$

country or region	CA	GH	NI	IC	AR	BR	RA	AO
κ_{t1}	.58 (9.6)	.36 (5.4)	.72 (7.0)	.49 (8.5)	.43 (8.4)	1.08 (22.0)	.93 (84.5)	.81 (24.6)
κ_{t2}	.32 (5.1)	.62 (9.1)	. .	.38 (6.5)	.43 (8.3)	-.12 (-2.4)	. .	.08 (2.5)
κ_{t3}	. .	. .	.17 (1.4)	. .	. .	. .	. .	.
R^2	.98	.98	.92	.98	.98	.99	.99	.99

Table 5: Import prices

$$PI_t = \kappa_1 PICCO_t + \kappa_2 PICCO_{t-1} + \kappa_3 PE_{t-1}$$

country or region	NA	WE	EE	RW
κ_{t1}	.54 (11.1)	.56 (14.2)	.54 (8.6)	.74 (15.4)
κ_{t2}	.51 (10.4)	.36 (9.0)	.50 (7.7)	.32 (6.5)
κ_{t3}	. .	. .	. .	. .
R^2	.99	.99	.99	.99

Table 7: Optimal control solution

year	ΔBST	simulated PICCO	target PICCO	controlled PICCO
1968	-13.83	64.16	69.29	61.85
1969	-41.67	86.86	78.20	79.86
1970	-29.49	94.21	85.60	90.23
1971	15.01	77.58	89.58	84.65
1972	43.51	63.15	96.28	76.68
1973	19.18	116.70	118.09	122.00
1974	-18.33	187.60	147.23	179.30
1975	-33.56	212.80	156.78	197.30
1976	-29.36	215.20	170.48	200.10
1977	-17.63	369.30	337.47	360.30
1978	4.76	305.60	307.36	310.00
1979	20.46	271.60	297.11	289.30
1980	28.66	225.00	297.46	246.50

$$\sum_{68}^{80} = -52.29$$

$$\min_t \{BST_t\} = BST_{77} = -6.17$$

operating costs   : 59,073,000.- US-dollars
inward cash flow : 75,728,000.- US-dollars

stabilisation index (simulation) : 341.59
stabilisation index (control)   : 228.62

Remark: The stabilisation index is defined as $\sum_{t=68}^{80} |PICCO - \underline{PICCO}|$. The operating costs for the buffer stock manager are defined as

$$\sum_{t=68}^{80} \Delta BST_t \times PICCO_t + (BST_{67} - BST_{80})(PICCO_{80} - [-.216 \times (BST_{67} - BST_{80})]).$$

The first term is the total yearly outward cash flow from selling and buying. The second term represents the costs for restoring the buffer stock at its initial level. The warehouse costs of the buffer stock are not taken into account .

Table 8: Game between buffer stock and producers (game 1)

year	ΔBST	$\sum_{i=1}^{8}\Delta ST_i$	$\sum_{i=1}^{4}\Delta ST_i$	total intervention	PICCO
1968	- 5.96	- 5.77	0.0	-11.73	62.20
1969	-32.02	0.44	0.0	-31.58	81.56
1970	-27.44	8.18	0.0	-19.26	91.84
1971	9.26	10.75	0.0	20.01	84.55
1972	37.67	6.92	0.0	44.59	75.31
1973	17.98	2.81	0.0	20.79	121.10
1974	-16.08	2.92	0.0	-13.16	180.10
1975	-31.57	6.81	0.0	-24.76	199.70
1976	-30.25	15.12	0.0	-15.13	204.30
1977	-22.42	26.82	0.0	4.40	366.40
1978	- 1.55	28.24	0.0	26.69	316.00
1979	15.90	25.16	0.0	41.06	293.70
1980	27.68	13.13	0.0	40.81	248.20

$$\sum_{68}^{80} = -58.80 \qquad 141.53 \qquad 0.0 \qquad 82.73$$

$$\min_{t} \{BST_t\} = BST_{78} = -2.38$$

operating costs   :   12,932,000.- US-dollars
inward cash flow   : 122,502,000.- US-dollars
benefits producers   : 500,007,000.- US-dollars
benefits consumers   : -245,125,000.- US-dollars

stabilisation index : 245.55

Table 9: Game between buffer stock and consumers (game 2)

year	ΔBST	$\sum_{i=1}^{8}\Delta ST_i$	$\sum_{i=1}^{4}\Delta ST_i$	total intervention	PICCO
1968	-13.30	0.0	4.58	- 8.72	62.88
1969	-35.52	0.0	- 2.70	-38.22	80.17
1970	-24.11	0.0	- 9.22	-33.33	88.75
1971	16.99	0.0	- 9.65	7.34	82.58
1972	43.98	0.0	- 5.13	38.85	76.25
1973	16.78	0.0	- 1.49	15.29	122.80
1974	-22.46	0.0	- 2.34	-24.80	179.40
1975	-36.41	0.0	- 7.08	-43.49	196.10
1976	-28.69	0.0	-16.07	-44.76	196.90
1977	-14.73	0.0	-25.87	-40.60	354.20
1978	9.73	0.0	-28.23	-18.50	302.20
1979	25.77	0.0	-24.83	0.94	282.80
1980	34.35	0.0	-12.02	22.33	245.10

$$\sum_{68}^{80} = -27.62 \qquad 0.0 \qquad -140.05 \qquad -167.67$$

$$\min_{t} \{BST_t\} = BST_{77} = 2.53$$

operating costs   :   53,749,000.- US-dollars
inward cash flow   :   23,950,000.- US-dollars
benefits producers : -542,746,000.- US-dollars
benefits consumers : 212,358,000.- US-dollars

stabilisation index : 229.74

Table 10: Game between buffer stock, producers and consumers (game 3)

year	ΔBST	$\sum_{i=1}^{8}\Delta ST_i$	$\sum_{i=1}^{4}\Delta ST_i$	total intervention	PICCO
1968	- 8.29	- 5.65	4.86	- 9.08	62.83
1969	-30.71	0.94	- 3.06	-32.83	81.05
1970	-24.26	8.73	-10.07	-25.60	90.11
1971	12.48	10.50	-10.14	12.84	83.18
1972	40.16	5.46	- 4.71	40.91	75.69
1973	16.66	1.06	- 0.48	17.24	122.10
1974	-20.25	1.82	- 1.52	-19.95	179.70
1975	-34.84	6.41	- 7.00	-35.43	197.70
1976	-29.86	14.95	-16.93	-31.84	200.10
1977	-19.41	26.59	-27.54	-20.36	359.40
1978	3.57	28.14	-30.22	1.49	308.10
1979	20.98	24.31	-26.17	19.12	287.60
1980	33.01	11.80	-12.35	32.46	247.10
$\sum_{68}^{80}$	-40.76	135.06	-145.31	-51.02	

$\min_{t} \{BST_t\} = BST_{77} = 1.68$

operating costs   :   32,499,000.- US-dollars
inward cash flow   :   72,712,000.- US-dollars
benefits producers   : -61,614,000.- US-dollars
benefits consumers   :   21,121,000.- US-dollars

stabilisation index : 230.37

List of symbols

BST   Buffer stock in 1000mt.

CC   Consumption of cocoa in 1000 mt.
Calculated by adding grindings and imports in bean equivalents of the various consuming areas. CCRR is obtained by substracting the consumption in the other four areas from world grindings.
FAO Cocoa Statistics (1951-1973) and Gill & Duffus Market Report (1974-1985)

CPI   Commodity price index (1980 = 100).
International Financial Statistics, 1953-1985

ERWT   World supply of cocoa beans: $\sum_{j=1}^{8} QR_j - \Delta ST_j$.

IRWT   World demand for cocoa beans: $\sum_{j=1}^{4} CC_j - \Delta ST_j$.

GNPR   Gross national product in purchasers values in billions of US-dollars (at exchange rates and prices levels of 1975).
Data available for the period 1960-1982 for Western Europe and North America. For the the rest of the developed world we used the data from Japan, Australia and New Zealand. The source is OECD National Accounts. For Eastern Europe and the USSR the data are taken from the Year-book of National Accounts (available as an index (1975 = 100) for the period 1960-1980).
OECD National Accounts and Yearbook of National Accounts.

HY   Percentage of total area planted with cocoa that is planted with hybrid varieties. This is defined only for Ivory Coast and Brazil.
'World Cocoa Production, Consumption and Price Prospectives' by M.J. Bateman, Mimeo. Period 1966-1983.

PC   Index of consumption prices (1975 = 100).
For the consuming regions this index is calculated by dividing nominal private consumption per region by real private consumption per region at 1975 prices and exchange rates from the OECD National Accounts for the period 1960-1982. For Eastern Europe and the USSR no data are available. For the producing countries data are available per country for the period 1953-1984 (except for Cameroon and Ivory Coast) from the International Financial Statistics. For Cameroon and Ivory Coast data for the missing years (1953-1962 and 1953-1960 respectively) were constructed by regressing the index for each country on the index for total Africa and 'predict' the missing observations. For the three remaining areas data are constructed as follows:
Africa Rest, the consumer index for total Africa, period 1953-1984.
Asia and Oceania, the consumer price index for total Asia, period 1953-1984.
Rest America, the average of the consumer price indices (weighted with production of beans) of Ecuador, Mexico and the Dominican Republic, period 1956-1984.
OECD National Accounts and International Financial Statistics.

PE   Unit value of exports in US-dollarcents per kilo.
Nominal exports are divided by real exports in 1975 prices.
FAO Cocoa Statistics and FAO Trade Yearbook, 1956-1982.

PFI   Index of producer prices in home-currency (1975 = 100).
Producer prices in home-currency are available for countries. For
Africa Rest a weighted average of producer prices in US dollar
cents of the four other countries is used. Producer prices for the
Rest of South America and Asia and Oceania are set equal to export
prices. Data are available for: Cameroon (1958-1982), Ghana (1953-
1982), Ivory Coast (1957-1982), Nigeria (1953-1982), Brazil (1966-
1982).
Gill & Duffus Market Report.

PI   Unit value of imports in US-dollarcents per kilo.
Nominal imports are divided by real imports in 1975 prices.
FAO Cocoa Statistics and FAO Trade Yearbook, 1955-1982 (except for
Eastern Europe and the USSR, 1965-1982).

PICCO   Annual average of daily prices of cocoabeans in US-dollarcents per
kilo.
FAO Cocoa Statistics and Quaterly Bulletin of Cocoa Statistics,
1960-1985.

POP   Population in millions.
OECD National Accounts and Yearbook of National Accounts,1960-1982.

PS   Price of sugar on the world market in US-dollarcents per kilo.
Trends & Prices, 1960-1982.

QR   Production of cocoabeans in 1000 mt per annum (1 oct. - 30 sept.).
FAO Cocoa Statistics and ICCO Quarterly Bulletin of Cocoa
Statistics, 1951-1985.

RE   Rate of exchange in units per US-dollar (for regions RE equals 1).
International Financial Statistics, 1953-1985.

ST   Strategic stocks held by a producing and consuming countries.

STWT   Free world stocks of cocoabeans in 1000 mt.
Calculated starting from 1960 stocks as reported by Gill & Duffus.

IN 1989 REEDS VERSCHENEN