Simulation

THE PROBLEMS AND CHALLENGES FOR INTERNATIONAL COMMODITY MODELS AND MODEL BUILDERS

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Introduction

Researchers today are encountering overwhelming economic and methodological problems in specifying, estimating and simulating commodity models in an attempt to adapt them to our rapidly changing economic environment. These problems in fact become amplified when dealing with international commodity markets where the uncertainties of political and economic behaviour increase as do the variety of shocks to the system. Since our means of coping with these problems are limited, a substantial gap exists between the simplistic nature of our models and the complexities of international markets. This paper will first provide a background on methodology and problems; it will then offer suggestions as to how model builders can cope accordingly.

Background

By a commodity model is meant a quantitative representation of a commodity market or industry; the empirical relationships included reflect demand and supply aspects of price determination as well as other related economic, political and social phenomena.

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The methodological approaches taken to construct such models can differ considerably. Of the major methodologies described in Table I, econometric market models, spatial equilibrium models, and system simulation models are applied most often to international commodity makrets.

Common to these methodologies is a structure represented as follows :

(1) $D = d(D_{-1}, P, P^{c}, A)$

(2) $Q = q(Q_{-1}, P_{-\theta}, N, Z)$

(3) $P = p(P_{-1}, I/D)$

(4) $I = I_{-1} + Q - D$

World demand is explained as being dependent on prices P, prices of one or more substitute commodities P^{c}, and economic activity A. World supply also would depend on prices as well as natural factors N(such as rainfall)and a possible policy variable Z. A lagged price variable is included since the supply process is normally described using some form of the general class of distributed lag functions. These prices are also linked to the inventory/consumption ratio I/D in the price equation. The model is closed using the world market clearing identity which equates inventories with lagged inventories plus supply minus demand. Other possible explanatory factors, expectations variables, and the customary stochastic disturbance term are omitted for simplicity.

It should be noted that when the above model refers to national commodity behaviour, the inclusion of trade relationships gives it an international character. For example, if commodity exports are determined endogenously and imports are given, the identity (4) would be replaced by two equations.

TABLE 1

COMMODITY MODELING METHODOLOGIES AND THE MODELING PROCESS

Methodologies / Modeling Process	What do the Methodologies describe?	What quantitative method is used?	What economic behavior is specified	Examples of Commodity Applications a/
Market Model	Demand, supply, inventories interact to produce an equilibrium price in competitive or non-competitive markets	Dynamic micro econometric system composed of difference or differential equations	Interaction between decision makers in reaching market equilibrium based on demand, supply, inventories, prices, trade, etc.	Cobalt (92) Energy (130) Lauric Oils (51) Soybeans (261) Sugar (220) Tungsten (299)
Process Model	Demand and production determined within an industry, focussing on transformation from product demand to input requirements	Dynamic micro econometric difference equation system suitable for integrating linear programming on production side	Interaction between decision makers in industries, markets, national economies based on demand, inventories, production, investment, capacity utilization, commodity inputs, prices, etc.	Petroleum (227) Steel (269)
Dynamic Commodity Cycle Model - Industrial Dynamics Model	Demand, supply, inventories interact to produce an equilibrium price emphasizing role of amplifications and feedback delays	Dynamic micro econometric differential equation system which features lagged feedback relations and variables in rates of change	Interaction between decision makers in adjusting rate of production to maintain a desired level of inventory in relationship to rate of consumption	Aluminium (2) Broilers (33) Cattle (166) Copper (2) Hogs (142) Orange Juice (218)
World Trade Model	Imports and exports balance between regions given adjustments in income. Transmissions versus structure of trade approach depends on use of trade matrix	Macro/micro econometric equation system with equilibrium obtained in a simulation framework through an iterative procedure	Interaction between decision makers in markets and national economies in reaching equilibrium based on adjustments in imports, exports, prices and national income.	No disaggregated models at present
Spatial Equilibrium Model	Spatial flows of demand and supply and equilibrium conditions assigned optimally in equilibrium depending on configuration of transportation network	Activity analysis of a spatial and/or temporal form. Degree of complexity depends on endogeneity and method of incorporation of demand and supply functions	Interaction between decision makers in allocating shipments (exports) and consumption (imports) optimized through maximizing sectoral revenues or minimizing sectoral costs	Bananas (12) Broilers (32) Livestock (155) Oranges (215) Palm Oil (105) Wheat (317)
Recursive Programming Model	Production conditions and input revenue determined through primal, dual of linear program. Recursivity introduced through feedback component which includes profit, capital and demand	Activity analysis involving a sequence of constrained maximization problems in which objective function limitation coefficients depend on optimal primal/dual solutions attained earlier in the sequence	Interaction between decision makers in reaching market equilibrium involes adaptive inter-temporal processes related to production investment and technological change	Coal (39) Iron, steel (272) Wheat, corn, soybeans (309)
Systems Model	Demand, supply and other major variables and objectives considered as a complete system rather than a single market	Dynamic micro econometric equation system which when formed into a simulation framework is coupled with activity analysis and/or decision rules	Interaction between decision makers belonging to the system environment based on performance variables such as revenues, costs as well as market variables such as demand, supply.	Beef (21) Energy (85) Fish (124) Livestock (161) Multicommodity (265) Rice (243)

(5) $$X = x(X_{-1}, P, A_x)$$

(6) $$I = I_{-1} + Q + M - D - X$$

The econometric description of such models as further explained in Labys (1973) is of the form :

(7) $$AY + \sum_{\theta=1}^{k} A_\theta Y_{-\theta} + CX = U$$

where Y is a vector of endogenous variables, $Y_{-\theta}$ is a vector of lagged endogenous variables, X is a vector of exogenous variables, U is a vector of stochastic disturbances, and A and C are appropriate parameter matrices.

Many of the problems encountered recently in applying and adapting these models pertain to international as well as domestic commodity models, but our focus is on the former. Forecasting of commodity quantities and prices since 1972 has been a major problem for international models. Not only did forecast and actual values differ considerably but forecasts in nominal rather than real terms proved impossible because of rapidly increasing inflation, the rates of which varied considerably among nations. Relevant to this problem is that fact that the market structures underlying international models change more rapidly than do the structures inherent to domestic or macro models. The impact of this structural instability is the ready obsolesence of model parameters.

International models also suffered from specification error, particularly in the omission of monetary and speculative factors which increase in importance during periods of uncertainty. Fluctuations in exchange rates made price and income forecasts difficult, most models excluding these factors. Speculation principally in the form of futures trading also influenced prices.

The volume of futures trading increased noteably not only because of a shift away from less tangible to commodity assets but also because of hedging against exchange rate instability and general uncertainty. Models embodying free trade also were hampered because of actual or expected movements towards producer cartels.

Finally, the widening of price differentials between countries led to substitution patterns which most models could not duplicate, either because of improper specification or of a failure to link the model in a multicommodity framework. Inherent to these problems was a shift in the technological-ecological availability of commodities. International commodity inventories were extremely low; models which now had to explain supply independent of inventory adjustments failed because of their inability to explain production in terms of the climatic or other factors responsible for reduced output.

In discussing contributions which can help in solving some of these problems, a general review of commodity modeling developments has been avoided. This has been provided recently by King, by Cromarty and Meyers, and by Labys (1975). Instead emphasis is placed upon a set of particular challenges which we could hope to meet.

Improving Model Forecasts

Not much progress has been made in improving forecasts with international commodity models. Although characteristics of macro models which contribute to their forecasting efficiency have been examined on a continuous basis, no similar approach has been taken for commodity models. Teigen has compared the forecasting performance of prices for five models describing the U.S. beef-cattle market, but the contrasts drawn have been mainly with respect to times series or unobserved component forecasting methods. Of the results obtained which might be of interest, he found that forecasts from the commodity models were not superior to those based on the no-change or naive forecasting method (using monthly, quarterly, and annual data). This would confirm the results of Labys and Granger who not only compared a number of times series forecasting methods including that of Box-Jenkins (ARIMA), but also attempted to fit the price forecast equations optimally using spectral analysis to decipher the underlying price behaviour. However, we should remember that commodity models are superior for explaining market behaviour, while the time series methods are valuable for providing forecasts of a low cost nature. The former are also probably better able to cope with the changes encountered during a period of uncertainty.

Updating Model Parameters

A problem often responsible for poor forecasting performance in international models is that structural adjustments in the underlying markets result in changes in the level of model parameters (as distinct from deficiencies in specification). These changes can arise from adjustments in the response of economic decision units such as shifts in technology or in tastes and preferences. Similarly, they can stem from the approximations used for macro relations. Here changes in the relative importance of groups constituting the micro units of such a relation can upset the given weighting pattern and hence the assigned parameters.

One approach taken to counteracting these difficulties has been to assume that the estimation process will improve as more information is added. As an application of time-varying parameter methods, Freebairn would combine Bayesian estimation strategies with adaptive control theory. The updating relations used in his model of the U.S. beef market would thus be defined as recursive functions. Based on an equation containing a single dependent variable from the econometric model (7).

(8) $$y_t + B_t x_t = u_t$$

the parameter adjustment function would be of the form :

(9) $$B_{t+1} = H_t B_t + w_t$$

where H is a coefficient transition matrix and w is a stochastic vector. Integrating these factors into the model according to adaptive control theory, Freebairn analyzes the selection of optimal beef import quotas. While some of these outcomes are reported in terms of control policies by Rausser and Freebairn, it would be useful to learn how the updating procedure could be used to improve basic model forecasts since 1972.

Other approaches to the time-varying parameter problem include systematic (non-random) variation methods and random-coefficient methods. Within the first category, Goldfield and Quandt assume that a model's parameters can change discontinuously, suggesting a solution which involves "switching regressions". For commodity applications, it is probably more relevant to consider the work of Cooley and DeCanio based on continuous parameter adjustment. Here the parameters are considered as being divided into permanent and transitory components :

$$(10) \qquad B_t = B_t^p + u_t$$

$$(11) \qquad B_t^p = B_{t-1}^p + v_t$$

where

$$\text{cov}(u) = (1 - a)s^2 \Sigma_u$$

$$\text{cov}(v) = as^2 \Sigma_v$$

For forecasting, the parameter process can be considered one period past the sample

$$(12) \qquad B_{T+1}^p = B_t^p + \sum_{s=t+1}^{T+1} v_s$$

$$(13) \qquad B_t = B_{T+1}^p - \sum_{s=t+1}^{T+1} v_s + u$$

Some results obtained by the authors in dealing with supply functions for cotton and wheat have implications for commodity modelers. First, systematic variation in parameters was discovered which could be explained. And second, this approach provided a means to test the expectations formation by farmers which would be valuable for making annual forecasts. Depending on whether the aggregate supply of a country is a minor or a major portion of world output, the expectations formation is further reflected in the permanent and transitory components of price variation.

The second or random-coefficient method also has received commodity application. In particular, Ong has used it to improve forecasts of daily quantities and prices in the U.S. hog market.

Including Monetary Factors

Another problem of international models relating to specification has been their frequent omission of monetary factors, namely inflation and exchange rates. The accepted procedure for incorporating the influence of inflation in a commodity model has been to deflate commodity prices by an index reflecting movements in the general price level, P/P^i. Such an index as represented in the GNP deflator or the wholesale price index should be well constructed and predictable. Recently Popkin has provided some guidelines for formulating such an index based on primary commodity activity.

Lovasy, however, has argued that the price index should be included directly into a given commodity price relationship, for example

$$P = p(P^i, I/D) \qquad (14)$$

This implies that commodity prices do not vary in a one to one fashion with the general price level but only in proportion. Yet a full determination of the influence of the general price level would require examining inflationary factors that shift demand as well as supply. On the demand side, inflation forces portfolio managers to switch from monetary to physical or more tangible assets. Income distribution can also be influences in a way that would lead to a shift in patterns of commodity consumption. However, these phenomena cannot be easily modeled; nor can their influence on supply be easily specified.

A better possibility exists for including the impact of exchange rate changes, since the latter can be introduced directly in demand, supply, or trade equations (leaving aside commodity feedback effects on the economy). These equations typically feature national price series and hence national currencies. Equilibrium model solutions are obtained by converting the price series to a common currency prior to estimation. In doing this, Bjarnason et.al. argued that one should use a base year exchange rate (and base year deflator if necessary), because yearly rates do not satisfy the "purchasing power parity theory", i.e. that exchange rates should vary directly with the purchasing power of a nation.

Elliott, however, prefers estimating the equations in national currencies and then converting the equations to a common currency by multiplying the price parameter by the assumed exchange rate. For example, the demand equation for country i would include the exchange rate e_{ij} relative to country j

$$D_i = d(e_{ij}P_i, A_i) \tag{15}$$

where e_{ij} can vary annually. Inflation could also be included by deflating the national price series stated in national currency prior to estimation. A related empirical study by Lamond has shown that cocoa consumption for different countries could possibly change by as much as 15% as a result of exchange rate adjustments. Dominguez also has constructed a general arbitrage incentive model for cocoa, which measures the interspatial price relationship between London and New York as a consequence of the 1967 pound devaluation.

Integrating Speculative Phenomena

Speculative and futures market activity which normally increase during periods of economic uncertainty can influence price behaviour and hence price forecasts. Evidence of this influence since 1972 has been furnished by Labys and Thomas, who studied the speculative and price behaviour of nine commodities traded on futures markets in London and New York.

This would demand an integration of futures market behaviourial relationships with those typically contained in a commodity model. In fact, such an integration can be based on two notions prevalent in received theory : (1) that futures markets accommodate the intertemporal allocation of commodities; and (2) that they also provide a forward pricing function. Both of these are consistent with the supply of storage theory, whereby futures prices can be substituted for expected prices in

(16) $$PF - P = P^{e}_{+1} - P = f(I/D)$$

with inventory coverage providing a link between the two. Among recent empirical work confirming this relationship, Kofi has shown that the forward pricing function is more evident for markets with inventories of an annually continuous rather than a discontinuous nature, e.g. wheat versus potatoes. And for the latter, Peck has shown that the pricing function improves as producer utilization of a futures market increases.

Based on work by Peck as well as by Labys and Granger, the commodity model (1)-(4) can easily be expanded to include futures market activity. The price equation would now include the futures price PF of contracts for delivery in k.

(17) $P = p(PF_k, I/D)$

The demand and supply of futures contracts would be roughly equivalent to the level of net long speculative commitments S^n and net short hedging commitments H^n, respectively

(18) $S_k^n = s(PF_k, R)$

(19) $H_k^n = h(PF_k, PF_k - P, I)$

where R is an appropriate interest rate. We still await evidence regarding the performance of such a model. For those international futures markets where speculative and hedging commitments are not reported, Wymer has devised an alternative approach based on his continuous disequilibrium model of the world sugar market.

Linking Models

What the previous two sections reveal is the need to relate commodity models to the broader economic environment. During the recent period, errors in macro forecasting as well as micro or commodity forecasting occurred because of a failure to relate the two. Research in linking macro and micro models which has taken place suggests that there is more than one philosophy to be followed. As an example, a class of "commodity oriented development models" proposed by Labys and Weaver would interrelate a macroeconometric planning model for a developing country with several commodity models. For a country which is a major producer of one or several commodities, the impact of changes in related domestic investment strategies could be evaluated by linking the export sector of the macro model to commodity models which generate prices based on world market conditions.

More germane to the forecasting problem is the linkage of a number of macro or regional models with a number of commodity models in an international context. As envisioned for the LINK model, Adams would relate commodity demand with economic activity in the developed countries; commodity models would yield prices determining export and import prices, and the resulting commodity export patterns would define foreign exchange earnings for the developing countries. An iterative procedure would assure consistency between the macro model variables such as income and the commodity quantities and prices. Since this project would require a substantial number of commodity models, Behrman and others have begun constructing minimum standard commodity models. That is, mini models designed to emulate market activity by including only the major international commodity characteristics.

Such models also have provided the basis for work by Hicks at the IBRD pertaining to the SIMLINK model system. More than 20 commodity models have been integrated with a macro-econometric regional income determination framework. Import demand for the commodities stemming from economic activity in the developed regions is compared with commodity exports from the developing regions, price levels being a function of the imbalances between the two. Not only can commodity prices be forecast in this broader context but multicommodity substitution patterns can be explored.

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commercial policies. The latter can include fixed import duty, ad valorem import duty, variable import levy, fixed export subsidy, fixed import quota, percentage import quota, bilateral quantity agreement, and domestic price support or acreage allotment. Examples of the impact of such policies on long term forecasts can be found in the spatial equilibrium trade models of Bawden related to wheat, feed grains and beef and of Schmitz and Bawden related to wheat. No results have appeared concerning how the forecasts of such models have held up over the recent period. With respect to support price and acreage restriction policies, Houck et.al. have shown how to combine these policies into an "effective support price" variable. The impact of these policies as related to soybean support prices as well as to crops competing with soybeans are evaluated in the soybean model constructed for this purpose.

A second approach would consider government intervention which has continued for a sufficiently long time that it exhibits certain regularities. These can be described as behaviourial relationships and integrated into the model. In this case, the government or policy variables become endogenous. Among the theories available for explaining this behaviour, one assumes that the political regularities are manifestations of optimizing behaviour on the part of policy makers. This approach has been contained in simulation studies which attempt to maximize some social welfare function. An approach advocated by Zusman (p.2) as being more realistic would view "political behaviour as a process of accommodation among conflicting interests, where the attained political-economic equilibrium represents a simultaneous solution to the economic system and the associated political conflict". To illustrate this view, he further presents a sugar model embodying the political relationships according to the theory of cooperative games, with implications given for Israel's sugar import policy. No forecasting results of applying this method have appeared.

Conclusions

This paper has focussed upon a number of econometric approaches which can be taken in constructing and applying international commodity models during a period of major economic change. We have thus examined the assumptions underlying the models as well as the responses that model builders can make. But the underlying premise has been that such models will remain useful for explanatory and forecasting purposes. Given present limits, this paper could not deal with a number of other important factors. For example, it would be useful to study the integration of public forecasts, the use of communications technology for more rapid updating, the benefits of modeling climatic conditions, the specification of non-competitive market adjustments, the introduction of better measures of risk and uncertainty including disequilibrium conditions, the analysis of intercommodity substitution, and the effects of changes in regional trade groups. But the approaches discussed here should offer immediate and practical possibilities for model revision.

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