QUANTITATIVE EVALUATION OF STABILIZATION POLICIES IN INTERNATIONAL COMMODITY MARKETS

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In recent years there has been heightened interest in the stabilization of international commodity markets. The "commodity boom" of 1972-75, and the rapid rise in grain prices in 1973-74 generated political pressures in both developed and less-developed countries for commodity control. The 1974 World Food Conference in Rome had as one its main subjects, the establishment and management of international reserve stocks to stabilize grain markets and provide food security. The 1976 meetings of the United Nations Conference on Trade and Development (UNCTAD), in Nairobi were dominated by a proposal to introduce an integrated program for commodities (IPC). This program has as its centerpoint the creation of an extensive series of international commodity agreements to act as market stabilizers.

Such developments have stimulated the interest of economists, who have sought to examine the issues raised from both theoretical and empirical perspectives. The purpose of this paper is to briefly discuss the major approaches that have been adopted in the empirical analysis of stabilization policy, to identify their major advantages and disadvantages, and to indicate some important analytical questions that arise in the modeling of instability. The primary focus is on agricultural commodities, but methods and problems discussed are not confined to these alone.

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Empirical Application of Stabilization Theory

Economists have been interested in the impact and desirability of commodity market stabilization for some time. Although the implications of stabilizing income, and consumption or production have received limited attention the major focus has been on price stabilization (Turnovsky). Much of the analysis has been carried out in a comparative static, partial equilibrium framework utilizing the concept of economic surplus.

In an important contribution to the literature, Massell employs linear supply and demand curves with additive stochastic disturbances, to assess the impact of price stabilization at the mean through a costless buffer stock. He demonstrates that whether producers or consumers gain depends on the source of random fluctuation. However, stabilization will always produce a potential pareto improvement in aggregate (consumer plus producer) welfare. Subsequent extensions to the Massell approach have sought to examine the effect of alternative assumptions on these results. Major modifications have included the introduction of response lags and multiplicative disturbances. Although Massell's overall conclusion continues to hold, the distribution of gains between participants is sensitive to such assumptions (Turnovsky).

Massell's formulae for gains and losses have been used empirically by McNicol to estimate expected annual gains from buffer stock price stabilization for the ten "core" commodities in the IPC.1/ Econometric estimates of supply/demand elasticities, and a simple probability distribution, are applied to 1971 average price and production to compute expected gains/losses under various assumptions about the origins of

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1/ Cocoa, coffee, copper, cotton, jute, rubber, sisal, sugar, tea, and tin. Seven other commodities are included in the program viz. bananas, bauxite, beef and veal, iron ore, rice, wheat, and wool.

instability. Konandreas and Schmitz, building upon an extension of the Massell model, use somewhat more sophisticated econometric modeling to analyze the effects of grain price stabilization on the welfare of U.S. producers and consumers.

Part of the theoretical literature has concentrated on the impact of price stabilization on the income or export earnings of producers (Grubel). In an empirical context Brown (1970) employs a two-period comparative static analysis to examine the effects of buffer funds, buffer stocks, and export quotas on the export earnings of cocoa producers. Using a somewhat different approach Brook, Grilli, and Waelbroeck attempt to assess the probable impact of price stabilization on producer earnings from seventeen primary commodities. Drawing upon Grubel's analysis they argue that a positive relationship between deviations from historical trend indicate that demand shifts are the major cause of instability, and that price stabilization would therefore reduce earnings. The opposite relationship is taken to signify that supply shifts dominate, and hence stabilization would increase earnings.

One of the major advantages of theoretical analysis is that within a given set of assumptions, a definitive answer to the question of the impact of stabilization can be derived. However, there is necessarily a high price incurred in terms of the level of abstraction that must be made from the complexity of the "real world". Comparative static, equilibrium analysis has a role to play in suggesting factors or issues that may prove important (Just), but from the perspective of providing a framework for direct empirical application it clearly has severe limitations. Indeed, important questions tend to be overlooked by this mode of analysis. An overwhelming concentration on the single objective of price stabilization, and the general assumption that the policymaker (buffer-stock manager for example) behaves "optimally" to stabilize price at the mean, prove limiting. Furthermore, the temporal effects of actual or proposed policies, possibly involving multiple objectives and subject to operational costs and constraints, are frequently of greater interest than a result which may hold asymptotically.

For these reasons, many analysts have concentrated on the development and use of more realistic market analogues, through which the temporal effects of various stabilization policies on prices, incomes, or economic surplus can be determined. In some cases analysis has taken the form of _ex post_ evaluation, that is with reference to a particular historical period (frequently the period used to estimate an econometric model), in others it has been _ex ante_, where the model has been used in a forecasting mode. The most popular method adopted has been simulation.

Simulation Analysis of Stabilization Policy

A basic component of simulation analysis of is a rule, or rules, for market intervention. The most widely used are storage rules to determine the operation of a commodity reserve or buffer stock. They can be divided into two major categories: (1) quantity rules; and (2) price rules.

The former specifies the quantity stored as a function of production, supply, or a target quantity, for example

$$x_t = q_t - q_t^* \qquad (1)$$

where x is the change in the level of stocks held, q is actual production, and q* is target or desired production. If production exceeds q*, or some specified upper bound, then the difference is stored. If production falls below q*, or some specified lower bound, then the difference is released from storage (e.g. Reutlinger). The rule may be modified by storage capacity/stock availability, or other constraints. The use of quantity rules has been primarily confined to the analysis of grain reserves.

Price rules generally specify storage activity as a function of target or desired price, for example

$$x_t = k(p_t - p_t^*) \tag{2}$$

where p is the "free market" price, p* is a desired price, and k represents a function which relates storage activity to the price difference. If free market price exceeds p*, or some specified upper bound, the product is sold by the storage agency. If free market price falls below p*, or some specified lower bound, stocks are accumulated (e.g. Behrman; Cochrane and Danin; UNCTAD).

Both deterministic and stochastic simulation techniques have been used to assess the impact of storage rules. In some cases simple non-dynamic models have been the medium of analysis (e.g. Murray and Atkinson; Reutlinger). These have the advantage of relative analytical simplicity. They permit the evaluation of alternative decision rules and the effects of constraints, and can be used to examine the impact of alternative response parameters and types of disturbance. In stochastic applications, the probability of success in achieving alternative objectives under various scenarios can be inferred. However, since simple, frequently synthetic, models are employed this type of analysis tends to suffer from the same problems of realism that affect empirical applications of stabilization theory.

The most interesting use of simulation is in the context of dynamic market models which are typically derived econometrically. Although the characteristics of individual models can vary quite widely, they generally explain demand (consumption), supply (production or exports), and price formation or inventory behavior (Labys). Such models can be characterized as a system of first- or higher-order difference equations.

In a recent example of a deterministic application Behrman assesses the possible costs and impact of buffer-stock stabilization for thirteen commodities in the IPC. Stabilization around actual secular price trend, and an increasing secular trend, is evaluated over the period 1963-72. In a comparable UNCTAD study stochastic simulation is employed to assess the costs of buffer stock operations for ten "core" commodities in the IPC. Randomness is introduced through additive error terms in estimated supply equations. Randomly-generated disturbances are derived from a normal probability distribution with zero mean, and standard deviation estimated from sample period residual errors. Three hundred replications, over a five year forecast period (1979-83), are used to assess the probability of successful stabilization around alternative target prices with various levels of financial resources.

Simulation is a flexible approach which, particularly in the context of dynamic models, can provide useful insight into the effect of stabilization policy. It proves most useful for the analysis of single objectives such as the stabilization of price around trend. One of its major limitations, however, is the difficulty of identifying "optimal" policy, that is the decision rule which achieves a given set of objectives most efficiently. Behavioral rules are usually imposed in an ad hoc way and it is difficult or extremely tedious to determine the most appropriate. Analytical approaches based upon mathematical optimization remedy this difficulty.

Optimization Analysis of Stabilization Policy

An alternative, although less widely employed, approach is mathematical optimization. In this approach policy aims are specified formally in an objective function, market behavior and other constraints define the feasible region, and "optimal" policy actions are determined by constrained optimization. A simple example is illustrative

$$D = \alpha - \beta p \qquad \text{Demand} \qquad (3)$$

$$S = \gamma + \delta p + e + x \qquad \text{Supply} \qquad (4)$$

$$S = D \qquad \text{Market Clearing} \qquad (5)$$

where e is an additive disturbance term of known value, and x is the net change in stocks held by a storage agency. Assume for simplicity that storage is costless and that the policy objective is to maximize an index of social benefit defined by consumers' surplus

$$\text{Max } W = \int_{\alpha/\beta}^{p} (\alpha - \beta p)dp \qquad (6)$$

Evaluation of the integral, subsitution for equilibrium price from (3)-(5), and differentiation with respect to x yields

$$x = \frac{\alpha}{\beta(\beta+\delta)} + (\gamma + e - \alpha) \qquad (7)$$

This is the quantity rule for storage activity which maximizes the policy objective function. It implies that ceteris paribus such activity is a decreasing function of the slope of the demand (or supply) curve.

Alternatively, the policy objective might be to minimize the difference between market price and a desired price (p*). This could be expressed by an objective function of the form

$$\text{Min } V = (p-p^*)^2 \tag{8}$$

Substitution for equilibrium price, and differentiation with respect to x yields

$$x = -(\beta+\delta) \quad (p-p^*) \tag{9}$$

This is the price rule for storage activity to minimize the objective function. It implies that if p is greater than p* sales from existing stocks are required, whereas if p is less than p* purchases are required. It is interesting to note that in this case stocking activity is *ceteris paribus* an *increasing* function of the slope of the demand (or supply) curve.

These simple examples illustrate some important issues in the empirical analysis of stabilization policy. The nature of policy objectives is of fundamental importance in determining appropriate market-intervention behavior. If such objectives can be specified in a mathematically tractable way then optimization provides an attractive framework for deriving and assessing the impact of decision rules. From a slightly different perspective, *ad hoc* decision rules of the type frequently employed in simulation analyses may imply strong undefined assumptions about stabilization objectives. Even if "ad hocery" more closely reflects the character of most centralized intervention in commodity markets, it seems useful to have some means of determining how near the results are to "optimal" behavior.

Although optimization, like simulation, has been employed in the context of static models (e.g. Johnson and Sumner), its greatest potential lies in the application of optimal control theory to the stabilization of dynamic commodity markets. For example, let us assume that the appropriate econometric model is linear and that the following reduced-form can be derived

$$y_t = A_1 y_{t-1} + \dots A_n y_{t-n} + B_0 x_t + \dots + B_m x_{t-m} + b_t + e_t \qquad (10)$$

where y_t is a vector of endogenous variables, x_t is a vector of control (policy) variables, b_t is a vector of exogenous variables not subject to control, e_t is a vector of random disturbances, and the elements of the matrices $A_1, \dots A_n, B_0, \dots B_m$ are known constants. Through the use of appropriate identities the system can be simplified to

$$y_t = Ay_{t-1} + Bx_t + b_t + e_t \qquad (11)$$

where the vector y_t now includes current and lagged dependent variables, as well as current and lagged control variables.

If we define an objective or "welfare" function of the general form

$$W = f(y_t, x_t, e_t) \qquad (12)$$

then the problem is one of maximizing or minimizing the function (12) over T time periods, subject to the constraints imposed by the market system (11). This is achieved by the selection of an optimal set of control variables which are determined from the equations

$$x_t = G_t y_{t-1} + g_t \qquad (13)$$

where G is the feedback gain matrix and g is a vector of tracking elements.2/ In the context of stock management, where x would represent purchases or sales by a storage agency in each period, equation (13)

2/ Their exact form and derivation through the methods of Lagrange multipliers and dynamic programming are contained in Chow.

defines the storage rule to maximize or minimize the criterion function over the planning horizon.

The extension of the price variability minimization problem (8) to a control framework would imply a loss function of the form

$$\text{Min } E(W) = \sum_{t=1}^{T} (p_t - p_t^*)^2 \tag{14}$$

Following Chow, this can be decomposed into deterministic and stochastic components

$$\text{Min } E(W) = \sum_{t=1}^{T} (\overline{p}_t - p_t^*)^2 + E \sum_{t=1}^{T} (p_t - \overline{p}_t)^2 \tag{15}$$

where $\overline{p}$ is a price determined solely by systematic forces in the market system. The storage rule derived from (13) is

$$x_t = - \phi(p_t - p_t{*}) \tag{16}$$

where ϕ is the sum of response coefficients on current price included in (11).[3/]

Equation (15) highlights the importance of systematic versus stochastic variability in the implementation of stabilization policy. In deterministic control applications only the former is considered. For example, Dalton uses a deterministic approach to analyze stocking policy for wool. He argues that this is appropriate since the major cause of price fluctuation is the variability of systematic economic factors.

In dealing with stochastic fluctuations some authors have adopted the related certainty equivalence concept (e.g. Kim, Goreux, and

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[3/] Although (16) bears some similarity to the type of *ad hoc* price rule (2) employed in simulation analysis, it is important to note that its derivation through control theory implies that storage behavior will minimize price deviations from desired values over the multi-period planning horizon.

Kendrick), in which appropriate policy is derived ex ante by setting random variables equal to their expected value of zero. One difficulty with this approach is that it effectively de-emphasizes stochastic disturbance, when frequently this is the most important source of variation in commodity markets. In fact centralized storage activity is often intended solely to offset its effect. Hence, the greatest potential for control theory would seem to be as a method for evaluating the effects of alternative stabilization objectives, instruments, and decision rules in the presence of system disturbances. Its employment in an ex post or ex ante simulation mode would seem to be most promising. Previous studies (e.g. Kim, Goreux, and Kendrick) suggest the potential which exists for assessing trades-off between multiple objectives within this type of framework.

The simple quadratic/linear specification illustrated by (14) and (11) above can prove useful in some cases, however solution methods have been developed for other types of problem, for example one involving non-linear constraints (Chow). Furthermore, considerable potential may exist for the incorporation of uncertainty about the parameters of the system, and decision-maker learning through adaptive control (Rausser and Freebairn).

Some Problems in Modeling Instability

One of the fundamental requirements for empirical analysis of stabilization policy is that the model employed should adequately reflect the nature, source, and transmission of instability in the market system. Commodity models generally incorporate two sources of fluctuation: (1) systematic factors, and (2) non-systematic factors. Changes in variables which are assumed to be exogenous such as population, incomes, and technology create systematic fluctuations in endogenous variables such as price. Non-systematic factors, which are indeterminate or difficult to specify explicitly such as weather, also create fluctuations in endogenous variables. The influence of such factors is usually relegated to residual error terms, but may also be reflected through dummy variables. In a simultaneous system, the effect of a residual disturbance which is attributed to one endogenous variable will be transmitted to other endogenous variables during a single time period.

The impact of changes in systematic factors on system variability can be analyzed either by assuming a specific set of values for an exogenous variable, or by generating these randomly from a density function. To some extent fluctuations in these variables are predictable and are frequently identified as "acceptable" market instability. Solution of the model, with observed or forecast values of such variables and stochastic disturbances suppressed, can be used to provide target values for simulation or control analysis. These may prove to be more appropriate than the rather crude moving average, or secular trend alternatives, which are frequently adopted (e.g. Behrman; Kim et al; UNCTAD).[4]

In much empirical analysis of stabilization policy major attention has been focused on instability derived from non-systematic factors, assumed to be reflected in residual error terms. This is because stabilization devices, such as buffer or reserve stocks, are mainly oriented towards the control of short-term fluctuations rather than long-run cyclical or secular changes. It is common practice, for

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[4] For example, in the case of (15) a neutral storage policy, having no effect upon systematic price changes, would be defined with the vector $\overline{p}$ as target prices.

example, to identify the unexplained variation in yield or production as a system disturbance attributable to weather, and to use this as a major input in the evaluation of stabilization policy.

Two alternative methods of using such disturbances exist. In the first, which we will call Method A, the actual residuals from least-squares regression are used to assess the impact of policy response over a particular period. This has its most obvious application to the ex post evaluation of alternative policies over the sample period. In the second method, which we shall call method B, regression residuals are used to specify a probability distribution for system disturbances. Both methods raise some interesting issues.

In employing method A an assumption is presumably made that the series of estimated sample disturbances (u), is an acceptable representation of a corresponding series of true system disturbances (e). However, it should be recalled that one of the properties of least-squares residuals is that even if the elements of e are serially independent the elements of u are not (Theil, p. 196). Furthermore, even if the true residuals are homoscedastic the least-squares residuals may be heteroscedastic. These residuals may not therefore have desirable properties, and we may doubt their ability to reflect a pattern of true system disturbance.

One possible remedy for this problem would be to use an appropriate estimator to derive estimates of true disturbances which would possess desirable properties, and use these in a method A-type application. For example, the use of the BLUS procedure developed by Theil could be one way to derive a set of such disturbances, albeit at the cost of truncating the period of analysis. Whether the gain in terms of analytical "purity" would outweigh the added computational cost is perhaps open to debate.

Method B, the use of least-squares residuals to define a probability distribution for the true stochastic disturbance, has proved extremely popular in the past. The most usual approach has been to employ the variance of the residuals as an estimator of the variance of the true disturbances, which are assumed to be normally distributed with zero mean and constant variance.[5] When interdependency between system disturbances exists more complex methods may be required to derive the appropriate probability distribution. Nagar, for example, discusses a method for obtaining estimates of a multivariate normal distribution for a simultaneous equation system with contemporaneously independent disturbances. Appropriate moments of a non-simultaneous system with contemporaneously correlated disturbances can be derived from Zellner's method of seemingly-unrelated regressions, while three-stage least-squares would be appropriate in the corresponding simultaneous case.

A number of important questions are raised by the use of sample disturbances to estimate a density function for true system disturbances. In the first place, to what extent is a constant variance assumption realistic? Many commodity models, particularly those which seek to explain the operation of international markets, use quantity-dependent supply functions. The variance of an underlying stochastic disturbance in yield may be constant, but with significant changes in acreage the variance of disturbances in supply will certainly not be so. In this case homoscedasticity is an unreasonable assumption which should affect both choice of estimation technique, and the specification of a probability function for system disturbances.

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[5] An appropriate estimator of the true variance in the case of small samples would seem to be $u'u/(n-k)$ where n is the number of observations and k is the number of explanatory variables.

A second issue is the implication of the use of dummy variables to account for "exceptional" weather conditions, or other factors which create "outliers" in dependent variables. It is frequently necessary to adopt this technique because of the sensitivity of least-squares estimators to extreme observations in small samples. But what if such weather conditions are part of the true weather variance? By their removal the estimate of the true variance is truncated, and the relevance of an analysis based upon it is thereby limited. This would seem to present especially serious problems when the objective is to provide a probabilistic assessment of the success of a particular stabilization scheme. One way to deal with the outlier problem would be to produce adjusted least-squares residuals by including the shift-effect of dummy variables. These adjusted disturbances would then be used to estimate the variance. An alternative would be to incorporate specific explanatory variables to explain system disturbance due to such factors as weather, rather than relying upon the error term. In aggregate market models such an approach may prove difficult and expensive.

A further issue of some importance is the validity of the assumption of normality. It should be recalled that this is not needed for least-squares to yield best linear unbiased estimators of structural parameters, however it is required to perform conventional significance tests. In the case of stabilization analysis considerable importance is attached to the disturbances *per se*, and it therefore seems appropriate to pay greater attention to their actual distribution than would usually be the case. *A priori* the normality assumption might seem perfectly appropriate for a disturbance which is specifically attributed to the influence of weather. In other cases, however, the situation is much less clear. In some studies, for example, disturbances in demand equations have been equated with the impact of unspecified policy changes. It is not immediately obvious that these should be normally distributed, nor indeed serially independent. A case could therefore be made for more careful analysis of error terms than has been typical hitherto. Anscombe indicates a number of methods that can be used to examine the characteristics of estimated residuals, Ramsey also discusses the problem.

Careful analysis of residuals may have the added advantage of permitting a fuller assessment of the appropriateness of a particular model specification, especially in terms of whether additive or multiplicative disturbances seem to be more appropriate. This question has been identified by some analysts as crucial to the empirical evaluation of the effects of stabilization policy (Just).

Concluding Comments

Empirical modeling will undoubtedly continue to prove a major medium for the analysis of alternative stabilization policies in international commodity markets. In the past, simulation has proved the most popular technique, but optimal control theory seems to possess a number of distinct advantages. Most important are the way in which appropriate decision rules for market intervention are directly derived from underlying policy objectives, and the ability of the method to deal with multiple, and sometimes conflicting, aims.

Numerous problems arise in the specification, estimation and use of commodity models and there are many possible directions for future improvement (Just; Klein; Labys). Some of the most important, and neglected, methodological issues relate to the identification of systematic and stochastic disturbances in market systems. Appropriate decomposition and analysis of such disturbances is central to a meaningful empirical evaluation of stabilization policy.

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