MODELLING THE INTERACTIVE EFFECT OF ALTERNATIVE SETS OF POLICIES ON AGRICULTURAL PRICES

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I. Introduction

Understanding agricultural prices is a complex and highly evolutionary process. In most countries, agricultural prices are more highly regulated than other prices. Thus, understanding the effects of domestic agricultural policy is crucial. This problem is complicated by frequent revisions not only in the levels of policy instruments but also by changes in the active set of instruments. Moreover, each major new agricultural price swing over the last several decades has drawn attention to an additional set of policy instruments that has important spillover effects on domestic agriculture. These sets of policy instruments include domestic macroeconomic policy, foreign agricultural policy, and foreign macroeconomic policy as well as domestic regulation of other sectors.

This paper discusses the role of alternative sets of policy instruments in determining agricultural commodity prices, evaluates alternative approaches for modelling agricultural commodity prices, and briefly discusses some empirical experience. Some of the points in the paper are substantiated by specific examples while others are offered simply as a summary of intuition and experience. The two main messages of the paper are (1) that increasing volatility in the agricultural economy calls for imposing more structure in estimation in order to capture the global properties of important relationships and (2) that increased volatility has revealed many important international, intersectoral and macroeconomic linkages that necessitates an ever broadening scope in agricultural modelling.

II. Domestic Agricultural Policy Instability

The most important variable on the supply side that drives agricultural crop prices is acreage planted. Acreage of some of the most important crops

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depends heavily on government policy. The set of instruments through which agricultural policy is administered has been subject to frequent change. The US feed grain program serves as a major example.

During the 1950s, these grains (e.g., maize and sorghum) were regulated only by price supports which were occasionally at ineffective levels. At times in the early 1960s they were also regulated by binding farm-level acreage limitations (allotments). Beginning in the mid-1960s, these programs became voluntary so that each farmer received the price support only when electing to plant within the allotment. Later, minimum feed grain acreage diversion levels were specified under which part of each farm's base acreage had to be removed from production of a specified set of commodities for eligibility in the program. At times, farmers have been offered a per acre payment for diverted land and occasionally an additional per acre payment has been offered for land voluntarily diverted beyond the minimum. For several years in the mid 1970s, the commodity boom tended to make the feed grain program ineffective. Since 1977, support has been tied to a farmer-owned reserve under which grains enter the reserve at the price support level, generally do not come out of the reserve until prices rise to a release price, and must come out at the call price (all three levels are policy instruments). In addition, farmers' voluntary decisions to put grains into the reserve are affected by the extent of interest subsidy provided to farmers on loans made against the reserves. Beginning in 1983, payments to farmers began to be made in kind.

The point of this brief review, which omits many other minor changes, is that policy regimes have changed so often that only a few annual observations are available under each policy regime. Thus, from a purely objective standpoint, econometric identification is technically impossible in many policy regimes given the number of other variables such as input prices and technological change that interact with policy instruments in determining acreage. This leads to the first principle of this paper.

PRINCIPLE 1. *Empirical modelling and understanding of commodity prices in heavily regulated industries with frequent changes in policy regimes is possible only by imposing substantial subjective and theoretical structure on the data.*

An example can serve to make to make this point. Early on, acreage response was modelled as an *ad hoc* linear function of market price and support price, $A = A(P_m, P_s)$. Because of high collinearity of the two, however, this approach often lead to an implausible sign on one or the other. More plausible and useful results have been found by specifying acreage following $A = A(P_f)$ with farm commodity prices following the kinked relationship $P_f = \max(P_m, P_s)$ even though the market price is an uncertain variable at the time of the acreage decision whereas the price support is not (Just, 1973).

Limited dependent variable models have also been suggested to address problems where mandatory allotments may or may not be binding depending on economic conditions (Chambers and Just, 1982b). Nevertheless, the typical approach to modelling acreage response in the presence of voluntary programs is to specify a linear acreage equation with

(1) $A = A(\pi_c, \pi_n, \pi_a, A_{-1}, G_v)$

where π_c is anticipated short-run profit per acre under (voluntary) compliance with government programs, π_n is anticipated short-run profit per acre under noncompliance, π_a is anticipated short-run profit per acre from production of competing crop(s), A_{-1} is lagged acreage representing production fixities, and G_v is the government payment per acre for voluntary diversion beyond the minimum (see, e.g., Rausser, 1985; Love, 1987). In this formulation, the levels of profit under compliance and noncompliance are assumed to pick up the change in voluntary compliance.

A common-sense approach which imposes more structure on the data is as follows. Suppose first that free market acreage follows $A = A_f(\pi_n, \pi_a, A_{-1})$.

Then when government programs are voluntary, the nonparticipating component of acreage can be assumed to follow this free market equation on the nonparticipating proportion of farms so nonparticipating acreage is

(2) $A_n = (1 - \phi)\, A_f(\pi_n, \pi_a, A_{-1})$

where ϕ is the rate of participation in the diversion program.

Using common sense and an assumption of constant returns to scale which often provides a reasonable approximation for agriculture, participation in a voluntary program and access to its price subsidies would not be attractive unless the acreage limitations were effective. Thus, the participating acreage is, for practical purposes, determined by program limitations with

(3) $A_p = B\, \phi\, (1 - \theta) - D(G_v)$

where B is the program base acreage, θ is the minimum proportion of base acreage required to be diverted for participation, and D describes additional voluntary acreage diversion beyond the minimum as a function of the payment per acre for additional diversion. The estimating equation for total acreage given the participation level is obtained by combining (2) and (3),

(4) $A_t = B\, \phi\, (1 - \theta) - D(G_v) + (1 - \phi)\, A_f(\pi_n, \pi_a, A_{-1})$,

where $D(\cdot)$ and $A_f(\cdot)$ follow linear specifications.

To determine the level of participation in this framework, each farmer i is assumed to participate if anticipated profit per acre (given diversion and diversion payment considerations) is greater under compliance than under noncompliance ($\pi_c^i > \pi_n^i$). Assuming that individual perceived profits differ by an amount characterized by an appropriate random distribution across farmers, the participation rate at the aggregate level can be represented by a logistic relationship with[1]

(5) $\ln \frac{\phi}{1 - \phi} = \phi^*(\pi_n, \pi_c)$.

To illustrate the difference in performance of the approach in equation (1) compared to that in equations (4) and (5), both were used to estimate acreage response of wheat and of feed grains in the US over the period 1962-82 and then to forecast acreage in the 1983-86 period. (See Just, 1989, for a detailed specification of the models and data used for the analysis.) The results are given in Table 1. The results for equation (4) take the participation rate as exogenous whereas the results where the model is specified as equations (4) and (5) include forecasting errors for the participation rate as well.

In the case of feed grains, the *ad hoc* formulation in (1) leads to a much smaller standard error in the sample period than the structural form in (4) even though the structural form performs better than the *ad hoc* form in *ex ante* forecasting of the post-sample period. The model combining equations (4) and (5) obtains an even lower standard error. In the case of wheat, the structural form fits the sample data better than the *ad hoc* form and performs substantially better in *ex ante* simulation. These results suggest

SUBPRINCIPLE 1.1. *When theory or intuition has strong implications for nonlinearities, kink points, boundary values, etc., estimation of heavily structured relationships based on theory and intuition leads to better understanding of commodity prices than flexible (unstructured) relationships necessary for objective identification.*

The superior performance of the structural model carries through when errors in forecasting the participation rate are also considered. The reason the structural form can outperform the *ad hoc* model even in the sample period is that nonlinearities and kinks in response over a wide range of policy parameters put a premium on global properties of the function. The participation rate over the sample period ranges from zero (a kink point) to near 90 percent in others. As a result, the effects of profits with and without compliance cannot be well represented by a smooth approximating function following (1). This substantiates

SUBPRINCIPLE 1.2. *When policy instruments vary widely, a plausible global relationship consistent with the intuitive structural role of policy is* *preferred to locally flexible functional representations.*

Next, consider the role of government policy in demand. In many countries, the government has become involved in buying agricultural commodities and thus add an additional component of demand to the usual components of food, feed, inventory, etc. Changes in government policy can have distinct and discrete effects on the structure of both public and private demand.

SUBPRINCIPLE 1.3. *Disaggregating demand by its various components (food, feed, inventory, etc.) with a separate component for government commodity purchases can permit inclusion of more structure in demand and aid understanding of commodity price behavior.*

In one sense, this subprinciple says little more than that use of more disaggregated data leads to better understanding of how a system works. Econometric investigators of agricultural commodity markets have long found that disaggregation of demand into food, feed, export, and inventory components leads to better understanding of total demand because the additional data allows identification of the role of as many exogenous variables for each component as could be identified for total demand in a total demand formulation. For example, consider a demand system for a given commodity of the form

$$Q_i = Q_i(P_m, X_i) \qquad Q_f = Q_f(P_m, X_f)$$

$$(6) \quad Q_x = Q_x(P_m, X_x) \qquad Q_m = Q_m(P_m, X_m)$$

$$Q_{m,-1} + A_t \cdot Y_a = Q_i + Q_f + Q_x + Q_m$$

including the supply-demand identity where the -1 subscript represents a one period lag and

Q_z = quantity demanded with z = i for food/industry, z = f for feed, z = x for export, and z = m for market stocks

X_z = exogenous variables which determine the relevant demand.

Clearly, if all of these demands are aggregated into a total, $Q_t = Q_i + Q_f + Q_x + Q_m$, then the resulting demand equation, $Q_t = Q_t(P_m, X_i, X_f, X_x, X_m)$, may not be identified for econometric purposes even though all of the individual demands are. Furthermore, regardless of identification, information is lost as a result of aggregation so econometric estimators of total demand are inefficient compared to estimators of the disaggregated demand system. The same principle applies to the role of, say, a government inventory demand equation, $Q_g = Q_g(P_m, X_g)$, which includes an additional set of exogenous factors, X_g.

Another reason for estimating government demand separately is to include the theoretical and intuitive structure associated with various policy interventions which can give a model better global properties as discussed above on the supply side. These considerations may call for limited dependent variable models. Alternatively, qualitative definitions of right hand side variables may suffice. For example, in the case of government acquisition of feed grains in the US, one finds

$$\begin{aligned} Q_g = \underset{(0.38)}{0.3873} + \underset{(9.04)}{0.5838}\, Q_{g,-1} + \underset{(7.74)}{39.85}\, \max\{0, (1.1\, P_s - P_m)\phi\} \\ + \underset{(6.90)}{20.37}\, D - \underset{(-0.09)}{0.1172}\, T_1 + \underset{(1.33)}{1.821}\, T_2 + \underset{(0.45)}{0.5981}\, T_3 \end{aligned}$$

$R^2 = 0.927$, $\bar{R}^2 = 0.919$, DW = 1.42, Sample = 1973:1-1987:3

where D is a policy variable reflecting the payment-in-kind program of 1983, the T_i's are are quarterly dummy variables, other variables are as defined above and t-ratios are in parentheses (see Just, 1989, for a complete definition of variables and data sources).[2,3] This equation captures the qualitative relationship whereby stocks are not turned over to the government until market price falls to near the government support level but are increasingly turned over as the market price falls below that level (note that only grain produced under voluntary compliance with the program is supported so the market price can fall below the support price). Here the price variable is highly significant as compared to standard cases where a continuous function of market and support prices is used as a term explaining government stocks (see, e.g., Rausser, 1985, where the price term is a ratio of support price to market price and an implicit t-ratio of 1.48 is obtained in an otherwise similar equation).

III. Domestic Macroeconomic Policy

Traditionally, the consideration of policies in the study of agricultural prices did not go beyond domestic agricultural policy. The effects of policies for individual farm products and productive inputs could be investigated entirely in a microeconomic framework. Such a narrow perspective is no longer adequate.

PRINCIPLE 2. *If international trade, inventory holding, or productive asset holding plays an important role in a commodity market, then understanding the role of the macroeconomy is an important part of understanding a commodity market.*

The narrow microeconomic perspective was perhaps adequate prior to significant events related to exchange-rate determination in the 1970s. However, with the shift away from the Bretton Woods system of fixed exchange rates and the ensuing exchange-rate variability, the importance of macroeconomic policy to the agricultural sector began to be recognized (Schuh, 1974).

The related events caused many analyses of the macroeconomic impacts on agriculture to focus on the effects of exchange rates on agricultural prices. These studies have overwhelmingly found exchange rates to be a dominant force effecting agricultural prices. For example, Chambers and Just (1981) in studying the commodity boom of the 1970s estimate a market system of equations similar to (6) for US wheat, corn, and soybeans where the exchange rate appears as an exogenous variable in the export equation. The resulting reduced-form elasticities of price with respect to exchange rate tend to dominate all others (see Table 2). Only lagged inventory (carryin) for wheat and consumer income for corn have larger elasticities in explaining prices. Given sample variation in the exogenous variables (which is small for consumer income), an examination of standardized (beta) regression coefficients (see Goldberger, 1964, pp. 197-198) reveals that exchange-rate variation explains more short-run variation in each price than any other variable except carryin. In the long run where carryin is determined endogenously in the system, exchange-rate variation explains more variation than any other variable.

These results imply that exchange rates play a larger role in agricultural commodity markets than the agricultural policy instruments designed to regulate them. Moreover, at times the two tend to work against one another. For example, several studies have recently found that the effects of macroeconomic policies on agriculture can more than offset its sector specific policies in terms of the relative price signals guiding producers and consumers (Rausser, 1985; Valdes, 1986). These results substantiate

SUBPRINCIPLE 2.1. *In a world of exchange rate volatility, investigation of the effects of sector policy on tradable commodity prices requires considering interactions of policy instruments with exchange rates.*

As the instability of the macroeconomy evolved through the 1970s and early 1980s, the high levels of volatility enabled more linkages between the macroeconomy and agriculture to be identified. Exchange rate volatility beginning in the early 1970s with the collapse of the Bretton Woods Agreement allowed the importance of exchange rates to be clearly identified empirically about a decade ago. More recently, the sharp swings in interest and inflation rates in the late 1970s and early 1980s have similarly allowed their importance to be identified empirically. The work that identified a strong empirical linkage to agricultural commodity markets through interest rates occurred in the mid 1980s in response to the data with wide variations in interest rates generated in the early 1980s (Rausser, 1985).

Interest rates have their primary effect on agricultural commodity markets through the incentive to carry stocks of storable grains and to adjust breeding herds of livestock. To illustrate the importance of these points, consider the estimated equation for wheat stocks,

$$Q_m = \underset{(0.94)}{316.6} + \underset{(5.80)}{0.6803}\, Q_{m,-1} - \underset{(-1.85)}{46.84}\, P_f - \underset{(-2.24)}{22.84}\, r_m$$

$$+ \underset{(1.75)}{191.7}\, D - \underset{(-1.63)}{140.9}\, T_1 - \underset{(-0.83)}{119.4}\, T_2 + \underset{(8.32)}{1464}\, T_3$$

$R^2 = 0.948$, $\bar{R}^2 = 0.940$, DW = 1.55, Sample = 1973:1-1986:2,

where all variables are as defined above and t-ratios are in parentheses (see Just, 1989, for a complete definition of variables and data sources). Here, the interest rate is statistically more significant than own price. If one reestimates this equation with data terminating in the second quarter of 1979 just before the interest-rate boom, the t-ratio for the interest rate drops to -0.90. This t-ratio compared to the t-ratio of -2.24 above demonstrates the importance of interest-rate variability beginning about a decade ago in identifying interest-rate effects on agricultural commodity markets. These results suggest

SUBPRINCIPLE 2.2. *In a world of interest rate volatility, investigation of the effects of sector policy on storable commodity prices requires considering interest rate effects on inventory holding.*

The importance of interest rates in agricultural commodity markets is illustrated even more dramatically in livestock markets. Consider the following two estimated equations for breeding hog inventories and pork production,

$$Q_h = \underset{(3.01)}{759.2} + \underset{(24.08)}{0.9509}\, Q_{h,-1} - \underset{(-3.83)}{23590}\, P_c/P_p - \underset{(-3.45)}{32.36}\, r_m$$

$$- \underset{(-0.67)}{49.00}\, T_1 + \underset{(1.64)}{120.0}\, T_2 - \underset{(-2.32)}{170.5}\, T_3$$

$R^2 = 0.925$, $\bar{R}^2 = 0.916$, DW = 1.75, Sample = 1973:1-1987:4

$$Q_p = \underset{(2.35)}{864.9} + \underset{(0.40)}{2403}\, P_c/P_p - \underset{(-0.86)}{0.1016}\, (Q_h - Q_{h,-1}) + \underset{(3.40)}{34.70}\, r_m$$

$$+ \underset{(7.59)}{0.1456}\, Q_{n,-2} + \underset{(1.43)}{116.2}\, T_1 + \underset{(1.59)}{121.6}\, T_2 + \underset{(1.71)}{203.4}\, T_3$$

$R^2 = 0.826$, $\bar{R}^2 = 0.802$, DW = 1.42, Sample = 1973:1-1987:4

where Q_h is breeding hog inventory, Q_p is pork production, Q_n is new pig crop (which itself is a function of breeding hog inventory with a lag), P_c is corn price, P_p is pork price, other variables are as specified earlier, and t-ratios appear in parentheses (see Just, 1989, for details). The first equation reveals that the interest rate has a significant effect on farmers' willingness to carry breeding herds. (Again, to illustrate the importance of interest-rate variability over the last decade in identifying this coefficient, note that the corresponding t-ratio when using a sample period ending in the second quarter of 1979 is only -1.18.) The second equation, on the other hand, illustrates an important dynamic effect of interest rates on agriculture. A higher interest rate has not only a direct effect of lowering profitability but the associated liquidation of breeding stocks causes short-run meat production to increase thus further reducing profitability. This feeds back in the form of lower meat prices thus tending to cause a short-run overadjustment.

The importance of interest rates in determining the cost of carrying productive assets, however, is only part of the picture. Because productive assets can serve as a store of value in periods of inflation, the role of inflation must also be considered. The flow of funds in and out of agriculture induced by interest rates and inflation can be substantial because agricultural production asset markets are transacted in markets that are highly competitive. For example, agricultural land attracts investment as a store of value in periods of high inflation but funds are drawn away from the financing of land purchases by high real interest rates. The resulting effects on variability of farmers' wealth have been extraordinary over the last fifteen years.

These points are made here on the basis of the study of macroeconomic effects on land prices by Just (1988b) which again illustrates the importance of utilizing structural versus *ad hoc* specifications (SUBPRINCIPLES 1.1 and 1.2). A common econometric approach to explaining land prices is to use an *ad hoc* function of a lag distribution of short-run returns or rents per acre from farming (e.g., Burt, 1984). Alston (1984) generalized this approach to consider interest rates and inflation in a "capitalization" formula by using an equation with

$$(7) \quad P = \frac{\alpha_0 + \alpha_1 R}{\beta_0 + \beta_1 I}$$

where P is land price, R is a free form 13-period lag distribution on real returns per acre, and I is the real interest rate (16 estimated parameters).

By comparison, it was found that an equation derived almost entirely from theory fits the Alston data better. The equation is of the form

$$(8) \quad P = (1 + f) \frac{(1 - \rho)(1 - \nu\psi)P^* + (1 - \tau)R^* - \beta\Sigma}{1 + \gamma\theta(1 - \tau) + r\eta(1 - \theta)(1 - \tau) + \lambda + X}$$

where f is the rate of inflation, ρ is the rate of transactions cost (commissions, etc.) on land sales, ν is the rate of tax on capital gains, ψ is the proportion of capital gains in land value, P* is expected real land price after the next production period, τ is the rate of tax on ordinary income (which includes interest income and treats interest expense as a deduction), R* is expected real returns to farming per unit of land in the next production period including government program payments, β is a coefficient of risk aversion, Σ is the risk (variance) of returns plus capital gains over the next production period, γ is the real rate of interest earned on savings or alternative investments, θ is the proportion of land not financed by debt, r is the real rate of interest paid for farmland mortgage funds, η is a term representing transactions cost in borrowing, λ is the rate of real estate taxation, and X is a term representing opportunity cost associated with imperfections in the capital market (credit limitations).[4] Equation (8) is basically a generalized capitalization formula. The numerator is the returns to ownership corrected for taxes, transactions costs, and risk premium. The denominator is the opportunity cost of capital corrected for taxes, transactions costs, and capital market imperfections.

Data were available for all the terms in this model except β so only one coefficient was estimated.[5] Nevertheless, a better fit of land price data (R^2 of 0.98 versus 0.95) in the Midwestern US was obtained by specifying simple naive expectations of land prices and returns (rational expectations, adaptive expectations, and extrapolative expectations obtained poorer but similar fits).

Admittedly, equation (8) includes many more variables than equation (7). But this is part of the point. The reason more variables can be included in (8) is that the form of the equation is imposed from theory. One cannot hope to obtain plausible signs for so many variables simultaneously by estimating an *ad hoc* or flexible econometric relationship particularly given that many of the variables have minor effects individually. Also, the nonlinearities of variables in (8) are likely to elude an *ad hoc* or flexible econometric approach except as a local approximation. Thus, not only would predictive ability be lost when values of some variables move outside the range of data used for estimation, but the intuitive understanding of how variables interact would be reduced. These results give

SUBPRINCIPLE 2.3. *In a world of interest rate and inflation volatility, investigation of commodity prices in sectors with competitive markets for productive assets requires considering effects of interest rates and inflation on productive capacity.*

Another result obtained with the equation in (8) is that the estimated model changes very little as the sample period is altered (Just, 1988b). This is because the model has only one estimated parameter which is basically a calibrating parameter. Thus, for example, a fit of the model prior to the land boom or prior to the land price decline of the 1980s produces almost the same *ex ante* fit of the 1980s data as an *ex post* fit based on a sample through

1986. This suggests a concept similar to SUBPRINCIPLE 1.2.

The results of this section demonstrate that the effects of macroeconomic policy are transmitted to the agricultural sector through exchange rates, interest rates, and inflation in addition to consumer income. The importance of multiple channels of effects suggests

PRINCIPLE 2.4. *When several macroeconomic variables have a direct role in an individual commodity market, the effects of macroeconomic variables on commodity prices can be meaningfully investigated only by incorporating a model of the macroeconomy that assures consistent levels of macroeconomic variables.*

Many researchers have attempted to measure the influence of changes in macroeconomic variables on agriculture. However, these exercises have often proven to be unreliable because they are based on incomplete macroeconomic models that assume various macroeconomic linkage variables to be exogenous (Farrell, DeRosa, and McCown, 1983). The point here is that macroeconomic linkage variables such as the exchange rate, interest rate, inflation, and consumer income are determined by macroeconomic policies. Since they all appear in models of agricultural commodity markets, plausible implications of commodity market models can only be assured if the macroeconomic linkage variables are set at levels which are mutually consistent given the set of macroeconomic policies available. This is accomplished either by using historically observed levels of macroeconomic linkage variables (which considerably narrows the scope of investigation) or by generating predicted levels from a simultaneous macroeconomic model with specific macroeconomic policy choices.

IV. Foreign Agricultural Policy

Foreign sector-specific policies can also play a crucial role in explaining domestic agricultural commodity prices. Many studies have found that foreign prices, and thus the policies that determine foreign prices, are important in explaining real trends in export sectors (e.g., Ansu, 1985).

Chambers and Just (1981) find that the European Community's (EC) threshold price for wheat is statistically the most significant variable explaining US wheat exports in the early 1970s based on the equation,

$$Q_x = \underset{(2.52)}{4.396} + \underset{(1.74)}{0.2914}\, Q_{x,-1} - \underset{(-0.82)}{9.498}\, P_m - \underset{(-1.18)}{2.282}\, E - \underset{(-1.82)}{0.008416}\, P_t$$
$$+ \underset{(0.81)}{0.008831}\, W - \underset{(-0.61)}{0.004221}\, G + \underset{(1.10)}{0.2014}\, T_1 + \underset{(1.33)}{0.1764}\, T_2 - \underset{(-0.03)}{0.003492}\, T_3$$

Sample = 1969:1-1977:2

where P_t is the EC threshold price, W is stocks of wheat in other major exporters, G is government (Public Law 480) shipments of wheat from the US, other variables are as defined above, and t-ratios are reported in parentheses (R^2 and Durbin-Watson statistics are not reported because the market system of equations was estimated by three stage least squares). These conditions are the product of a situation where world agricultural commodity markets are dominated by a relatively small number of very large exporters and where domestic agricultural sectors in these countries are heavily regulated.

A more recent example related to the role of the US wheat sector in the world market can also serve to illustrate the significance of foreign agricultural policies for domestic agricultural sectors. The US is the major exporter of wheat in the world market with a market share of 43 percent (based on 1980-82 data). A number of agricultural economists have argued that because of this dominant share, US wheat price supports act essentially as world price supports (US Department of Agriculture, 1985). Because of this dominant role, a decision to discontinue price supports in the US (such as was considered in 1985) has significant implications for countries attempting to develop domestic wheat production sectors such as Argentina. For example, Gardner (1985) has estimated that curtailing US wheat price supports would cause the world wheat price to decline by 17 percent. Clearly, this foreign policy change could have devastating effects on the domestic wheat policies of a country like Argentina. Similarly, US sugar import policies play an important role in determining the foreign exchange earnings of developing countries that are able to export sugar to the United States (occasionally at prices five times the world level) under its import quotas. These considerations suggest

PRINCIPLE 3. *Understanding domestic prices of traded commodities that are characterized by concentrated world markets and regulated markets in major foreign exporting countries requires consideration of foreign sector policy.*

V. Foreign Macroeconomic Policy

In the same way that the results above imply critical dependence of exchange rates on domestic macroeconomic policy, they imply a critical dependence of exchange rates on the macroeconomic policies of foreign trading partners. Evidence of the importance of foreign macroeconomic policy to domestic agriculture is clear from the increased portion of adjustment in world agricultural trade that has involved middle income developing countries in recent years. During the late 1970's when the United States was pursuing a liberal monetary policy that led to devaluation of the dollar, agricultural imports by these countries accounted for almost half of the increased value of US exports. They also accounted for almost half of the decline in 1982 when the United States sharply tightened its monetary policy and the dollar appreciated rapidly (Schuh, 1985). The availability of cheap agricultural commodities as a result of US macroeconomic policy in the 1970s has been cited as a major disruption of efforts to develop domestic agriculture in these countries. These observations emphasize the importance of considering foreign macroeconomic policies pursued by trading partners in formulating domestic agricultural policy.

PRINCIPLE 4. *Understanding effects of foreign macroeconomic policy on exchange rates can be crucial to understanding variation in domestic commodity prices and the effects of domestic sector policy.*

The difference in responses of US exports to depreciation of the dollar in the early 1970s and mid 1980s gives another example of the role of foreign macroeconomic policy. In the early 1970s, the depreciation of the dollar relative to currencies of major importers lead to a sharp increase in US agricultural commodity prices and exports. The response was not as great to an equal devaluation of the dollar in the mid 1980s because major competing grain exporters followed macroeconomic policies that maintained par with the dollar. That is, while the dollar devalued with respect to importers' currencies, it did not devalue with respect to exporters' currencies as it had in the 1970s. This implies the importance of third country macroeconomic policies.

SUBPRINCIPLE 4.1. *The set of potentially important macroeconomic policies abroad for explaining domestic commodity prices includes not only those of trading partners but also those of trading competitors.*

These principles collectively imply that consideration of the effects of foreign macroeconomic policies on domestic commodity prices is a complex issue.

VI. Overshooting in Flexible Markets

Increasingly, world markets for agricultural commodities have come to be viewed as more flexible or volatile than those for other sectors of the international economy. Explanations have been advanced associated with the explosion of trading in major futures and commodities exchanges. Commodity futures trading increased 437 percent in the US from 1972 to 1981. In 1980, the volume of futures trading in soybeans was over 32 times the volume of the entire crop (Commodity Research Bureau, 1982). This simultaneous development has raised the issue of whether excess volatility in agriculture is due to excessive speculation by traders using technical rather than fundamental trading rules (see discussion from the session on Excess Volatility in Agriculture in the December, 1988, *American Journal of Agricultural Economics*). While this debate is not closed, empirical results are beginning to suggest that excess volatility in agriculture is largely due to excess volatility in macroeconomic policy; the level of trading activity in agricultural markets is important only insofar as it contributes to their competitive and flexible nature.

As experience has accumulated more studies have realized that monetary policy causes differential rates of inflation among commodity markets due to different degrees of price fixity (Dornbusch, 1976; Hicks, 1974; Okun, 1975; Mussa, 1981; Phelps and Taylor, 1977). Dornbusch (1973) has shown that a monetary shock in an economy with both fixed and flexible prices will cause flexible price markets to overshoot their long-run equilibrium in the short run. Okun argues that the difference in characteristics between manufactured goods and services (customer markets) and basic commodity markets such as in agriculture (auction markets) justify the fixed-price/flex-price framework. He characterizes customer markets by imperfect competition and differentiated products which make price adjustments sluggish compared to competition and rapid price adjustment in auction markets.

This framework has been applied to agricultural prices by Lawrence and Lawrence (1985). In their general equilibrium model of a dualistic economy, agricultural commodities are traded in auction or flex-price markets while other commodities are traded in customer or fixed-price markets. Primary commodity markets for agricultural goods clear in the short run by price adjustments whereas manufactured goods markets clear in the short run by quantity adjustments. The result of this dichotomy of adjustments is that unanticipated monetary disturbances affect relative commodity prices in the short run even while long-run real effects are neutral. As a result of this fixed-price/flex-price duality, the burden of monetary instability that is otherwised placed on the agricultural sector by virtue of its importance in trade is further exacerbated.

Increasingly, empirical results are verifying the validity of this explanation for agriculture. For example, the elastic response to money supply found by Chambers and Just (1982a) was early evidence in this respect.[6] Lombra and Mehra (1983) also found that money supply has a statistically significant effect on food prices consistent with more flexible price response in the more basic commodity markets. Van Duyne (1982) was the first to specifically use the fixed-price/flex-price model in explaining food prices. More recently, Stamoulis and Rausser (1988) have verified overshooting for US agriculture in a more complete empirical model paralleling the theoretical model of Lawrence and Lawrence (1985). Cavallo has found in an analysis of exchange rates in Argentina that monetary and exchange-rate policies have short-run real effects that differ from those in the long run where the law of one price becomes effective. Amranand and Grais (1984) found that the fixed-price/flex-price dichotomy explains general equilibrium adjustments and distributional implications of macroeconomic policy in Thailand. The lessons from these studies are

PRINCIPLE 5. *Understanding volatility of basic commodity markets requires modelling their flexibility along with the fixity of related markets in a general equilibrium framework.*

SUBPRINCIPLE 5.1. *Neutrality of monetary policy cannot be imposed on individual commodity markets in the short run.*

SUBPRINCIPLE 5.2. *Discernment of the source of short-run price adjustments and the extent to which they are a consequence of overshooting is crucial in determining the likelihood of continuation.*

While many of the studies on overshooting focus on monetary policy, similar principles apply to fiscal policy as well. Collectively, they identify some important considerations that tend to be ignored in macroeconomic policy formation. Macroeconomic policy debates focus primarily on macroeconomic variables and measures of aggregate performance. In so doing, the inefficiencies and costs of adjustment imposed on individual sectors through sluggish adjustment in some and overshooting in others are ignored. Variability in macroeconomic policy imposes externalities on individual sectors because these various sector-specific consequences are not taken into account at the level of macroeconomic policy formation (Just, 1988a). Only recently have empirical results been developed that show these effects to be important at the aggregate level (Kormendi and Meguire, 1984 and 1985; Fry and Lilien, 1986).

The same priniciples of overshooting apply to commodity markets in an international context where the commodity is heavily regulated (fixed) in some counties and unregulated (flexible) in others. Johnson (1973), in his analysis of world agriculture in disarray, argues that some kinds of agricultural policies have characteristics which export instability to world markets. The variable trade levies of the EC are an example. Through variable trade levies, the internal price is stabilized but exports and imports are destabilized thus imposing excess instability on world markets (Just, Lutz, Schmitz, and Turnovsky, 1977). Many developing countries also have adopted policies that fix internal prices for purposes of assuring cheap food while maintaining production incentives. For example, Mexico has policies that fix internal farm and consumer prices of agricultural grains with the government relying on world markets to make up the difference. These circumstances suggest another application of the fixed-price/flex-price characterization of market behavior where the fixed-price markets are characterized by government intervention which prevents price adjustment. These considerations have been examined empirically by Zwart and Mielke who find that instability of world markets for wheat have been significantly exaggerated as a result of policies that fix internal prices in the EC. Thus, continuation of EC policies has significant implications for commodity price variability in other countries.

SUBPRINCIPLE 5.3. *Understanding the volatility of basic commodity markets that are subject to various levels of price regulation among countries requires modelling the price and quantity volatility imposed on free market countries by fixed market countries.*

Because these results are realized only by analyzing the specific structure through which foreign policies operate, they underscore the principles of Section II.

VII. Volatility, the Increasing Endogeneity of Exogenous Variables, and the Expanding Scope of Commodity Price Models

Many of the sections of this paper recount developments as modelers have realized that some variables previously treated as exogenous must necessarily be treated as endogenous. These realizations include policy variables as well as choices of technology and price linkages to other sectors of the economy. This increasing scope of modelling suggests

PRINCIPLE 6. *Commodity modelers should continually seek to endogenize the exogenous variables in existing commodity models and be prepared to revise and refine interpretations accordingly.*

In early efforts to model commodity markets, government involvement was often taken to be exogenous. However, governments rarely leave policy instruments unchanged over a long period of time. Changes in policy are motivated by policy disequilibria that arise when markets do not follow the preconceived conditions that surrounded policy formation (Just and Rausser, 1984). As a result, such unexpected conditions as high food prices, high treasury exposure, or depressed performance of agricultural exports can lead to public pressure that causes an endogenous change in agricultural policy (Rausser, 1982). The volatility of commodity markets in recent times has caused these conditions to develop with increased frequency. When the endogenous nature of government policies is ignored, econometric models cannot give a complete understanding of commodity price formation and behavior. This leads to

SUBPRINCIPLE 6.1. *When government involvement in a commodity market is responsive to market conditions or to political conditions that depend on market conditions, endogenous consideration of government behavior is necessary for adequate understanding of commodity price behavior. This necessitates understanding the political economy of policy formation.*

The endogeneity of agricultural policy controls was first investigated by

Rausser and Freebairn (1974) who found US meat import quotas to be explained by an estimated policy criterion function. Love (1987) and Just (1984) present results that show policy instruments for major US agricultural grain markets to be significantly responsive to lagged market conditions, exchange rates, and government inventory levels. Obviously, if policy instruments follow these relationships, models which treat them as exogenous will give a poor understanding of the sustained effect of various shocks. The limitation of assuming government behavior to be exogenous is analogous to the limitation of partial equilibrium models in capturing general equilibrium relationships.

Consider next the increasing endogeneity of non-policy variables. For example, agricultural acreage equations have been estimated historically as a function of prices and possibly yields with technology and the cost of input prices assumed fixed. After the volatility of the 1970s and early 1980s, changes in cost per acre were successfully included in econmetric equations explaining acreage. Implicitly, these specifications permit variability in technology and input prices but take those changes to be exogenous. More recent results, however, suggest that such specifications are inappropriate.

Based on a Chicago School view of market adjustments, Gardner (1984) argues that the prices of inputs will be bid up until the cost of production is equal to output price. This suggests that the per acre cost of production is not exogenous but rather is responsive to commmodity prices. Testing this hypothesis for corn and soybeans obtains

$$C_c = \underset{(-0.69)}{-13.16} + \underset{(2.11)}{0.5360}\,T + \underset{(5.34)}{13.39}\,P_c + \underset{(3.41)}{0.4212}\,C_{c,-1}$$

$R^2 = 0.8179$, $\bar{R}^2 = 0.7930$, DW = 1.83, Sample = 1962-1987

$$C_s = \underset{(-1.52)}{-14.30} + \underset{(1.87)}{0.2211}\,T + \underset{(7.08)}{3.958}\,P_s + \underset{(5.61)}{0.4886}\,C_{s,-1}$$

$R^2 = 0.9117$, $\bar{R}^2 = 0.8997$, DW = 2.08, Sample = 1962-1987

where T is a time trend reflecting increases in yield that have roughly followed linear trends over the sample period and P_i is the real price of the respective commodity (see Just, 1989, for details). In each equation, the commodity price is highly significant confirming that costs of production previously taken as exogenous are responsive to commodity prices.

These equations could likely be improved by adding consideration of input prices in a modern cost function framework if collinearity did not prevent identification of separate coefficients. The point, however, is that variables that have previously been treated as fixed or exogenous should be considered endogenous in modelling agricultural commodity markets. Furthermore, there is no reason to expect that future conditions will maintain the same collinearity of output and input prices that makes these equations an adequate representation of production costs. Future conditions may reveal that some of the relationships that cannot yet be identified include additional endogenous variables that must be considered. As further endogenous variables are identified, the policies of other sectors of the economy are also likely to come into play. These kinds of experiences suggest

SUBPRINCIPLE 6.2. *Understanding commodity prices is limited by past conditions that may not support identification of relationships that will explain future commodity price variations. Increasing commodity market volatility tends to invalidate models limited in scope and identification by historical data.*

The best hope for effective commodity modelling in the case of SUBPRINCIPLE 6.2 appears to be incorporation of structural information based on theory and intuition following the principles of Section II when it is available.

VIII. The Scope of Economic Analysis of Agricultural Prices

Because of the complexity of the various policy interactions discussed in this paper, adequate policy analysis is difficult if not impossible without a formal framework. However, models that embody all of these interactions are not available. Models are needed that facilitate analysis of agricultural policy recognizing the complex interactions of agricultural and macroeconomic policies both domestically and abroad. Addressing such policy questions requires modelling a number of components of economic activity both domestically and abroad.

First, a component describing a particular commodity market must be developed for both the country in question and for the (groups of) trading competitors and partners whose policies are important. Each of these must include significant agricultural policy instruments and macroeconomic phenomena related to the effects of exchange rates on trade; the effects of interest rates on storage, investment, and productivity; and the effects of taxes, subsidies, and other barriers on production and trade. In addition, since each country represents substantially less than the total world market, a commodity-specific component may be needed for the rest of the world.

Next to consider the implications of macroeconomic policy, a rest-of-the-economy component must be included for both the country under consideration and the trading competitors/partners. This component is necessary because the effects of macroeconomic policy on agriculture are correlated with those of other sectors; the strength of this correlation determines the magnitude of feedback relationships that govern exchange-rate and interest-rate determination. To reflect this phenomena appropriately, the rest-of-the-economy component must be sensitive to the shares of traded and nontraded goods in the total economy which may require separate modeling.

These considerations seem to require large complex models for studying commodity prices. However, large complex models are limited because intuition and understanding of the mechanism of change is lost. For this reason, an advantageous approach is to specify economic sectors with decreasing detail and increasing aggregation as one moves away from the specific domestic agricultural commodity under consideration rather than using a uniformly detailed general equilibrium specification (Just, Hueth and Schmitz, 1982; Rausser and Just, 1981). Thus, general equilibrium properties can be maintained with greater simplicity and understanding.

The approach advocated here is to develop fairly streamlined models with emphasis on understandability but yet models that cut across all relevant economic variables. This is made possible by using specifications that reduce the number of estimated coefficients, by making maximal use of extraneous information such as theory and intuition, and by using summary variables rather than representative variables. With this approach, models of commodity prices combine some aspects of theoretical analysis with some aspects of econometric and simulation methods. That is, the models can be analyzed under a wider range of conditions and values of certain key parameters as is typical of theoretical analysis while certain other, perhaps better identified, coefficients can be determined econometrically. These suggestions are summarized by

PRINCIPLE 7. *Models that combine a broad set of phenomena affecting general equilibrium can convey more understanding by incorporating less detail and more aggregation in components less closely related to the commodity market in question and by imposing more intuitive and theoretical structure combining the many variables of importance.*

The development of models that incorporate decreasing detail and increasing aggregation in specifying components of commodity models less closely related to the commodity in question suggests the following subprinciple.

SUBPRINCIPLE 7.1. *Specific purpose rather than general purpose commodity models are more easily structured to enhance understanding of commodity prices.*

A similar principle is discussed by Rausser and Just (1981) so the point will not be further belabored here.

With little doubt, the approach of foregoing estimation of numerous coefficients by imposing heavy structure on data through theory and intuition meets with substantial resistance by those advocating the traditional concept of "objectivity" attached to econometrics in theory. However, econometric practice suffers pitfalls whereby objectivity is lost through judicious selection of variables and substantial pre-test estimation that is not completely reported in the literature (Leamer). By removing this "appearance of objectivity" constraint, the researcher is freed to use his intelligence in making sense of the data and to combine in an intimate way the methodology of theory and estimation.

Developing heavily structured models for empirical analysis is much like constructing theoretical models. In principle, an infinite set of alternatives are possible. Without a standard of comparison, there is no reason to expect this process to converge on any representation or understanding of a market particularly when many researchers are involved in similar activities. However, when a heavily structured model can outperform the standard *ad hoc* or flexible models in the literature (supposedly the best economists have to offer) then a degree of empirical validity is achieved that demands attention.

SUBPRINCIPLE 7.2. *Models that impose heavy structure on the data should be judged on the basis of how well they fit the data and how well they generate ex ante forecasts in comparison to ad hoc and flexible specifications.*

Since this approach also clearly abandons the "objectivity" that makes econometric and statistical measures of significance valid, another set of criteria are necessary for comparing and selecting models.

SUBPRINCIPLE 7.3. *If several models fit the data with about equal precision, then plausibility of structure, stability of estimated structure with respect to sample period, and ex ante forecasting ability are appropriate means of model discrimination. All models that satisfy these criteria must be held as potentially valid until additional data is generated under economic conditions that permit discernment.*

An example of a model where these criteria are met is the model of land prices discussed in Section III.

IX. Conclusions

Agricultural commodity prices are affected in major ways by many sets of policies. These sets of policies are subject to frequent change in both the the level of policy instruments and the active set of policy instruments. Heavy regulation and frequent changes in active sets of agricultural policy instruments demands heavily structured models for econometric identification. Tradability, storability, concentration of world markets for agricultural commodities, and competitive markets for productive assets cause significant interaction with foreign and macroeconomic sectors which demands general equilibrium considerations. Varying levels of price flexibility among markets must be captured to understand short-run overshooting and volatility. Increasing volatility is expanding the set of policy and price variables that must be considered endogenous in commodity price models. These conditions call for liberal use of theory and intuition in analyzing and understanding commodity price variation. Hopefully, the principles put forward in this paper can be useful toward this end.

Table 1. The Performance of Structural Versus *Ad Hoc* Models: The Case of US Wheat and Feed Grain Acreage[a]

Crop	Model Definition (Equation)	Estimation Period	Forecast Period	Standard Error Within Sample (million acres)	Standard Error Post-Sample (million acres)
Wheat	(1)	1962-82	1983-86	4.41	14.90
Wheat	(4)	1962-82	1983-86	3.32	6.21
Wheat	(4),(5)	1962-82	1983-86	[b]	9.07
Feed Grain	(1)	1962-82	1983-87	1.73	6.40
Feed Grain	(4)	1962-82	1983-87	6.26	6.38
Feed Grain	(4),(5)	1962-82	1983-87	[b]	5.50

[a] See the text for equations which define the various models.
[b] No within sample error is computed since the model is derived by combining the estimated equations corresponding to (4) and (5).

Table 2. Estimated Reduced-Form Price Elasticities for Selected US Agricultural Commodities[a]

Exogenous Variable	Model		
	Wheat	Corn	Soybeans
Lagged Disappearance	0.001	-0.173	-0.233
Lagged Inventory	-1.535	-1.168	-0.841
Lagged Exports	0.177	0.101	0.605
Lagged (Expected) Price	-0.575	-0.285	-0.085
Support Price	-0.563	-0.227	-0.047
Exchange Rate	-1.243	-1.903	-2.643
Consumer Income	0.817	-2.316	-0.689
Cattle on Feed		0.739	0.601
Pigs on Feed		1.091	
Non US Stocks/Shipments	-0.212	-0.213	-0.031
EEC Threshhold Price	-0.623		

[a] See Chambers and Just (1981) for a complete report of the estimates and complete definitions of variables and data sources.

FOOTNOTES

[1] An equation similar to (5) was used by Chambers and Foster (1983) to explain participation in the farmer-owned reserve but was not used further in conjunction with a structural acreage equation such as (4).

[2] Of course, other changes can be incorporated into an inventory equation that impose more structure. For example, some of the features of the land price equation discussed below which apply to holding assets can be readily included. The example provided here is merely intended to suggest a simple first step in that direction.

[3] Note that throughout this paper the Durbin-Watson (DW) statistic is reported even though it is not strictly applicable in cases with a lagged dependent variable (Nerlove and Wallis, 1966). While appropriate adjustments can be made to correct this problem, the equations are reported only for illustrative purposes. For most of the cases in this paper, calculation of the h statistic which corrects for inclusion of a lagged dependent variable following Durbin (1970) reveals very low significance. Nevertheless, the t-statistics should be interpreted with caution where the DW statistic is low.

[4] For brevity, the latter two terms are not explained in detail here; it suffices to say that they are not a major part of the explanation.

[5] This statement must be qualified to some extent because some proxy data was used for a few minor variables. A complete statement of the qualifications is omitted here for purposes of brevity.

[6] Chambers and Just (1979) present arguments that exchange-rate elasticities should not be tied directly to own price elasticities when cross price elasticities are omitted in estimation. The problem is that the exchange rate affects each of the other prices of traded goods. Even though each of these other prices may be individually unimportant and thus omitted in

estimation, the collective exchange-rate effect that comes through all other foreign prices can be important. This implies that the export demand equation must be in the form $Q_x = Q_x(P_m, E, X_x)$ or $Q_x = Q_x(P_m \cdot E, E, X_x)$ if P_m represents a small subset of all traded prices in order to capture the aggregate effects of exchange-rate variation. Chambers and Just (1981) show that these considerations are important for agricultural commodities. Estimated exchange-rate elasticities of US export demand for wheat, corn, and soybeans are all considerably higher than the corresponding price elasticities. Similarly, the reduced form exchange-rate elasticities of price are greater than 1 for all three commodities (see Table 2). Without the flexibility of this export demand specification with respect to the exchange rate, this type of overshooting phenomena cannot be detected.

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MODELLING THE INTERACTIVE EFFECT OF ALTERNATIVE SETS OF POLICIES ON AGRICULTURAL PRICES

by

Richard E. Just

ABSTRACT

This paper considers the various sets of policies that affect agricultural commodity prices. A number of general principles are proposed for econometric investigation of policy impacts on prices in sectors with heavy government intervention, frequent changes in policy regimes, significant international trade, substantial storage activity, competitive markets for productive assets, and concentrated world markets. For example, the importance of structural versus *ad hoc* or flexible specifications for modelling effects of qualitative policies (price or production limits) is emphasized. Four general sets of policies are considered: (1) domestic sector policy, (2) domestic macroeconomic policy, (3) foreign sector policy, and (4) foreign macroeconomic policy. The ability to identify the effects of each set of policies has progressively evolved in response to the commodity and macroeconomic instability that has occurred since the early 1970s. As a result, much broader models of agricultural price formation are both feasible and necessary. Principles for incorporating these broad sets of policy forces in agricultural commodity models are considered.