PN-ABA-396

# Simulation and Optimization of Price Stabilization Policies: Maize in Kenya

Thomas C. Pinckney
Carl H. Gotsch

Reprinted from the
Food Research Institute Studies
Vol. 20, No. 3, 1987

INTERNATIONAL
FOOD
POLICY
RESEARCH
INSTITUTE

1776 Massachusetts Avenue N.W.
Washington, D.C. 20036 U.S.A.

Reprint No. 120

Thomas C. Pinckney and Carl H. Gotsch*

# SIMULATION AND OPTIMIZATION OF PRICE STABILIZATION POLICIES: MAIZE IN KENYA†

Like many countries, Kenya is faced with the difficult task of managing a high degree of production instability for its staple foodgrain, white maize. Government actions and statements reveal at least three conflicting goals: maximizing self-sufficiency (minimizing imports); minimizing fiscal costs; and, minimizing price variability. The present paper examines two analytic frameworks, simulation and optimization, for assisting policy makers in evaluating the trade-offs among these objectives. The data used in the study are specific to Kenya, but the methodological concerns and the effort to spell out the operational implications of administering different types of policies are relevant to all countries in which high variability in staple foodcrop production has prompted government intervention in domestic markets.

## BACKGROUND

The first goal, self-sufficiency, is less a commitment to the politics of independence than it is to a preference for white maize. The world market for white maize is thin and, when imports are required, Kenya is forced to import yellow maize. This is viewed as a policy failure by most Kenyans, leading to large political costs to the government. The second objective, minimizing fiscal costs, is universal but has taken on added significance in recent years under pressure from the foreign aid community for greater

* Research Fellow, International Food Policy Research Institute, and Professor, Food Research Institute, respectively.

† The authors are grateful to Richard Goldman and Anne E. Peck for substantive help and editorial assistance that went well beyond the usual collegial comments.

austerity. Deficits of Kenya's National Cereals and Produce Board (NCPB) have increased significantly, making the agency an obvious target for budget cutting.

The third goal, price stability, focuses primarily on the changes in average real prices from year to year. The government wants farmers to be assured of a reasonable price and consumers to be satisfied with the price and quantity available. Beyond this, however, lies a strong predilection to control prices directly. Price controls in Kenya date to the Second World War, are deeply ingrained in the political preferences of the government, and are most evident in what the government has not been willing to do in several recent years. For example, despite large losses on every ton that was imported and sold domestically in 1980/81, the official price remained firm. Similarly, when the NCPB ran out of cash buying the bumper crop in 1981/82, official prices were not lowered. Moreover, a series of reports like that of the 1966 Maize Commission of Inquiry have accepted the price stabilization objective without commenting on the possible trade-offs between it and other objectives.

*Government's Tools: Stocks, Trade, and Price Variability*

Given the above objectives, the government requires a strategy for answering several questions. With knowledge of the stock on hand, the world price, and present production as well as expectations about next year's values for these variables, how should the government intervene in the domestic market? How many tons of grain should be carried over into next year? How much should be imported or exported? And, how much should prices be permitted to vary?

A so-called stabilization policy is simply a systematic way of deciding under what circumstances to use each of these mechanisms. One frequently discussed policy of this type is a buffer stock price band scheme where domestic prices are permitted to fluctuate only between pre-set maximum and minimum prices. The government guarantee is made good through sales from stocks and purchases into stocks. Government imports and exports may also be permitted, triggered by pre-set levels of government-owned stocks. For example, if stocks reach a maximum level when the government is defending the floor price, all additional grain purchased domestically may be exported.

The costs and benefits of a price band scheme can be estimated through the use of Monte Carlo simulation techniques. Simulation also permits the analyst to vary both the underlying parameters of the commodity system and those of the policy itself in order to examine questions of sensitivity and trade-offs among objectives. However, simulation of a particular set of administrative rules omits from consideration other policy instruments that might achieve the desired goals at a lower cost. For example, allow-

ing a scheme to be responsive to world prices might significantly affect its efficiency and the trade-offs among conflicting government objectives. Unless specifically explored with appropriate parameter and rule variations, simulation will not provide this information.

An optimization model chooses the best level of policy variables for each possible combination of stocks, production, and world price given an objective function and will explore the policy alternatives more completely. Although optimizing is more difficult, there are several reasons for using this method rather than simply simulating additional chosen policies. The optimizing process screens all possible policies and chooses the best, insuring that trade-offs between objectives are measured accurately. When optimizing a multi-dimensional objective function, trade-offs between objectives are measured by varying the weights assigned to the various objectives. For example, if the emphasis on price stability is increased, optimization insures that policies are adjusted so as to insure that the cheapest method of increasing price stability is chosen.

Furthermore, once an optimal policy has been identified, it can be simulated in the same way as price band schemes so as to permit direct comparison with policies based on administrative rules. The optimal policies and administrative rules can be compared and administrative rules adjusted in ways suggested by the optimal policies. It is this latter procedure, using simulation methods to evaluate the returns to components of increasingly complex policy packages, components identified by the optimization model, that forms the backdrop of the present paper.

*Maize Policy in Kenya*

By law, the government controls maize marketing within the country, with the NCPB acting as its agent. Before planting each year, the government announces the price at which it will buy maize at harvest time.[1] The NCPB is supposed to purchase all of the maize that it is offered at this price, and to supply all that millers and agents want to purchase at the corresponding selling price. All foreign trade is handled by the Board, but trade decisions are made by the Cabinet, not the NCPB.

The law makes most commercial transactions other than those through the board illegal. Farmers may sell maize to families who consume it directly, but may not sell to traders or institutions. These restrictions are rarely enforced, and trade within district boundaries is relatively free. Restrictions on the movement of maize, however, are enforced much more rigorously than the restrictions on sales. Moving more than two bags requires a permit, as does moving maize across district boundaries.

[1] The government also controls corresponding prices at each level of the marketing chain, including the retail price of a two-kilogram packet of sifted meal, but these prices usually are not announced until a later date.

A substantial amount of illegal movement of maize unquestionably takes place. The government has not given the Board the fiscal resources necessary to fulfill its mandate, and it has not been able to buy all the maize available in bumper years or to provide all that has been demanded in scarce years. Observers have charged the Board with inefficiency and corruption for not carrying out its mandate.[2] However, it is unlikely that any organization could succeed. The Board is supposed to buy whatever is offered at a price over which it has no control, sell whatever is demanded at a second price over which it has no control, export and import only when given approval by the Cabinet, and store all stocks remaining. Even an exceptionally efficient organization would lose money under such constraints.

With production instability, shocks must be absorbed by government stocks, the foreign trade account, or domestic consumption. All three methods have been used in recent years in Kenya. In 1979/80, domestic stocks fell almost to zero, maize was imported, and the NCPB was still unable to provide all that was demanded from it (*The Standard*, 1980). The situation in 1984/85 was similar except that government stocks were over 100 thousand tons when the imports began to arrive. Conversely, in 1981/82, stocks increased substantially and exports were approved after a lag, but the NCPB did not buy all the maize that was offered to it. Within each crop year, the NCPB bought and sold only at the controlled price, but its financial constraints meant local market prices varied significantly from official prices. Simulation of these policies will provide estimates of anticipated total costs to better prepare policy makers for providing the necessary fiscal resources.

*Organization of the Study*

In order to examine both substantive trade-offs between various government objectives and the merits of alternative techniques for investigating the problem, the remainder of this paper is divided into four sections. It first describes the basic simulation model of the maize market and then evaluates basic price band policies similar to those the Kenyan government has frequently used. The results demonstrate that these policies are both expensive and will continue to rely heavily on imports.

The next section develops an optimization model which allows the identification of the most efficient policies to accomplish the multidimensional objectives of the government. Specifically, optimal policies incorporate responsiveness to world prices, domestic production, and existing stock levels. These policies are simulated, and the results compared with price

[2] The Board's many problems have been documented in several studies, including Bookers International (1983), Schmidt (1979), Hesselmark and Lorenz (1976).

band policies. In the third section, the lessons learned from an examination of the optimal policies are applied to price band rules and substantial improvements in government policy prove to be possible with only modest alterations of the administrative rules. Comparison of the two approaches also makes clear, however, that complete optimization of the maize system would require a substantial increment in administrative complexity. The final section discusses the trade-offs between cost and complexity for the researcher and policy maker interested in food policy analysis.

## SIMULATION OF KENYAN MAIZE POLICY

The basic simulation model used here is similar to that developed by the Interministerial Working Group (1983) and illustrated in Chart 1. $P^*$ is the government's target price and $P_{max}$ and $P_{min}$ in are the "defense" prices. If domestic prices are between $P_{min}$ and $P_{max}$, there is no government intervention. Equivalently, if production falls between $Q_1$ and $Q_2$, no government action is required. If, however, actual production in year $t$ is $Q_t$, the government would have to sell $Q_1 - Q_t$ in order to keep the price at or below $P_{max}$. The lower portion of the chart shows the relation between production and government purchases and sales under such a system. In theory, the Board must buy all that is produced above $Q_2$ and must provide the entire shortfall when production is below $Q_1$.

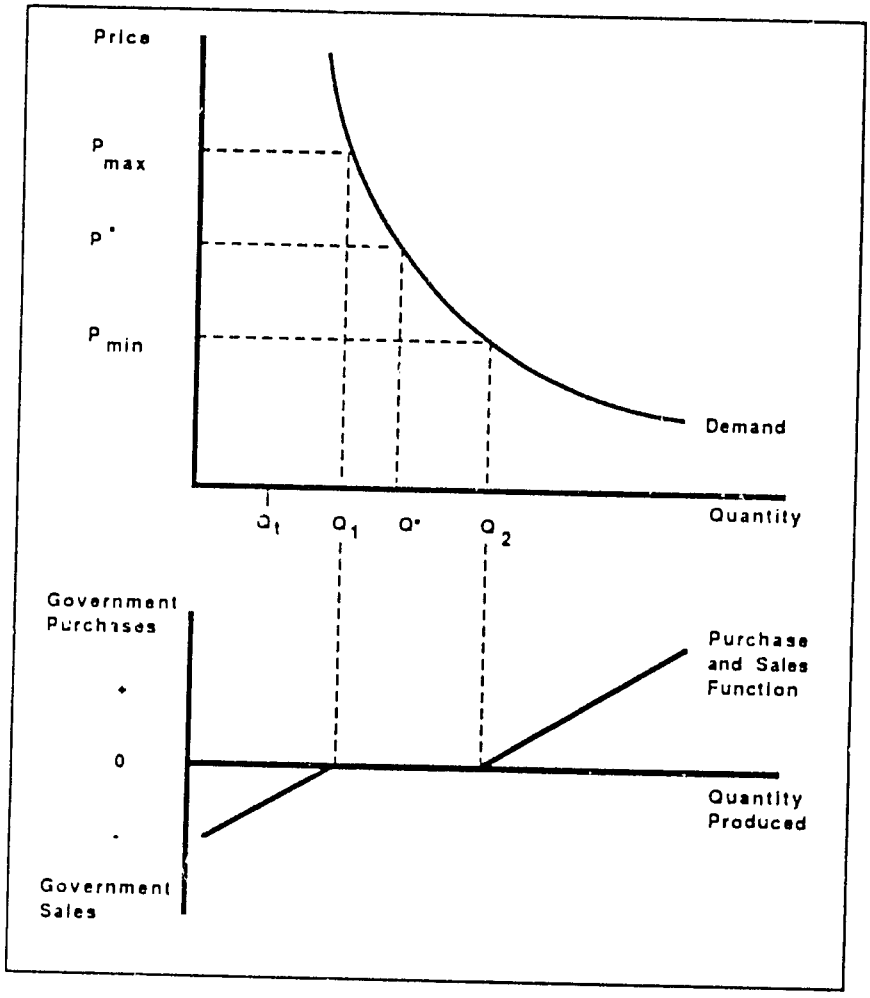
Since Kenya has been both an importer and an exporter in recent years, it is reasonable to assume their target price $P^*$ is approximately the long-run equilibrium price. The net purchase rule is clear, but the rules for exporting and importing are more difficult to specify a priori. Basically, Kenya has allowed its stock position to determine whether or not trade should take place, which means that there are maximum and minimum stocks levels, $S_{max}$ and $S_{min}$, which serve as triggers for foreign trade.[3] Their difference, $S_{max} - S_{min}$, measures permitted stocks variability and reflects the degree to which stocks can absorb production instability. Thus, given a constant target price and symmetric price bands, the policies evaluated in the simulation approach differ in only two parameters: the degree of price variability allowed and the stock variability.

### *The Underlying Model of the Maize Market and Government Operations*

For purposes of the simulation exercise, the maize market in Kenya is treated as a single unified market and regional and seasonal issues are taken as secondary to the question of how to stabilize national supply.

[3] Imports will not arrive in Kenya until three or four months after orders are placed, and hence $S_{min}$ should be greater than zero.

Chart 1.—A Simple Price Band Stabilization Scheme



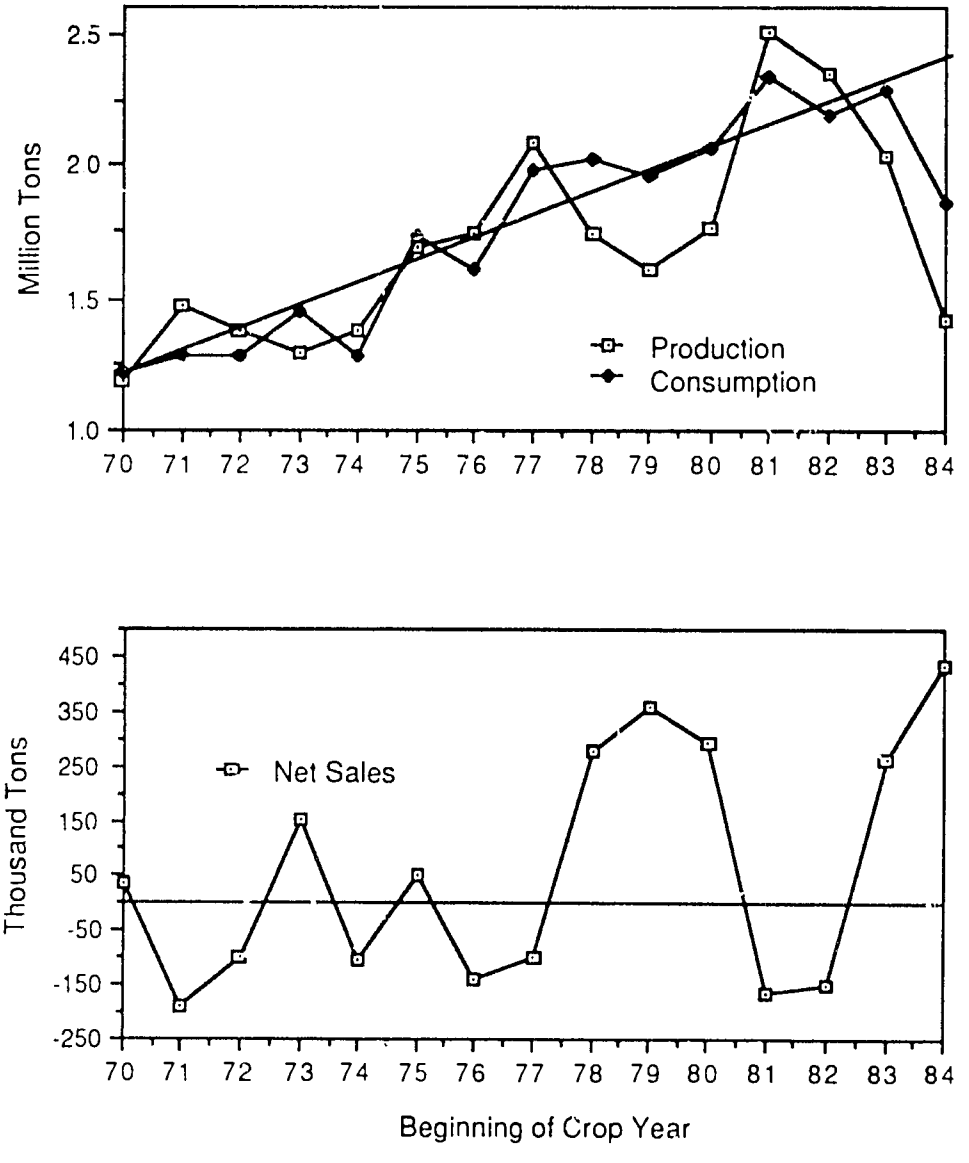

Production is modeled as a stationary, normally distributed, uncorrelated random variable with mean $Q_o$.

$$Q_t = Q_o + u_t, \tag{1}$$

where $E(u_t) = 0$ for all $t$.

The key assumptions here are stationarity and the lack of supply response to price. Stationarity is a convenience. Chart 2 displays the production data from 1970-1984. The overall trend amounts to 3.3 percent per year. However, production in 1984/85 was reduced significantly by the severe drought. Ignoring 1984/85, the production trend is 4.4 percent. In the present model, consumption is assumed to increase at the same rate,

Chart 2.—Kenyan Maize Production, Consumption, and NCPB Net Sales Activity, 1970–84




Source: Republic of Kenya, Ministry of Agriculture, Development Planning Division, Nairobi.

allowing both trends to be ignored.

The important assumption is the absence of a production response to price. In a recent study, Bookers International (1983) reports prior

estimates of supply elasticities ranging from 0.15 to 0.95 and their own "best guess" of around 0.4. Even with this comparatively high estimate,[4] the data in Chart 2 make clear that the supply elasticity explains little of actual production variability. If expected price varied as much as 10 percent each year, production response would account for only a 4 percent change. The historical coefficient of variation of the detrended series excluding 1984/85 is 13.0 percent; including 1984/85, it is 17.9 percent. Thus, by ignoring supply response, the model does no serious injustice to the representation of production variability.

For the simulation, the standard deviation of production is assumed to be 10 percent. It is a conservative estimate relative to historic levels of variation. But, the historic data also capture the effects of major changes in government policy (Kleist, 1985; Bookers International, 1983). Excluding the effects of the drought and policy-induced variations leaves unexplained variation of at least 10 percent.[5]

The consumption data are even more problematic than those on production, and demand is modeled in the simplest way possible. Annual maize consumption is shown in Chart 2, calculated as production less net NCPB sales (shown in the lower portion of the chart). Net of trends caused by income and population, demand is assumed to be representable by a non-stochastic, constant elasticity curve:

$$ln(D_t) = C + e * ln(P_t), \tag{2}$$

where $e < 0$ is the demand elasticity, assumed in the remainder to be $-0.3$.[6] As noted, the net consumption trend matches the production trend and both are ignored. Prices of other goods have also been ignored in this model because the focus is on maize policy which is assumed to leave other prices unaffected.

The market is assumed to clear

$$D_t = Q_t + M_t - X_t - (S_t - S_{t-1}).$$

Demand is equal to production plus imports minus exports less the change in government stocks. Net government purchases in any year, $NP_t$, are net exports $(X_t - M_t)$ plus the stocks change $(S_t - S_{t-1})$, so the clearing relation simplifies to

---

[4] Timmer, Falcon, and Pearson (1983, p. 109) suggest a "best guess" supply elasticity for a basic cereal grain of about 0.2 to 0.3 from comparative experience.

[5] The model was also run with production variability of 12 percent with no significant effect on the comparative results. See Pinckney (1986) for details.

[6] The comparative results presented here were also not sensitive to this assumption (Pinckney, 1986).

$$D_t = Q_t - NP_t. \tag{3}$$

Private stockholding is ignored in the model. No data exist from which to establish either the size or responsiveness of privately held stocks. Several studies (for example, Gustafson, 1958; Peck, 1977/78; Wright and Williams, 1982) have shown that rationally determined private stocks will stabilize a market much as government programs will. More to the point, government storage operations will largely substitute for private storage and, thus, models which exclude private stocks significantly overstate the effectiveness of government operations relative to a "free" market. However, the free market is not of concern here since the proposed comparisons are among government policies. Thus, the model assumes that most (if not all) of the substitution of public for private storage has occurred, and privately held stocks are insignificant in all the policy simulations.

The model must also simulate world prices in order to determine the costs of imports and receipts from exports. World prices are assumed to be log-normally distributed as:

$$ln(WP_t) = ln(WP_{t-1}) + m_t, \quad m_t \approx N(0,\ 14.5) \tag{4}$$

The hypothesis that the annual percentage change in U.S. Gulf Port prices of No. 2 yellow maize from 1957 to 1984 was log-normal with mean zero, and standard deviation of 14.5 percent could not be rejected at the 90 percent level of significance.

The costs of a stabilization program include four components: domestic operations, foreign trade, storage, and stock replacement. Costs of domestic operations are $P_t * NP_t$, where $NP_t$ is net government purchases, defined above to be negative when the government sells maize. Thus, only costs or proceeds from the difference between government purchases and sales are considered part of the total cost.

Actual foreign trade costs are difficult to compute in Kenya. Import parity prices are usually derived by adding local and foreign shipping costs to the world price, while export parity prices subtract local costs. The situation in Kenya is more complex for two reasons: in any one year, relatively small quantities of maize can be exported at a premium, and foreign food aid is available. Maize policy should take advantage of both these facts.

Export premiums are available at least for some exports because white maize is a preferred commodity in many neighboring countries in Africa. The market is thin, however, and most countries that want to import white maize lack foreign exchange. Nevertheless, the World Food Program, for example, has purchased Kenyan white maize for distribution to nearby areas, mainly Somalia, and passed on the savings in transportation costs to Kenya as a substantial price premium. Opportunities for this kind of

arrangement are fairly limited; if large amounts of maize were exported, it is unlikely that the premium would be maintained. In the model, Kenya is assumed to receive a \$40 per ton premium on the first 80,000 tons of exports in any one year. The premium decreases linearly and disappears entirely when exports reach 120,000 tons. Formally,

$$XR_t = X_t * (WP_t + 40 - XCOST), \tag{5a}$$

when $X_t \leq 80,000$,

$$XR_t = X_t * (WP_t - XCOST) + (3,200 + [160 - X_t]/2 * [X_t - 80]), \tag{5b}$$

when $80,000 < X_t < 120,000$, and

$$XR_t = X_t * (WP_t - XCOST) + 4,000, \tag{5c}$$

when $X_t \geq 120,000$. Export costs (XCOST) are constant at \$0970 per ton.[7]

On the import side, food aid complicates the picture in two ways. First, Kenya can and has arranged for food aid in crisis years, as, for example, in 1979/80 and 1984/85. Although the amounts received as aid in those years may have been larger than usual because of large surpluses in the developed countries, there is no doubt that for the foreseeable future the United States and other donor countries will assist Kenya in times of trouble, but not in years of minor shortfalls. Even in serious drought years, the first imports would have to be ordered commercially in order to assure prompt delivery.

Second, relief aid that is distributed freely does not affect demand for marketed maize and should not be included in the market model's accounting. Finally, although it is difficult to predict responses to a shortfall in production, donors are likely to base aid decisions on estimates of the total supply (production plus government stocks) rather than production alone or production plus planned imports. There is no obvious model to use here, but donors are assumed to make up 40 percent of the difference between total supply and 100 thousand tons below normal year production ($Q^*$). Formally,

$$AID_t = 0 \tag{6a}$$

[7] The latest official estimate of the costs to the NCPB of preparing maize for export is \$80 per ton. Purchase and transport costs are expected to decline under the changes in policy envisaged by this study. Assuming that this decline is 20 percent and that the government saves money through the use of some used bags, the figure can be lowered to \$70 per ton. This estimate of costs is consistent with Schluter (1984, p. 74).

when $Q_t + S_{t-1} > Q^* - 100,000$, and

$$AID_t = 0.4 * (Q^* - 100,000 - [Q_t + S_{t-1}]) \tag{6b}$$

otherwise. Total costs of imports, $MC_t$, are

$$MC_t = M_t * (WP_t + MCOST) - AID_t * (WP_t + DT), \tag{7}$$

where $AID_t$ is the amount of aid, $M_t$ is total imports, $DT$ is the domestic component of import costs, and $MCOST$ is import costs, assumed to be \$40 per ton.[8] These models of food aid and export premiums are admittedly arbitrary, but when both food aid and export premiums have significant effects on Kenya's maize strategy, it would be wrong to leave them out of the model. The relations formulated above include some reasonable sensitivity to these considerations but are certainly not the only way to proceed.

Costs of government purchases, sales and storage charges are calculated as

$$(P_t * NP_t) + (S_t * STCOST). \tag{8}$$

Storage charges (STCOST) include losses, railage to and from the stores, and any costs associated with turning over the stocks to keep them fresh. They are assumed to be constant per ton of stock at \$25. Interest cost is excluded because all costs are discounted to calculate net present values (Gardner, 1979).

Finally, allowance must be made for changes in government stocks from the beginning to the end of the simulation period. All simulations begin with 100 thousand tons in year 0. The different policy rules examined result in average ending stocks ten years later varying from 0 to 250 thousand tons, with individual cycles varying even more. Unless an allowance is made for these changes in stocks levels, policies which end with low levels will appear to be more profitable since they include the proceeds of selling the stock. There are two alternatives: value the excess or deficit stock at a constant price and add the charge to the total for that policy; or, introduce a constraint that forces exports or imports in the final year in order to end up with stores of 100 thousand tons. The former is used here.

---

[8] For the costs of importing, it is assumed throughout this study that the difference between the domestic selling and buying price of the NCPB covers the Board's cost. Imported maize is sold at the domestic selling price, which is the producer price plus the margin. The correct import parity price is thus the foreign transport cost—estimated to be \$35 per ton—plus the difference between the domestic marketing margin and the costs of handling imported maize, about \$5 per ton.

*Results of the Price Band/Buffer Stock Simulation*

Price band policies were simulated with four different band widths, $P*$ ±$6.6, $9.0, $12.1, and $16.4 per ton,[9] and stocks were allowed to vary by 0, 100, 200, 300, and 400 thousand tons for each price band. Each variant was simulated for 300, 10-year cycles and the results are presented as averages. Chart 3 summarizes the results graphically in terms of the required trade-offs among the policy objectives of import levels, costs, stocks variability, and price variability. The horizontal axis represents the average present value of the 10-year stream of net costs. The vertical axis measures average imports over the 10-year simulation.[10]

Each solid line is a trade-off curve, where price variability is held constant at the level specified at the bottom of the curve. The five marked points on each line represent, from top to bottom, stock variabilities of 0, 100, 200, 300, and 400 thousand tons as indicated by the identifying numbers on the ±$6.6 trade-off curve. Thus, each curve displays directly the trade-off between fiscal cost and imports for a specified level of price variability.

Several comments are suggested by the chart. First, there are large differences in cost and import levels between the different price variability curves, with costs decreasing as the variability of price is permitted to be larger. Moving from the ±$6.6 curve to the ±$9.0 curve and holding imports constant reduces the net present value of cost by $5 to $6 million, depending on the level of stocks permitted.

Second, it is less costly to reduce imports by increasing stocks the more price variability is restricted and the lower are stocks. The ±$6.6 price variability curve is much steeper than the ±$16.4 price variability curve, implying that increasing stock variability "buys" a relatively large decrease in imports at little additional fiscal cost. Similarly, equal stocks segments of each curve are less steep as price variability declines. For example, letting stock variability go from zero to 100 thousand tons at the ±$6.6 price variability level results in a 16 thousand ton decrease in imports at an increased cost of about $4.5 million net present value. On the other hand, increasing stock variability by the same amount when price variability is ±$16.4 costs over $8 million net present value and reduces import requirements less.

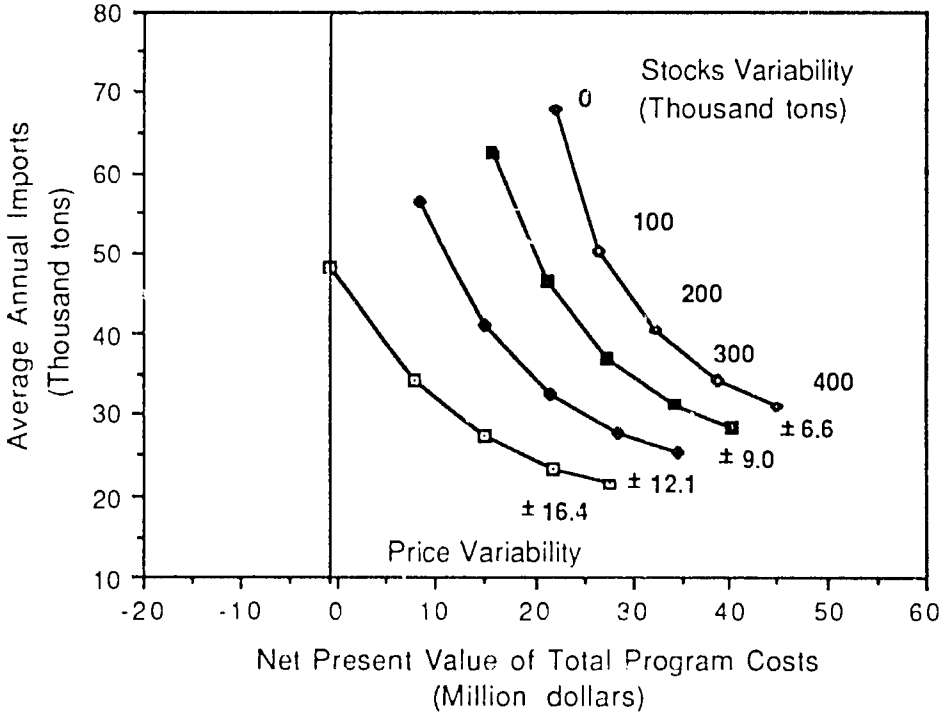
Finally, it is important to remember that the trade-offs measured here

---

[9] The model specification is in percentages, $P^* \pm$ 4.9, 6.8, 9.7, and 13.1 percent, which translate to the standard deviations used in the text discussion of the results.

[10] For example, if a particular policy led to average imports of 500 thousand tons per 10-year cycle, the average imports would be 50 tons per year. This measure ignores the frequency of actual imports during the 10-year cycle.

Chart 3.--Measured Trade-offs Among Government Policy Objectiv with Price Band Policies, Simulation Results




are a useful guide to government decision makers only if the simulated policies are the only possible policy choices. If other policy options are available, they likely overstate the costs of specific changes. For example, in the present simulation, buffer stock levels and consequently trade decisions have not been responsive to world market prices. It is quite likely that some flexibility in stock levels in response to world market conditions would reduce net stabilization costs. To address these issues requires the specification of an optimization model.

## OPTIMIZATION OF KENYAN MAIZE POLICY

An optimization model has a number of elements in common with the simulation. The basic market structure must be specified in equations like those above. However, instead of specifying the rules of a specific policy, optimization approaches specify the explicit objectives of the policies. Then, the objective function is maximized (or minimized) subject to the operation of the relations specified in the model. In the present case, the

government's objectives are to minimize costs, minimize price variability, and minimize imports. Formally, the objective function is

$$Minimize\ GC = \Sigma_t(COST_t + a[P_t - P^*]^2 + bM_t)/(1+r)^{t-1},$$

where $COST_t$ is the government's fiscal cost; $(P_t - P^*)^2$ is the square of the deviation of the present year's price from the target price; $M_t$ represents imports; and $(1+r)^{t-1}$ is the discount rate.

The components of the function were detailed in the specification of the simulation model. The parameters $a$ and $b$ are weights that measure the importance of each of the objectives relative to the other two. The weights are varied in order to find policies that efficiently produce more of one objective and less of the other two. By not putting a weight on $COST$, the monetary unit becomes the numeraire of the system.

Of the several techniques available to solve this optimization problem, stochastic dynamic programming is most appropriate.[11] However, use of this technique requires that the stochastic processes in the specification of the market relations produce only a finite number of possible outcomes. Thus, some modifications of the basic market model are required, and these are specified below.

*Discrete Characterizations of the Market Model*

In the simulation, world price was modelled as a random walk. In a ten-year cycle, a discrete random walk would have to have at least 21 possible values, an awkwardly high number for an optimization model to consider. If there are fewer possible values, either the expected price cannot always equal the present price, or there can be no possibility of an increase or decrease in price at the extremes of the range. To take a simple example, suppose that prices are constrained to three possible values: \$90, \$120, and \$150 per ton. If the price is \$120 in year one, the expected price in year two will equal \$120 if the probability of the price moving to \$90 equals the probability of its moving to \$150. But if the price is presently \$150, there is no higher price to which it can climb. Either the probability of the price dropping to \$120 or \$90 must be zero, or the expected price in the next year must be less than \$150. The latter option is used here with seven possible prices, as shown in Table 1. Generally, the differences between present and expected prices are rather small except at the extremes, where

[11] At least four techniques have been used to analyze storage problems including Bigman's (1985) optimizing algorithm, Eaton's (1980) programming method, stochastic control methods (e.g., Kendrick, 1980), and dynamic programming (e.g., Gardner, 1979).

they are about $7 per ton. Nevertheless, this stochastic representation of world prices does approximate a normal random walk and, for a current price of $120, the probabilities correspond to the simulation's specification of a 14.5 percent standard deviation.

Table 1.—Expected Values of World Price in the Dynamic Programming Model

| Price in year $t$ | Probability of price in year $t+1$ being: 60 | 80 | 100 | 120 | 140 | 160 | 180 | Expected price |
|---|---|---|---|---|---|---|---|---|
| 60 | .725 | .239 | .035 | .001 | — | — | — | 66.24 |
| 80 | .239 | .486 | .239 | .035 | .001 | — | — | 81.46 |
| 100 | .035 | .239 | .451 | .239 | .035 | .001 | — | 100.06 |
| 120 | .001 | .035 | .239 | .450 | .239 | .035 | .001 | 120.00 |
| 140 | — | .001 | .035 | .239 | .451 | .239 | .035 | 139.94 |
| 160 | — | — | .001 | .035 | .239 | .486 | .239 | 158.54 |
| 180 | — | — | — | .001 | .035 | .239 | .725 | 173.76 |

The other stochastic variable in the market model is production, modeled as a continuously distributed, normal variate with standard deviation equal to 10 percent of average production. For the optimization model, the distribution is divided into nine discrete outcomes, with probabilities assigned to each in accord with the normal distribution.

## COMPARISON OF SIMULATION AND OPTIMIZATION RESULTS

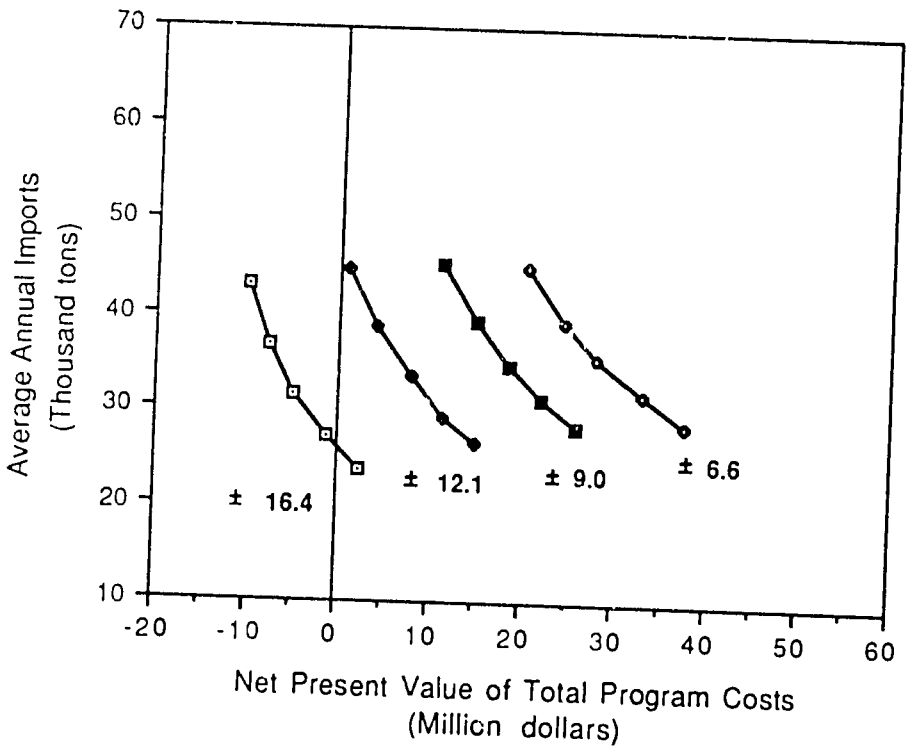
In order to make the comparison between the simulation and optimization results meaningful, it is necessary to put the results of the two exercises on a common footing. To do this, the optimal policies derived in the optimization routine are simulated in the same model that the administrative rules used. The result of a specific optimization is a set of annual tables listing each possible state of the world and the optimal values of the control variables in each state. Fortunately, models such as this one in which the system parameters do not vary from year to year usually stabilize after a few years, and these stabilized values ignore the terminal conditions. The table of stabilized values is used to determine the operational policy rules for the simulation, with linear interpolation between the discrete entries in the table. Simulations of the optimal policies puts the two approaches on common ground. There may be a loss in optimality, i.e., the so-called optimal policies may not be exactly optimal because of the differences in the underlying market models, but this difference is expected to be very

small.[12]

Chart 4 summarizes the effects of optimal policies in terms of the same import-fiscal cost trade-off used above for the price band simulations. Each point on the chart represents the result of one optimization run with a unique combination of weights. For the specific points plotted, the weights were chosen so that the resulting variability of price was constant for five points on each curve and covered approximately the same range as occurred in the price band simulations. The selection of weights required to produce these results was carried out by trial and error.

Visual comparison of Chart 4 with Chart 3 shows the extent of improvement of optimal policies over price band policies. For every combination of average imports and fiscal cost, an optimal policy produces less price variability. That is, each of the constant variability curves in Chart 4 lies to the left of the same curve in Chart 3.

Chart 4.—Measured Trade-Offs Among Government Policy Objectives with Optimal Policies, Simulation Results




[12] See Pinckney (1986) for a discussion of the likely effects of each difference.

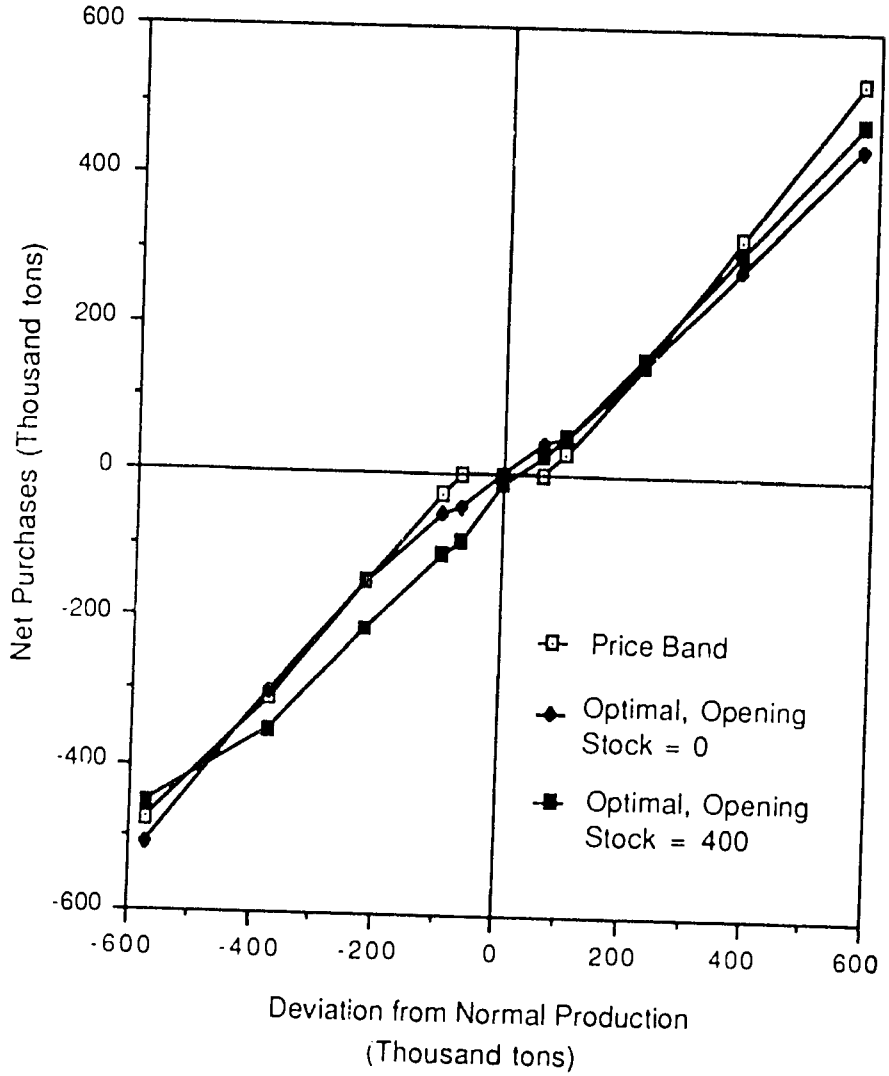
The question of how optimal policies differ from price bands is best understood in terms of relations between the policy control variables—net purchases and trade—and states of the world described by production, world prices, and initial stocks. Charts 5 and 6 compare the net purchase and stocks policy rules that keep the standard deviation of price at ±$12.1 per ton. In both figures, specifying the amount of permitted variation uniquely determines the price band rule. From Chart 1, production variation is translated through the demand relation to price variation. Constraining prices to ±$12.1 translates immediately to purchases (at production levels large enough to lower prices more than $12.1) and sales (at production levels small enough to raise prices more than $12). This kinked relation between net purchases and deviations in production is shown as the square with dot line in Chart 5. Note that this rule is invariant to both world price levels and opening stocks. Whatever the level of these variables, if production is 400 thousand tons short, the board must sell approximately 350 thousand tons.

Unlike the price band schemes, the net purchase rule in an optimal policy is sensitive to opening stocks, world price, and the penalty on imports. Two optimal rules are shown, the diamond line for zero opening stocks and the solid box line for a 400 thousand ton initial stock. In both, world price is fixed at $100. The optimal rules are smooth curves, very close to linear. Purchases or sales occur in virtually every year and, with large deviations in production, less is purchased or sold to stabilize price. The sensitivity of optimal rules to a change in one of the state variables is shown in the contrast between the diamond line (0 opening stocks) and the solid box line (400 thousand tons). As might be expected, with large stocks on hand, the optimal policy increases sales in deficit production years as long as the deficit is less than the 400 thousand ton stock on hand. The main point, however, is that optimal purchase rules do depend upon the particular conditions in each year whereas price band rules are sensitive only to the trigger values of the particular variable.

Once net purchases are determined, the stockholding agency is left with a quantity equal to opening stocks plus net purchases, which will be termed "available supply." If the available supply is negative, imports and aid are brought in to make up the deficit exactly. If the available supply is positive, it can be either stored or exported. Chart 6 displays price band and optimal policy rules to determine how much to store given the available supply. The two optimal rules shown are for world prices of $100 and $140.

All three curves are similar in shape, with the two optimal curves varying in their relative position on the chart and in the level of maximum stocks. The optimal maximum stock level varies with world price, much smaller for a world price of $140 per ton than for a world price of $100, reflecting the increased opportunity costs of stocks with higher world prices.

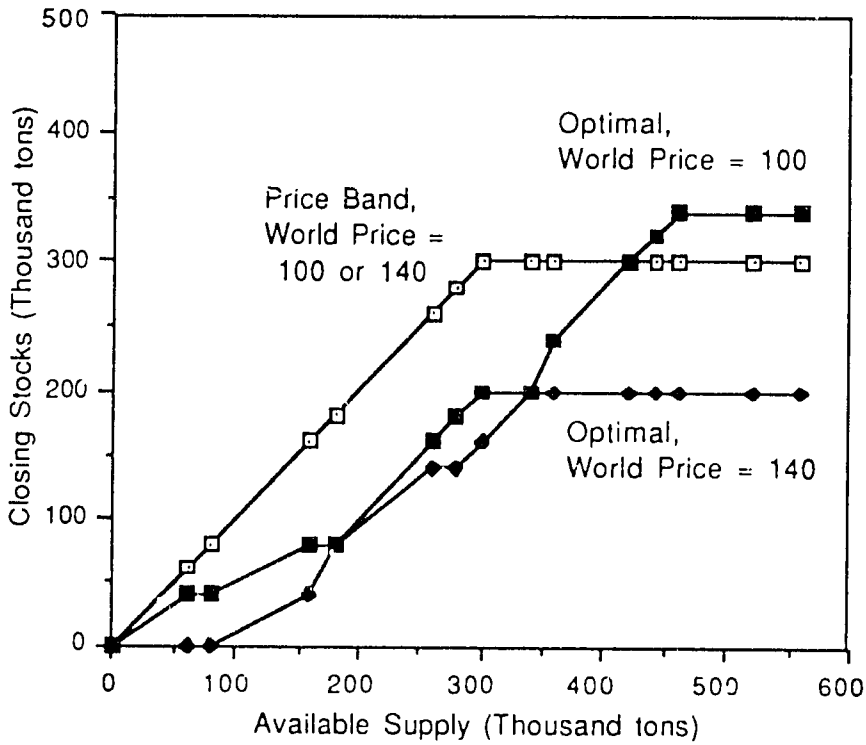
Chart 5.—Comparative Administrative Rules for Net Purchase Activity with Price Band and Optimal Policies




The advantage of holding stock in terms of lowering future imports declines as world prices rise, since, with higher world prices and a constant price differential, the ratio of export to import parity is a positive function of world price. The second difference between the optimal curves is that, at the higher price, 80 thousand tons of exports take place before any supply is placed in storage. Thus, the marginal value of the sales when export premiums are available is higher than the marginal value of the first units of storage.

Both of the optimal curves are in contrast to the price band rule, which simply places all supply into storage until the maximum stock is

Chart 6.—Comparative Administrative Rules for Closing Stock Levels with Price Band and Optimal Policies




reached, and then exports the remainder. The limitations of such administrative rules are clear: they ignore the presence of export premiums on small quantities of exports, and the fixed maximum stock level ignores the increased opportunity cost of holding stocks when world prices are high.

Finally, optimal rules are also sensitive to the choice of weights in the objective function, that is, to the relative importance of the different objectives, as illustrated in Chart 7. The curve labeled "Base" is the same optimal policy modeled in the previous paragraphs, which has a standard deviation of price of $12.1 and average imports of 44.7 thousand tons. The other two curves are the optimal purchase functions resulting from changing weights on the individual objectives in the objective function: "Low imports" represents an increased weight on minimizing imports and "Low price variability" represents an increased weight on minimizing price variability. The "Low imports" policy produces the same standard deviation of price as the base policy, but average imports of only 26.7 thousand tons. The "Low price variability" policy produces virtually the same level of im-

ports as the base policy, but has a standard deviation of price of $6.6. The displayed curves are all for a world price of $100 and opening stocks of 100 thousand tons.

All the policies are identical for production from 100 thousand tons below normal to normal. Each makes up the entire difference between actual and normal production in such years through sales in the domestic market. Under the low import policy, more is bought in high production years, and less is sold in low production years than in the base policy, clearly leading to lower average imports. The low price variability policy, on the other hand, sells more than the base in low production years and buys more in high production years. Thus, there is more intervention in almost all years leading to greater price stability, but the higher stock levels gained through higher purchases do not reduce imports on average because larger amounts of grain are required for sale in deficit production years.

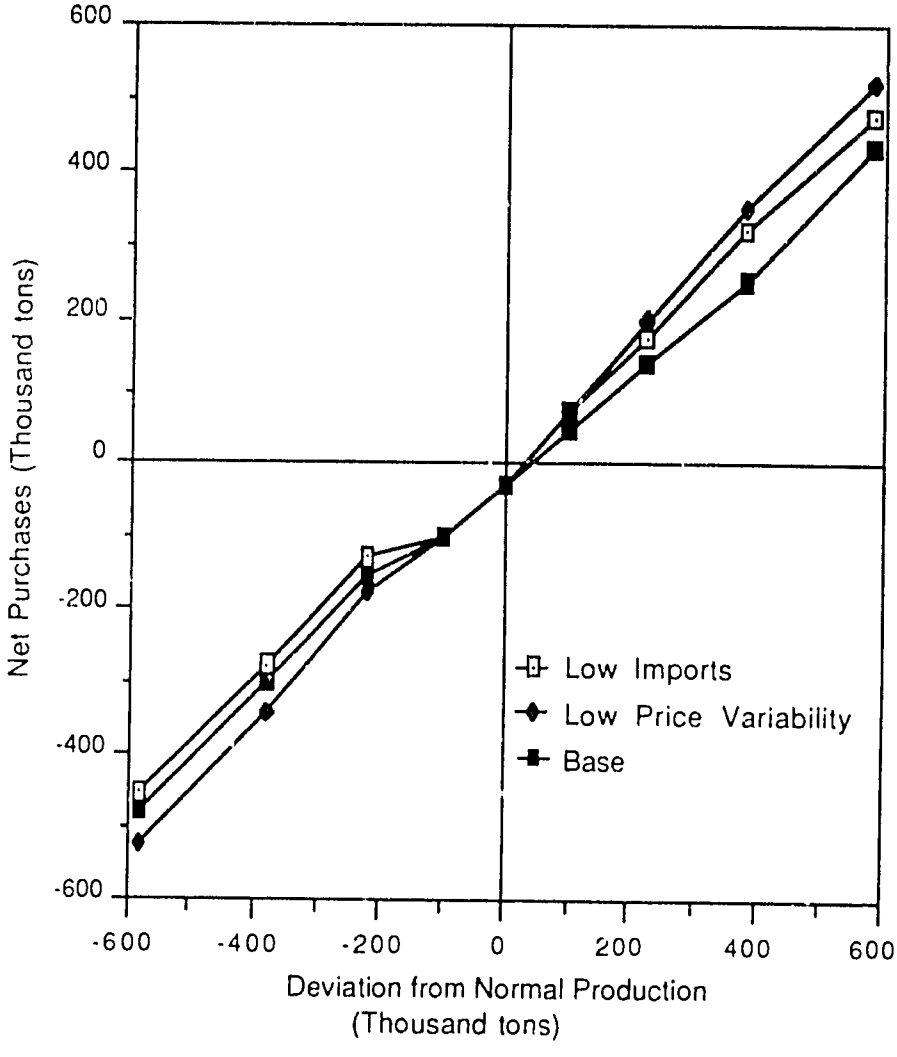
The basic results of price band and optimal policies and the differences between the structure of optimal and price band policies have now been examined. It remains to discuss in more detail the trade-offs between government objectives as implied by the different schemes.

### *Trade-Offs Between Government Objectives: Price Band Versus Optimization*

Marginal trade-offs between objectives for both optimal and price band policies are presented in Table 2. The amount of permitted price variability is the key determinant of cost for all policies. For example, for an optimal policy, each dollar decrease in price variability between $16.4 and $12.1 costs $2.85 million if imports are held constant at 41 thousand tons and $3.36 million when imports are at 31 thousand tons. The costs increase as price variability is reduced. The cost of decreasing imports, while not as large in absolute terms as the cost of decreasing price variability, is relatively larger, rising from $0.48 million per ton to $1.08 million. Clearly, heavier weights on price stability and self-sufficiency constrain how the optimizing model can adjust and increase the trade-off between cost and the other two objectives.

With a few exceptions, the price band and optimal policies yield trade-offs between imports and fiscal cost that are similar. The trade-off between cost and price variability is always understated by the price band policies, with the amount increasing with decreasing price variability. This appears to suggest that the price band schemes are more efficient at decreasing price variability than the optimal policies. This is not the case. Optimal policies are the most efficient way to maximize the three objectives in any given weighting of the objectives. Since buffer stocks are more efficient policy instruments at low levels of price variability than at high levels, as price variability decreases, the price band curve gets closer to the optimal curve,

Chart 7.—Variation in Optimal Net Purchases Rules with Changes in the Importance of Specific Goals in the Objective Function




biasing the measurement of the trade-off downward.

With these results in hand, the next section examines the trade-off between the complexity of policies and their cost. Based on the differences between the optimal and price band policies outlined above, changes are made in the price band policies to increase their efficiency. The final section presents policy recommendations as well as some suggestions for policy analysis.

Table 2.—Price Band Versus Optimal Policy Trade-Offs
(Figures in million dollars, net present value)

| | | Price variability | | | |
|---|---|---|---|---|---|
| | | $16.4 | $12.1 | $9.0 | $6.6 |
| Cost per thousand ton decrease in average imports: | | | | | |
| (41 to 31) | Price bands | 0.76 | 0.88 | 1.07 | 1.30 |
| | Optimal policies | 0.48 | 0.71 | 0.87 | 1.08 |
| Cost per dollar decrease in price variability: | | | | | |
| (Imports = 41) | Price bands | | 2.67 | 2.99 | 3.13 |
| | Optimal policies | | 2.85 | 3.51 | 3.87 |
| (Imports = 31) | Price bands | | 2.93 | 3.61 | 4.07 |
| | Optimal policies | | 3.36 | 4.05 | 4.74 |

## MOVING FROM PRICE BAND TO OPTIMAL: THE COMPLEXITY/COST TRADE-OFF

Despite the significant efficiency gains possible with optimal policy rules, most stockholding agencies in different parts of the world implement only price band plans. "In actual formulation of stockpiling strategy either at the national or international level...these [optimal stockpiling] models have barely been consulted" (Bigman and Yitzhaki, 1983). Cochrane (1980) suggests that risk considerations tend to make price band schemes more appealing intuitively to producers and consumers than the smooth intervention rules called for by optimal analysis.

Another reason why optimal policies are rarely implemented is the difficulty in explaining what they are. Policies interpolated from dynamic programming analysis are both hard to describe and hard to implement. Experienced decision makers who have seen complex cure-all projects disintegrate into chaos are likely to agree with Chambers' (1978) dictum that "simple is optimal" in policy design as well as project selection, and to be wary of a policy which even its proponents find difficult to explain. The process of public policy formulation is itself so complex that policies which are difficult to explain are unlikely to be accepted. If optimal stockpiling analysis is to have policy meaning, it is likely to be through the clues it provides for modification of price band policies, or through relatively simple policy interventions which approximate optimal policy in most circumstances.

### *Learning from the Optimal Policy*

One approach to the formulation of such policies is to introduce components of the optimal policy rules into the price band rules one at a time,

and to measure the gain in efficiency of each. For example, the first step might be to make the maximum stock level depend on the world price. Before this can be done, however, it is necessary to measure numerically the optimal policy rules that were presented graphically in Charts 5 and 6. The price band policies can then be adjusted to respond to changes in the state variables to the same extent as the optimal policies.

For this purpose, consider just the price band and optimal policies with a price variability of \$12.1 that have figured prominently in earlier examples. Chart 8 presents the trade-off curves of interest and the asterisk (*) points on each curve are the particular policies to be compared. The optimal * policy has weights of 17 and 60 for price stability and imports respectively, average imports of 44.7 thousand tons, and a fiscal cost of \$1.0 million, net present value. The price band * policy has a stock variability of 75 thousand tons, imports of 44.3 thousand tons, and a fiscal cost of \$13.1 million. The \$12.0 million average difference in cost is significant, the price band policy cost less than the optimal policy in only 17 of the 300 ten-year cycles of the simulation.

Earlier analysis suggested that the relationship between net purchases and the state variables - world price, opening stock level, and production--- is close to linear. The following regression results confirm the suggestion:

$$NP_t = -1,827 + .531 * WP_t + .785 * Q_t - .098 * S_{t-1}$$

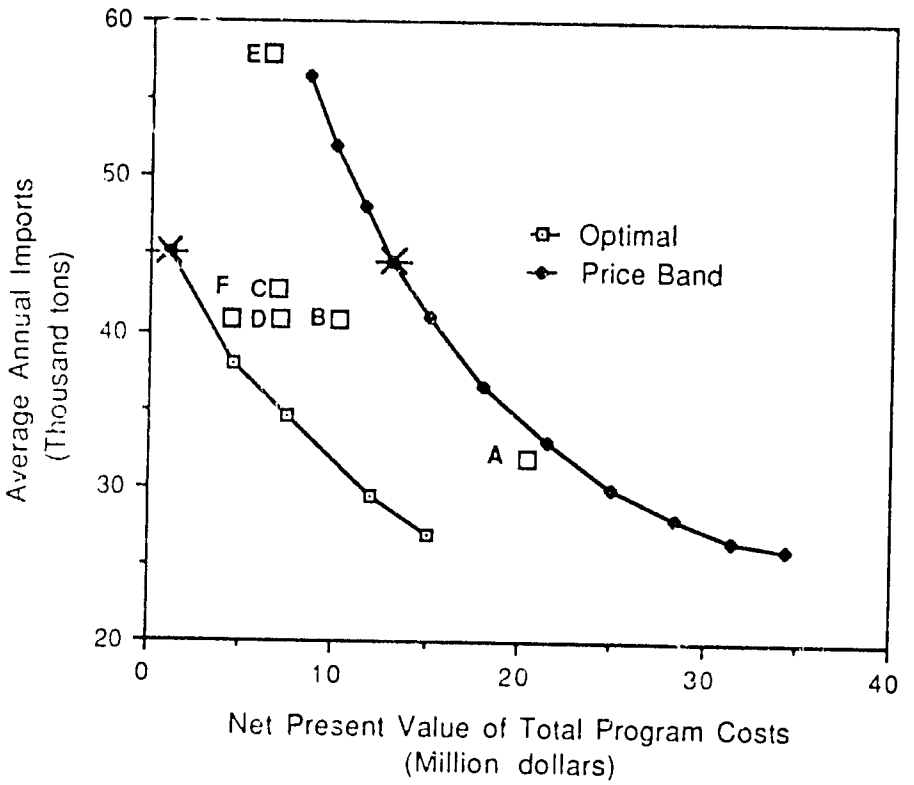
$$(.019) \qquad (.002) \qquad (.004)$$

$$N = 1350, \quad R^2 = .99, \quad S.E.E. = 16,$$

where $NP_t$ is optimal net purchases, $WP_t$ is the world price, $Q_t$ is production, and $S_{t-1}$ is the opening stock level. Standard errors are in parentheses. The regression includes all states in the model except for extreme world prices of \$60 and \$180, for which the optimal results are not deemed accurate since world prices cannot go below or above these figures. Further, since not all states of the world are equally likely, the observations are weighted by a combination of the probability of the production occurring, which is known in the model, and by a linear weighting scheme which decreases with increasing stocks.

Another important relationship depicted in earlier charts is that between available supply and closing stocks. That relationship, however, appears to be composed of three linear segments and thus is not amenable to linear regression. The regression that can be run is maximum stock level on world price. Unfortunately, there are few degrees of freedom since the

Chart 8.—Moving Toward the Optimal: Modifying Price Band Rules to Approximate Optimal Policy Effectiveness




optimizing model considers only seven values for world price, and the two extremes are somewhat suspect. With only five observations, the result is

$$MXST_t = 652 - 3.3 * WP_t,$$

where $MXST_t$ is the maximum stock level. The regression implies that when world prices are higher than $198, nothing will be stored. With these results in hand, the step-by-step analysis of the price band policies can begin.

The first adjustments are the easiest, making the maximum stock level sensitive to the world price and exporting small quantities frequently (Policy A). Surprisingly, the results of a price band scheme with a maximum stock level sensitive to world prices are only slightly better than when the maximum stock level is constant. Table 3 lists the components of cost for

the new result for a price band scheme with 250 thousand tons stock variability, which has the same level of average imports. Chart 8 displays the result as the point labelled "A."

Table 3.—Effects of Sequential Adjustments of Price Band Policies Toward Optimal Policies

| Import volume (1,000 tons) | Policy | Cost[a] (million $) | Average closing stock (1,000 tons) | Export receipts (million $[a]) | Import costs (million $[a]) |
|---|---|---|---|---|---|
| 30.0 | Price band | 25.2 | 126 | 21.2 | 31.4 |
| | A | 24.6 | 149 | 23.7 | 32.3 |
| 41.7 | Price band | 14.6 | 49 | 34.6 | 42.8 |
| | B | 10.3 | 60 | 41.0 | 43.1 |
| | Optimal | 2.6 | 60 | 44.3 | 41.7 |
| 42.8 | Price band | 14.0 | 44 | 35.7 | 43.8 |
| | C | 7.7 | 56 | 43.0 | 42.6 |
| | Optimal | 2.0 | 57 | 44.7 | 42.9 |
| 41.3 | Price band | 14.9 | 50 | 34.2 | 42.4 |
| | D | 7.8 | 57 | 43.7 | 40.8 |
| | Optimal | 2.8 | 61 | 44.1 | 41.3 |
| 41.5 | Price band | 14.8 | 49 | 34.4 | 42.6 |
| | F | 3.6 | 54 | 42.7 | 41.1 |
| | Optimal | 2.7 | 61 | 44.2 | 41.5 |

[a]Net present value.

As expected, export revenues increase substantially by selling when world prices are high. Average export prices increase over 20 percent, but the increase in stockholding reduces export volumes. Higher stock levels lead to higher storage charges, tempered somewhat by reduced costs of stock replacement. Import volumes are held constant by design, but the average price of imports rises since average opening stocks are lower when world prices are high. The net result of these different factors is a gain of $0.6 million net present value, only 4 percent of the difference between the optimal policy cost and the original price band/buffer stock cost.

The next step on the exporting side is to take advantage of the export premium that prevails when exports are small. The optimal policies examined in the previous section suggest that a convenient rule of thumb might be to export one-half of the first 200 thousand tons of available supply, putting the remainder in storage until the maximum stock level is reached. This adjustment has a large payoff, as is evident in Table 3 and Chart 8 (the relevant point is labeled "B" in the chart).

Policy B moves much closer to the optimal results, although a significant difference remains. Comparison with Policy A is obscured somewhat by the large difference in import volumes, but one major change is that additional exports in years of relatively low available supply keep export volumes from falling relative to the price band policy, as they did under Policy A. Despite the gains made on the foreign trade side, however, a large difference remains between net trade losses under Policy B and the profits from trade under the optimal policies.

Making the domestic market price sensitive to the world price is one way to close the gap. Policy C attempts that task. The domestic market continues to have a constant difference between floor and ceiling prices, but both maximum and minimum trigger prices move somewhat with world prices.[13] The resulting change in the price triggers is not particularly large; in Policy C, when world prices are at $120, the lower price trigger is $128, while the corresponding trigger for a world price of $100 is $126.[14] Even these small changes, however, have significant results, as Table 3 and Chart 8 indicate, with Policy C more than 50 percent of the way from the price band scheme to the optimal policy.

The major difference between B and C is in the cost of imports and returns from exports. Since less is sold domestically when world prices are high and domestic production is low, fewer imports are needed in these years, while relatively more is imported when world prices are low. A similar story can be told for domestic purchases and exports: average import prices are about 5 percent lower and average export prices about 4 percent higher under Policy C than under Policy B. Despite these gains, the optimal policy is still $5.7 million cheaper on average. This difference results from a combination of higher domestic profits, lower total storage charges, and a continued lead in foreign trade despite the substantial gains made.

The last remaining step to make the price band scheme more like the optimal policy while still maintaining maximum and minimum prices is to allow the triggers to vary with opening stocks. Policy D accomplishes this by multiplying the coefficient from the estimated regression by the

[13] This is done in the model by taking the world price coefficient from the net purchases regression estimated above, multiplying it by the deviation of world price from $120 (the base world price), and adding the result to the production volume triggers.

[14] Both Policy C and D must have a smaller maximum percentage deviation of price in order to achieve the same standard deviation of price. The standard price band scheme requires a percent limit of 9.37 percent to achieve a standard deviation of price of $12.1; the percent limit for C is 8.86 percent, while the limit of D is 8.74 percent. The percent variability allowed must be adjusted because of the price flexibility that is added by the sensitivity of the triggers to opening stocks and world price.

deviation of the stock level from 100 thousand tons, and adding the result to the volume triggers computed by Policy C. As with the world price adjustment, changes in price are not large. An increase in the stock level from 100 to 200 thousand tons raises the lower trigger from \$128 to \$130. Nevertheless, the results are significant as shown in Table 3 and Chart 8. Policy D is almost 60 percent of the way from the original price band policy to the optimal policy. Considerably lower profits are made domestically, but import volumes drop because of the increase in net domestic purchases when stocks are less than 100 thousand tons. Since most years fall in this range, average domestic prices rise slightly.

The next step in trying to approximate the optimal policy is to forego the idea of minimum and maximum prices altogether. Thus, Policy E adds the smooth relation between net purchases and production estimated in the regression. The result is disappointing. Policy E has a cost of \$6.9 million, average imports of 57.7 thousand tons, and, as shown in Chart 8, is only marginally superior to the price band policy.[15] Despite the very high $R^2$ of the purchases equation, the linearity assumption is evidently not capturing the true relation. Thus, the net purchases relation was re-estimated in three segments, for production at or above normal, for production less than normal but with the shortfall greater than opening stocks, and for production plus opening stocks less than normal.

Regression (1): $Q_t \geq 2,250$

$$NP_t = -1,937 + .612 * WP_t + .822 * Q_t - .053 * S_{t-1}$$

$$(.015) \qquad (.003) \qquad (.003)$$

$$N = 750 \qquad R^2 = .994 \qquad S.E.E. = 9.44$$

Regression (2): $Q_t < 2,250$ and $Q_t + S_{t-1} \geq 2,250$

$$NP_t = -1,916 + .510 * WP_t + .820 * Q_t - .074 * S_{t-1}$$

$$(.019) \qquad (.007) \qquad (.005)$$

[15] The standard deviation of price that results from simulating the net purchases equation estimated above is \$13.0. In order to lower the price variability to \$12.1, an equation was estimated for an optimal policy with a lower price variability, and the coefficients interpolated to yield the net purchases equation used for Policy E. The interpolated equation is $NP_t = -1,885 + .49 * WP_t + .80 * Q_t - .091 * S_{t-1}$.

$$N = 280 \qquad R^2 = .990 \qquad S.E.E. = 7.25$$

Regression (3): $Q_t + S_{t-1} < 2,250$

$$NP_t = -1,926 + .320 * WP_t + .855 * Q_t - .088 * S_{t-1}$$
$$(.034) \qquad (.008) \qquad (.012)$$

$$N = 320 \qquad R^2 = .989 \qquad S.E.E. = 12.92$$

All coefficients are significantly different in the three equations except for the coefficients of production in the first and second equations.

The results of simulating a policy (F) with net purchases defined by this piecewise linear function are also shown in Table 3 and Chart 8. Only small differences remain compared to the optimal policy. The largest is in export revenues, and it is most likely the result of always exporting 100 thousand of the first 200 thousand tons of available supply. The optimal policy makes timing of even the first 100 thousand tons of exports dependent upon the world price. At any rate, the modeled policy is quite efficient. The standard deviation of cost is approximately $21 million, which would make Policy F indistinguishable from the optimal policy in practice.

In sum, it is possible to make up about 60 percent of the difference between the price band and optimal policies while retaining the maximum and minimum triggers of a price band scheme. Most of the remaining difference can be made up by making net purchases a piecewise linear function of production, world price, and opening stocks. The implication of this analysis for policy and policy analysts are examined in the final section.

## CONCLUSIONS

In the preceding analysis, the trade-offs between different government objectives have been measured, and the optimal policies have been compared and contrasted with the price band policies. The results suggest that relatively simple policies can be designed which are virtually as efficient as the optimal policies. This section examines the implications of these results for policy and for policy analysis.

### *Implications for Policy*

The key concept for Kenyan decision makers that comes out of this study is the reduction in costs associated with greater administrative flexibility. For the lowest levels of price variability measured here, each dollar

increase in the permitted standard deviation of price saves $3.9 million to $4.7 million in net present value. This implies that a policy which has a standard deviation of price of $7, 5 percent of the target price, would cost at least $3.5 and probably closer to $6 million less in annual average cost than a policy which held prices constant, a sum that is between one-tenth and one-fifth of the Ministry of Agriculture's annual development budget.[16]

Under present policies, unsustainable budget costs have produced de facto price flexibility. The resources for holding prices constant in the face of production instability simply do not exist. An important policy step would be to acknowledge the price variability that already exists in the parallel market and to build some official price variability into the system. In addition, an explicit decision could be made by senior officials about the trade-off between cost and price stability rather than forcing parastatal officials to make policy because their resources do not match their mandate.

Both Policy D and Policy F described in the previous section appear to be large improvements over the present policy and the type of price band schemes previously proposed. While Policy F is considerably cheaper than Policy D, Policy D is closer to present policy and would require fewer changes in the way that the pricing system works. Questions about the implementation of these two policies are addressed in the following section.

*Considerations for Implementation*

The export rules for policies D and F are identical: one-half of the first 200 thousand tons of available supply is exported, and the maximum stock level varies inversely with world prices. Such rules are easy to administer, and the results clearly dominate stock level trigger rules. Further, since the policy can be administered so that the same amount of maize is imported as under any particular price band policy, this aspect of the policy modification can be made invisible on average to consumers and producers.

The changes required on the price side are more complex. At present, official producer prices are announced before planting time, and official consumer prices are announced for the next twelve months about one month before the first maize is harvested. Policy D could be implemented with relatively minor modifications of the present policy because the degree to which domestic prices respond to world prices and opening stock level is not large. An indicative floor price could be announced at planting time, based

[16] The ratio between the net present value of a ten-year cost stream discounted at 7 percent and the average annual outlay that would produce that net present value is approximately 7.5:1. Since the cost per unit decrease in price variability would continue to increase as price variability decreased, the numbers given in the text for average annual cost are slightly higher than the numbers given for net present value.

on predictions of end-year stocks and the world price. At the same time, the public could be informed that the floor price might be adjusted, but by no more than a fixed amount, the precise amount dependent upon differences between predicted and actual values of stocks and world prices. A similar procedure could be followed for the ceiling price. Given the present results, the maximum adjustments would need to be no more than about 5 percent of the announced price. Just prior to harvest, the government could announce the exact price at which it would buy throughout the season. After harvest, farmers would have the option of selling to the Board at the floor price or selling to a trader. Millers would have the option of buying from the Board at the ceiling price or buying directly from farmers or traders.

For the farmer the most significant change resulting from Policy D would be the possibility of adjustments in official prices after the crop had been planted. Nevertheless, a price risk of 5 percent is much less than what many farmers face currently when they may wait months to receive payment or may not be able to sell to the Board at all. For consumers, there would be lower prices at harvest time and higher prices before harvest in most years.[17]

A policy like F would not fit as easily into the present structures. Policy F can be thought of as a modification of Policy D in which the width of the price band is smaller, but the target price within the band moves with production. Consequently, estimates of production would also be needed and these, in conjunction with forecasts of world prices and stock levels, would determine the announced domestic prices.[18]

There are two ways to administer this policy, depending on whether the government wants to target price or net purchases. If prices are to be targeted, the policy could work as D, except that the possible adjustments to the price announced at planting time would have to be larger, and the last estimate of production made prior to harvest would be used to calculate the price. A scheme like this might be attractive for countries in which there is only one harvest of the staple foodgrain. It would be more difficult to implement in a country like Kenya with a diverse cropping calendar.

Targeting net purchases might be designed through a series of tender offers. Suppose it is August, harvest is beginning, and total annual pro-

[17] The price rise would result, not from changes in official prices, but from storage costs incurred by the private sector. Such price rises would only occur in years during which the price is between the NCPB floor and ceiling during some months. There would be no seasonal price rise during a poor crop year in which the NCPB's ceiling price was effective at harvest time and remained effective throughout the year.

[18] See Jones (1987) for a discussion of the feasibility of better maize production estimates for Kenya.

duction is predicted to be about 200 thousand tons above trend. Given the present stock level and world price, the strategy calls for a price of $125 per ton and net purchases of 100 thousand tons for the year. The Board could advertise an offer to buy, say, a total of 10 thousand tons in September (in appropriately sized lots) and ask for bids. The bidding process would also give the Board additional feedback on prices and production. Depending on this feedback, additional tender offers would be made in the months ahead. Such a procedure seems workable, but the mechanism would be considerably more complicated and management more intensive than setting floor and ceiling prices. The cost savings in moving from Policy D to F are about $4 million net present value, or almost $600,000 in average annual cost. Whether or not the benefits of these cost savings outweigh the increased complexity of implementation and administration is a political judgment.

*Implications for Policy Analysis*

The optimization process has been useful in screening many policy alternatives, accurately measuring trade-offs between objectives, showing the degree of sub-optimality of the alternative policies, and suggesting improvements in the administrative rules. The major methodological question addressed is whether the benefits of optimization outweigh the considerable costs of the optimization process. The answer is undoubtedly yes. The major objective of the study was to measure trade-offs. As shown, the simulated price band policies do not measure accurately the trade-off between cost and price stability. For that reason alone, the optimization process is necessary and worthwhile. The gains from optimization were not limited to the measurement of trade-offs, however. The optimization results provided a net purchases function and its best representation as a piecewise linear curve. The degree of sub-optimality of the price band policies was seen to be large, and therefore these policies were modified based on insights provided by the optimal policy.

The optimal policies themselves challenge some of the common assumptions about maize policy in Kenya. For example, most economists, including the authors of this study, thought that the carry-out stock levels of 650 thousand tons in 1982 and 1983 were too high and the government should have exported in those years. But, if the minimum stock required as a cushion for the arrangement of imports is about 300 thousand tons, then the real carry-out (total stock minus the import cushion) was only 350 thousand tons. There are weights on the objective function that would yield optimal carry-outs close to this amount given 1981/82 world price and production levels, particularly if production variability is 12 percent instead of the 10 percent assumed throughout.

At the same time, this analysis was not subject to the day-to-day

pressures of a government economist whose report is due "yesterday" if it is to affect the decision-making process. Optimization approaches may be impossible in such circumstances. Nevertheless, if the structure of the market is fairly similar to that described here, it would be possible to accept a policy similar to F as a proxy for an optimal policy and simulate that policy with a large number of parameter variations in order to approximate a non-inferior set. Trade-offs could be measured by this curve, and other policies compared to it for sub-optimality.

Of course, there are circumstances when the basic structure of the policy has already been decided and thus optimization is not necessary. For example, if a country has decided ahead of time that a price band policy will be implemented that is not sensitive to world prices or opening stocks, the trade-offs measured by a simulation will be the relevant numbers for the government. If the pre-selected policy is reasonably simple, it will not be difficult to find the best policy of that type without optimization. More complex policies which include many parameters will be less amenable to finding the best choice through simulation, but such policies will be more difficult to optimize also.

Optimization is useful in spite of the fact that the specific policies are not themselves implemented. This point has been made elsewhere: "Formal and simplified optimization can provide a number of useful starting points for a process of policy design and dialogue. In no sense does it guarantee an optimal or even adequate policy" (Clark, Jones, and Holling, 1979, p. 32). Utility functions of decision makers are always more complex than those that become the objective functions of optimization models. In addition, the process of reforming public policy always involves a set of compromises between officials with different utility functions. No optimization model can possibly deal completely with such complex situations. Nevertheless, optimization is an aid to policy design—as a screening method across policy alternatives, as a reference point for other policies, and as a measuring device for the ever necessary trade-offs.

## CITATIONS

David Bigman, 1985. *Food Policies and Food Security Under Instability and Analysis.* Lexington Books, Lexington, Massachusetts.

David Bigman and Shlomo Yitzhaki, 1983. "Optimizing Storage Operations: An Integration of Stochastic Simulations and Numerical Optimization," Working Paper No. 8305, Center for Agricultural Economic Research, The Hebrew University, where?

Bookers International, 1983. *Grain Marketing Study*, World Bank and the Ministry of Agriculture and Livestock Development, Nairobi.

Robert Chambers, 1978. "Project Selection for Poverty-Focused Rural Development: Simple is Optimal," *World Development*, Vol. 6, pp. 209-20.

W. C. Clark, D. D. Jones, and C. S. Holling, 1979 "Lessons for Ecological Policy Design: A Case Study of Ecosystem Management," *Ecological Modeling*, Vol. 1, pp. 1-53.

Willard W. Cochrane, 1980. "Some Non-Conformist Thoughts on Welfare Economics and Commodity Stabilization Policy," *American Journal of Agricultural Economics*, Vol. 62, pp. 508-11

David J. Eaton, 1986. *A Systems Analysis of Grain Reserves*, Technical Bulletin No. 1611, Economics, Statistics, and Cooperative Service, U.S. Department of Agriculture, January.

Bruce Gardner, 1979. *Optimal Stockpiling of Grain*, Lexington Books, Lexington, Massachusetts.

Richard H. Goldman, 1983. "Production Instability, Marketed Surplus, and NCPB Behavior," Development Planning Division, Ministry of Agriculture, Nairobi.

Robert L. Gustafson, 1958. *Carryover Levels for Grains: A Method for Determining Amounts That Are Optimal Under Specified Conditions*, Technical Bulletin No. 1178, U.S. Department of Agriculture, October.

Olof Hesselmark and Gunter Lorenz, 1976. "Structure and Problems of the Maize Marketing System in Kenya," *Zeitschrift Fuer Auslandische Landwirtschaft*, Vol. 15, pp. 161-79.

William O. Jones, forthcoming. "Food Crop Marketing Boards in Tropical Africa," *Journal of Modern African Studies*, Cambridge, England.

David A. Kendrick, 1981. *Stochastic Control for Economic Models*, McGraw-Hill, New York.

Ted Kleist, 1985. *Regional and Seasonal Food Problems in Kenya*, African Studies Centre, Report No. 10, Leiden, Netherlands.

Anne E. Peck, 1977/78. "Implications of Private Storage of Grains for Buffer Stock Schemes to Stabilize Prices," *Food Research Institute Studies*, Vol. 16, pp. 125-40.

Thomas C. Pinckney, 1986. "Production Instability and Food Security in Kenya: Measuring Trade-Offs Between Government Objectives," unpublished Ph.D. Dissertation, Stanford University.

Republic of Kenya, 1966. *Report of the Maize Commission of Inquiry*, Government Printer, Nairobi.

_____, 1983. "Report of the Inter-Ministerial Working Group on Maize Market Policy," May, mimeo.

Michael Schluter, 1984. *Constraints on Kenya's Food and Beverage Exports*, Research Report No. 44, International Food Policy Research Institute, Washington, D.C., April.

*The Standard*, 1980. "Where the Maize Really Went," Nairobi, July 2.

C. Peter Timmer, Walter P. Falcon, and Scott R. Pearson, 1983. *Food Policy Analysis*, Johns Hopkins University Press, Baltimore.

Jeffrey C. Williams and Brian D. Wright, 1982. "The Economic Role of Commodity Storage," *Economic Journal*, Vol. 92, pp. 596-614.