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General Economics Division
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We gratefully acknowledge the comments received from our colleagues.

This paper describes work on the determination of primary commodity prices in world spot markets and in trade. Reduced-form equations for four product group price indices are estimated as functions of OECD activity, world prices, interest rates, exchange rates, oil prices, and other variables. The equations are tested for stability on their own and within the OECD INTERLINK system. The effect of exogenous shocks upon primary commodity prices is studied as well as the effect of commodity price changes upon OECD inflation and activity. The commodity price equations enter in the INTERLINK system through export unit value equations, the estimation of which is described in the paper.

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Cet article décrit les travaux entrepris sur la détermination des prix des produits de base sur les marchés mondiaux au comptant. Pour quatre groupes de produits on a estimé des formes réduites des indices de prix sous forme de fonctions de l'activité de l'OCDE, des prix mondiaux, des taux d'intérêt, des prix du pétrole, des taux de change et d'autres variables. Ces équations sont testées pour leur stabilité et sont aussi testées à l'intérieur du système INTERLINK de l'OCDE. On étudie les effets de chocs introduits via les variables exogènes sur les prix des produits de base ainsi que la transmission des variations de prix des produits de base sur l'activité et les prix à l'intérieur de la zone OCDE. Les équations de prix des produits de base sont introduites dans le système INTERLINK par le biais des équations des valeurs unitaires des exportations dont l'estimation est décrite dans cette étude.

TABLE OF CONTENTS

TABLES

FIGURES

ANNEX TABLE

FIGURE

COMMODITY PRICES IN INTERLINK

I. INTRODUCTION

1. A number of commentators have come to assign a considerable importance to the role of primary commodities in the world economy on several counts. A "hog cycle" of commodity prices whereby supply and investment respond negatively to low prices, ensuring higher prices later at any swift increase of world demand, has been alleged to be an important source of instability in the world economy (1). The steep decline of commodity prices in recent years has also been credited with the major role in slowing OECD inflation (2); an implication is that the slowdown could be temporary if commodity prices rise with faster growth. The debt crisis, affecting many less-developed countries which are primary-product exporters, has made their terms of trade, and so the level of real commodity prices, a matter of concern for OECD policy-makers. Hence the effect of OECD policies on these prices has become an urgent topic of analysis. This paper describes work to endogenise commodity prices in the Secretariat's world economic model INTERLINK. This is intended eventually to assist the Secretariat in analysing the issues noted above. Part I gives an overview of the work and describes the modelling strategy. Part II gives empirical results for commodity-price equations including their single-equation simulation characteristics in INTERLINK. Part III reports results for export unit-value equations.

2. To provide a context for the results quoted in this paper the principal uses of the INTERLINK system are recalled. One is to ensure the international consistency of the OECD's twice-yearly forecast. The model is "locked" on to baseline forecasts produced by country specialists, through the calculation of relevant add-factors. It is then solved to get an internationally coherent forecast taking all linkages into account. Formerly, a baseline forecast of commodity prices was made "off-model" and was used to inform forecasts of export unit values for food and raw materials of OECD countries and non-OECD zones. The model locked on these too by calculation of necessary add-factors. One aim of the present work was to investigate how far this forecasting could be done more on-model through the explicit manipulation of add-factors to commodity-price equations. The present work does not encompass energy prices, which are dealt with by "technical assumption" in the forecast. They are normally assumed to remain unchanged.

3. A second purpose of the model is simulation analysis, particularly of policy changes. The impact of changes in OECD activity and inflation on world commodity prices and their feedback on the OECD economy is a potentially important linkage mechanism in a world model. In past versions of INTERLINK

it has been dealt with by specifying export unit values for food and raw materials to be functions of OECD GDP at constant prices and OECD inflation. The equations were identical for all countries and non-OECD regions. Interpreted as a reduced form, the specification implied that, for every country, export unit value indices were related with an unlagged unit elasticity to world spot commodity prices, themselves functions of OECD GDP volume and GDP deflator changes. Other explanatory variables or empirically-based dynamics were lacking.

4. The focus of work on commodity prices in the OECD Economics Department is therefore very aggregate and macroeconomic, seeking some quantitative indication of how commodity prices as a set interact with the world economy in broad terms. The operation of individual commodity markets or their stabilisation is not the focus of concern. The advantages of a world model for such work is evident. Commodity prices are likely to remain substantially exogenous in even the largest national macro-model. Furthermore, refined models of individual commodity markets in all their institutional detail will miss out the feedback effects of those commodity prices on the world economy (3).

The strategy for endogenising commodity prices

5. It was sought to endogenise commodity prices in the simplest and most economical way possible. The approach followed was to model a series of "world" prices for groups of commodities. A reduced-form equation for each price is derived from a simple theoretical model of a storable-commodity market. Commodities have been grouped into four sets: agricultural raw materials, food, metals and minerals, and tropical beverages. Price indices for these groups of commodities, determined in a separate block of the model, are then passed to the models for different countries and zones in the system. The "world" prices become explanatory variables in the export unit value equations of individual countries. The trade model transmits the effect of commodity price variations into import prices. Domestic wage/price blocks further transmit them into domestic costs and prices. These in aggregate influence the commodity price equations directly and the circle is complete. Figure 1 is a flow chart showing the main influences in the model.

6. The specification and estimation of the reduced form commodity price equations are dealt with in Section II. Essentially they are linked to the rest of the model by using as inputs certain aggregate variables for OECD activity, monetary conditions, and, implicitly, inflation. The three other parts of the linkage system are:

a) The influence of commodity prices on export unit values;

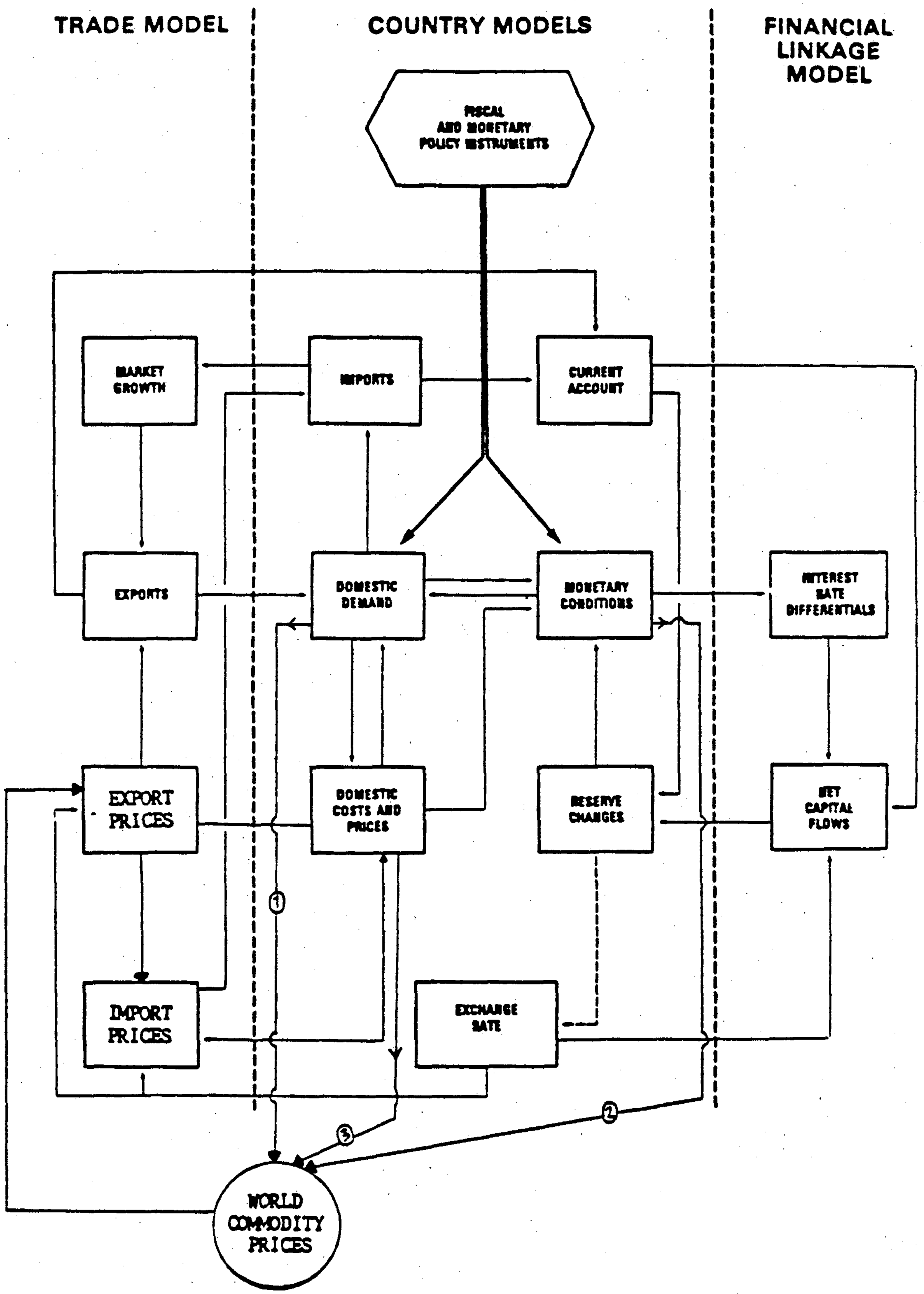
b) The effect of export unit values on import prices;

c) The influence of import prices on domestic prices and costs and thence on commodity prices in further rounds of reaction.

Unit value equations are described, and regression results reported, in Section III below. Export prices are translated into import prices by the trade model according to the formula:

Figure 1

INTERLINK TRADE AND FINANCIAL LINKAGES



$$\%\Delta PM_{jk} = g(L)\sum_i w_{ijk}^{t-1} \; \%\Delta PX_{ik} + \alpha \left[\frac{\%\Delta PGDP}{\%\Delta WPGDP}\right], \qquad \alpha = 0.1$$

where: PX_{ik} = export unit value of country i, U.S. dollar index for goods in class k

PM_{jk} = import price of country j, U.S. dollar index for goods in class k

w_{ijk}^{t-1} = market share weights as of previous period for k goods

g(L) = distributed lag function

PGDP = domestic cost variable, GDP deflator in country j, local currency

WPGDP = world cost variable, OECD GDP deflator in dollars divided by the exchange rate of country j.

The presence of the distributed lag function g(L) reflects the transportation lag between the export of a good and its being recorded as an import. In effect, this means that projected import prices are a function of export prices for both the current and previous period. This delay is, on the basis of recent empirical evidence, assumed to be of the order of 2 1/2 weeks (4). In the case of manufacturing, some small allowance is also made for the influence of domestic prices on the prices of imports. For consistency reasons this adjustment is made identical across all countries (5).

7. Import prices affect domestic inflation via several channels in the larger country models of INTERLINK. Imports enter directly into expenditure aggregates and domestic expenditure deflators are weighted averages of domestic and foreign inflation. Margins of domestic producers and hence domestic output prices are also influenced by the prices charged by foreign competitors of tradeable goods. Consumer inflation enters wage determination; the specification of the wage equations is described in Coe and Gagliardi 1985 (6). As domestic production, unlike trade, is not broken down by commodity, disaggregated effects of commodity market prices on domestic prices in producer countries are not directly accounted for.

8. The procedure adopted is in some respects an <u>ad hoc</u> one adapting to the current structure of the model, but it echoes some features of reality. Recorded prices of many commodities are those established on "world" spot markets. These are in practice residual markets, while much trade takes place on the basis of long-lived bilateral contracts between purchaser and supplier. The free-market prices are established by the activities of speculators in forward markets and by transactions between those suppliers and buyers whose requirements have not been met by bilateral contracts. Such market prices will therefore reflect unexpected developments in supply or in demand (owing to higher or lower activity than anticipated, for example), as well as speculative buying and selling on the basis of news. Nonetheless, the prices established in such markets are very often used as the basis for pricing of bilateral contracts. For this reason, it may not be unreasonable to make actual export prices derivative of current and past "world" commodity prices.

II. MODELLING AGGREGATE COMMODITY PRICES

i) Data and the approach to specification

9. Two published sets of indices were used for the four commodity groupings selected as the basis for the price indices to be modelled. One is that of UNCTAD which weights commodities according to the exports of less developed countries. These indices are directly relevant to the export prices of the non-OECD zones in INTERLINK. Another set of published indices is those of the Hamburg Institut für Wirtschaftsforschung (HWWA); these weight commodities according to their position in imports of OECD countries (7). Given intra-OECD commodity trade, these should be more useful in explaining OECD export prices of commodities than the UNCTAD indices, and so it has proved. Table 1 gives the weights of different commodities in the indices used (8). As each index dominates the other in "determining" export unit values for one group of countries, both are modelled for incorporation in INTERLINK.

10. A necessary assumption in what follows is that a price index of one of those groupings can be modelled like the price of a homogeneous storable commodity in a single market. Aggregation biases are ignored. The starting point is a simple partial equilibrium model of price formation in a storable materials market. It involves three behavioral equations: consumption demand, inventory demand and supply. Demand and supply are treated as functions of price and a set of exogenous variables. Storage demand depends on the expected capital gain (expected future price minus today's price both relative to a general price index minus carrying costs, chiefly interest rates) and exogenous variables. Stock equilibrium is assumed and the equilibrium condition ensures that inventory and consumption demand equal supply:

$$D_t = d[(L)P_t, (L)S_t, (L)Y_t, T, u_t]$$
$$Q_t = q[(L)P_t, (L)X_t, T, v_t]$$
$$I_t = i[(P^e_{t+1}-P_t), r_t, I_{t-1}, (L)W_t, z_t]$$
$$D_t + \Delta I_t = Q_t.$$

The endogenous variables are:

D_t = consumption demand,

Q_t = production,

I_t = inventories,

P_t = current spot price in dollars relative to an index of the overall price level ("real" price)

P^e_{t+1} = expected "real" spot price for period t+1.

The exogenous variables are:

Table 1

COMPARISON OF UNCTAD AND HWWA INDICES

	UNCTAD weights: dollar value of LDC exports		HWWA weights: import trade of industrialised countries
Food	100	Food	100
Sugar	39.3	Maize	32.9
Rice	11.1	Soyabeans	26.3
Maize	11.2	Wheat	19.7
Soymeal	10.6	Barley	5.3
Bananas	8.3	Rice	3.9
Beef	7.1	Coconut, palm,	
Wheat	5.9	sunflower oil	9.2
Others	6.5	Others	2.7
Tropical beverages	100	Tropical beverages	100
Coffee	71.4	Sugar	39.8
Cocoa	18.4	Coffee	30.1
Tea	10.0	Cocoa	10.8
		Tea	4.8
		Tobacco	15.7
Agricultural raw materials	100	Agricultural raw materials	100
Tropical timber	33.7	Wood pulps	36.6
Cotton	32.5	Sawn wood	28.7
Rubber	25.3	Cotton	12.9
Others	8.6	Rubber	7.9
		Others	13.9
Minerals	100	Minerals	100
Copper	33.3	Copper	28.7
Iron ore	21.0	Iron ore	34.3
Aluminium	13.1	Aluminium	10.2
Tin	12.1	Tin	4.6
Phosphate rocks	10.9	Steel scrap	9.3
Others	6.4	Nickel	5.6
		Lead	2.8
		Zinc	4.6

Y_t = consumers' income or activity level;

S_t = real price vector of substitute products;

T = time trend representing technical change in the supply equation and technical change and/or trends in taste in the demand function;

X_t = other variables which are relevant to supply such as interest rates, productive capacity, cost of inputs, etc;

r_t = interest rates;

W_t = exogenous variables relevant to the market for storage such as insurance rates;

u_t, v_t, z_t = error terms assumed to be normally distributed with zero mean;

(L) indicates a distributed lag in the relevant variable.

11. The expected signs of steady-state partial derivatives with lags worked through are as follows:

$d_p < 0$, $d_y > 0$, $d_s > 0$, $q_p > 0$, $q_T > 0$, $i_{p^e} > 0$, $i_I < 0$, $i_r < 0$, while q_x, i_w and d_T are indeterminate. It is assumed the system can be solved to yield a reduced-form equation in the price:

$$P_t = p(\,(L)Y_t,\ (L)P_{t-1},\ (L)X_t,\ T,\ \Delta P^e_{t+1},\ (L)S_t,\ (L)r_t,\ (L)W_t,\ I_{t-1},\ u_t,\ v_t,\ z_t) \qquad [1]$$

where expected signs are: $p_Y \geqslant 0$, $p_{\Delta p^e} > 0$, $p_r < 0$, $p_I < 0$, $p_s > 0$ and other partial derivatives are indeterminate.

12. Several unobservable variables appear in these equations -- price expectations, productive capacity, existing stocks and costs of production. Productive capacity, and existing stocks are both unobservable because data are not collected at the necessary level of aggregation. They are a function of current and past investment activity and as such may exhibit cyclical as well as secular movements.

13. To the extent that the unobservable supply-related variables are correlated with other variables appearing in the model, the estimated coefficients will be biased. Even more probable is that some of the omitted variables (in the vector X_t for example) are stock variables reflecting capacity levels and hence the course of past fixed investment, just as the omitted variable in lagged inventory levels embodies the effect of past inventory investment. That investment was no doubt a function of then-current price expectations and profitability. Low prices implying low profits could retard inventory and capacity creation leading to higher prices later and vice versa. When the stock variables in X_t are omitted owing to data constraints, it is therefore probable that the equation should be supplemented by more terms in lagged values of the dependent and independent variables, reflecting the investment cycle. Failure to specify the appropriate, probably

lengthy, lag structures will generally lead to high-order autocorrelation in estimated residuals.

14. On the other hand, all of these influences may be relatively unimportant where speculation dominates the market. Many commodity markets are dominated by inventories which can represent more than a year's production. Changed demand for inventories (which themselves change relatively slowly) may then be responsible for most variation in prices. If that demand is mainly a function of expectations about future prices, altering as a function of randomly arriving bits of news, price movements will have a large random element and may show little autocorrelation after all. This was treated as an empirical matter.

15. The chief assumption made about price expectations is that they may be represented as a forecast based on a view of prices as a general stochastic process on a stationary series with q moving average terms and r autoregressive terms. This series can then be represented:

$$(1-\phi 1.B - \ldots - \phi r.B^r)P_{t+1} = (1-\theta 1.B - \ldots - \theta q.B^q)e_{t+1},$$

where B's are backward shift operators and e_t's are forecasting errors or unanticipated disturbances to the price process. The expectation of e_{t+1} is zero and past forecasting errors are known values so the expectation of P_{t+1} can be reformulated as:

$$P^e_{t+1} = \phi 1.P_t + \phi 2(B)P_{t-1} - \theta 1(B)e_t. \qquad [2]$$

16. The distributed lag term in the dependent variable of the reduced-form price equation [1] (derived from lagged adjustment of demand and, particularly, supply to price) thus is overlaid with other autoregressive elements related to the assumed process of expectation formation. In addition, the equation could acquire a moving average error process $\theta 1(B)e_t$ as well as the hypothesised white-noise error, $u_t + v_t + z_t$.

17. The other assumption that could be made is that expectations are "rational", so that $P^e = P+\mathcal{E}_t$ where $\mathcal{E}$ is a white noise error process and $\mathcal{E}_{t+1} = 0$. The reduced-form equation then becomes:

$$P_t = p(\ (L)Y_t,\ T,\ (L)P_{t-1},\ (L)X_t,\ P_{t+1},\ (L)r_t,\ (L)W_t,\ (L)S_t \\ I_{t-1},\ u_t,\ v_t,\ z_t,\ \mathcal{E}_t) \qquad [3]$$

This can be estimated by an errors-in-variables approach using the value of the real price with a one-period lead (similar methods were used to estimate exchange-rate equations for INTERLINK) (9). The practical usefulness of such an approach will be greater when the model acquires software facilitating rational expectations solutions.

18. Equations like [1] determine the real price. However, it is necessary to take account of the fact that real prices can vary with the inflation rate in the short run. This could reflect temporary money illusion due to information or learning lags, the influence of contracts fixed in nominal terms, aggregation problems when dealing with aggregate price indices or the influence of omitted variables correlated with inflation.

19. There is another nominal or "numeraire" effect to be considered. Commodity price indices reflect prices in dollars. These would be expected to change with the exchange rate of the dollar. In other words, the "real" price is the price in a basket of currencies where the basket weights are given by the importance in trade and production of various countries and their currencies. This real price, being determined by the "real" factors specified in [1] should be invariant to exchange-rate movements except insofar as those imply real changes in the market. However, there is some possibility of a "numeraire effect" whereby dollar prices do not adjust instantly to changes in the exchange rate so that, for a period of some months at least, exchange-rate movements are not fully offset and hence affect the real price. In addition, the weights of different currencies in the aggregate OECD general price index are probably not those appropriate to deflation of commodity prices.

20. An attempt was made to take account of these factors by defining the general price level in terms of a dollar price index. That was done by calculating an OECD GDP price deflator in dollars. Nominal GDP of each OECD country is converted to dollars at the current exchange rate. These nominal GDPs are summed and divided by the sum of constant-price GDPs (GDPV) converted to dollars at the exchange rate of the base year of the index:

$$\text{i.e.} \quad PG = \frac{\sum_i GDP_{ti}.Exch_{ti}}{\sum_i GDPV_{ti}.Exch_{oi}}$$

where PG is the OECD price level, i is an index of all OECD countries, t is a time subscript and t = 0 indicates base-year. $Exch_i$ is the exchange rate of country i expressed as US dollars per unit of local currency.

21. This price index will clearly vary with the dollar exchange rate. If the dollar appreciates ($Exch_i$ falls for all i $\neq$ USA), then PG declines. If homogeneity between the nominal commodity price and PG is enforced, the theoretically appropriate long-run behaviour of commodity prices, with an absence of money illusion, is assured -- abstracting from weighting questions. Temporary numeraire effects could be reflected in a lagged adjustment of commodity prices to the general price index.

22. It is clear, unfortunately, that the type of reduced-form price equation to be estimated will not permit the identification of the parameters of the hypothesised structural system. In particular, it will not be possible to disentangle dynamic adjustment in the supply and demand equations from expectation-formation processes. Where the same variable occurs in supply and demand equations there are also identification problems. Furthermore, because the equation reflects the influence of both supply and demand curves, short and long run, it is generally difficult to have firm expectations about even the sign of the coefficients of many explanatory variables.

ii) Estimation methods

23. The equations to be estimated are in a number of respects not very promising for routine regression techniques. In the first place, there is reason to believe that the dependent variable may be correlated with long lags on itself yet the length and structure of the lags are not known *a priori*. Moving-average errors may also be present. In general, it seems improbable

that any parsimonious regression equation would have white noise errors. A strategy of over-parameterisation, of specifying a most general equation embodying many lags, is normally approved in modern econometrics. Here, however, it is likely to fail because of the complexity of the most general specification and the multi-collinearity between different variables and different lags of the same variable. Because of this a mixed procedure was followed of attempting to combine classical regression analysis with techniques of causality analysis.

24. The estimation of equations like [1] used regression techniques but other time-series techniques were used for three purposes:

- Filtering and cross-correlation of time series was used in an attempt to get some idea of causal ordering and to aid in identifying the appropriate lags in the subsequent regression equation; these cross-correlations are of some interest in their own right (see below);

- Box-Jenkins techniques of model identification were used on the regression residuals of equations; this was to find any regularities not explained by the explanatory variables and in particular to identify any long cycles (autocorrelations at long intervals) in the residuals that would point to omitted supply effects, particularly investment cycles;

- ARIMA models of real commodity prices were also constructed as a benchmark; to ensure that the regression equation contained all the information captured in the ARIMA model, fitted values of the latter were tested as additional explanatory variables in regression equations; forecasts of ARIMA and regression equations were also compared.

25. The next section (II, iii)) gives results of empirical work. The first part reports the tests for "causality" in the system. The second part reports regression results for selected equations. The third part discusses stability forecast and other properties of the equations.

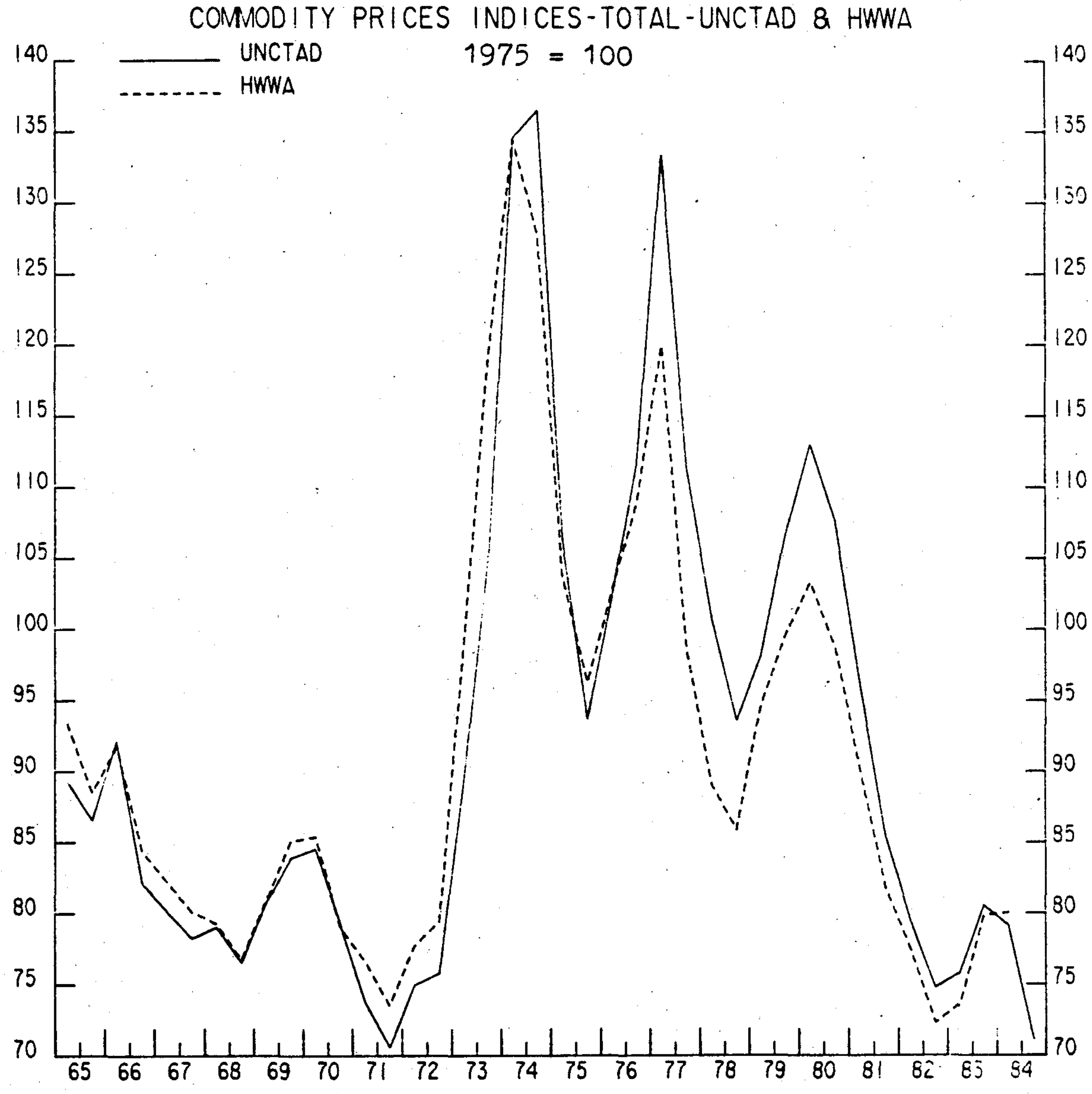
iii) Empirical results

a) Causal ordering of real commodity prices and determinants

26. Graphs of the UNCTAD and HWWA real price indices are in Figure 2. In broad terms, the real price developments have the same pattern in both indices. The composite indices indicate a downward trend in real prices which seems chiefly to be due to a down-trend in minerals prices. Generally, any trends are dominated by the large swings of the 1970s, resulting in the present low level of prices.

27. Some of the peaks on the chart were the result of supply-side shocks that would not be captured by any of the variables included in the specification. Hence, a number of *a priori* dummy variables for supply shocks were included in the food and tropical beverages equations. The shocks allowed for are the Russian grain harvest failure (1973-74), the Brazilian coffee frost (1976, 1977:1) and the sugar crop failure (1980). The dummies

Figure 2


COMMODITY PRICES INDICES-TOTAL-UNCTAD & HWWA
1975 = 100
UNCTAD
HWWA
140
135
130
125
120
115
110
105
100
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90
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Figure 2 continued

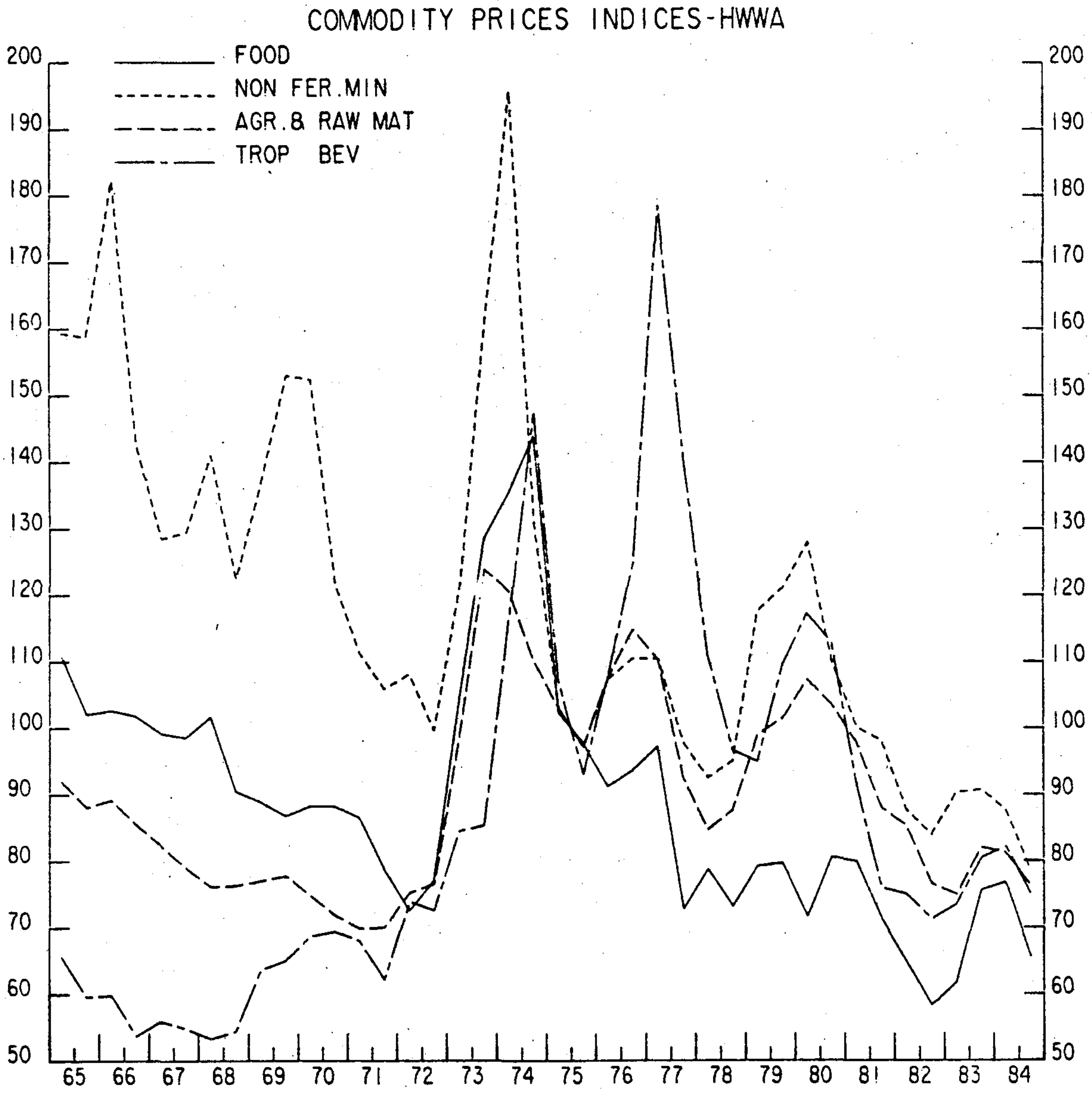
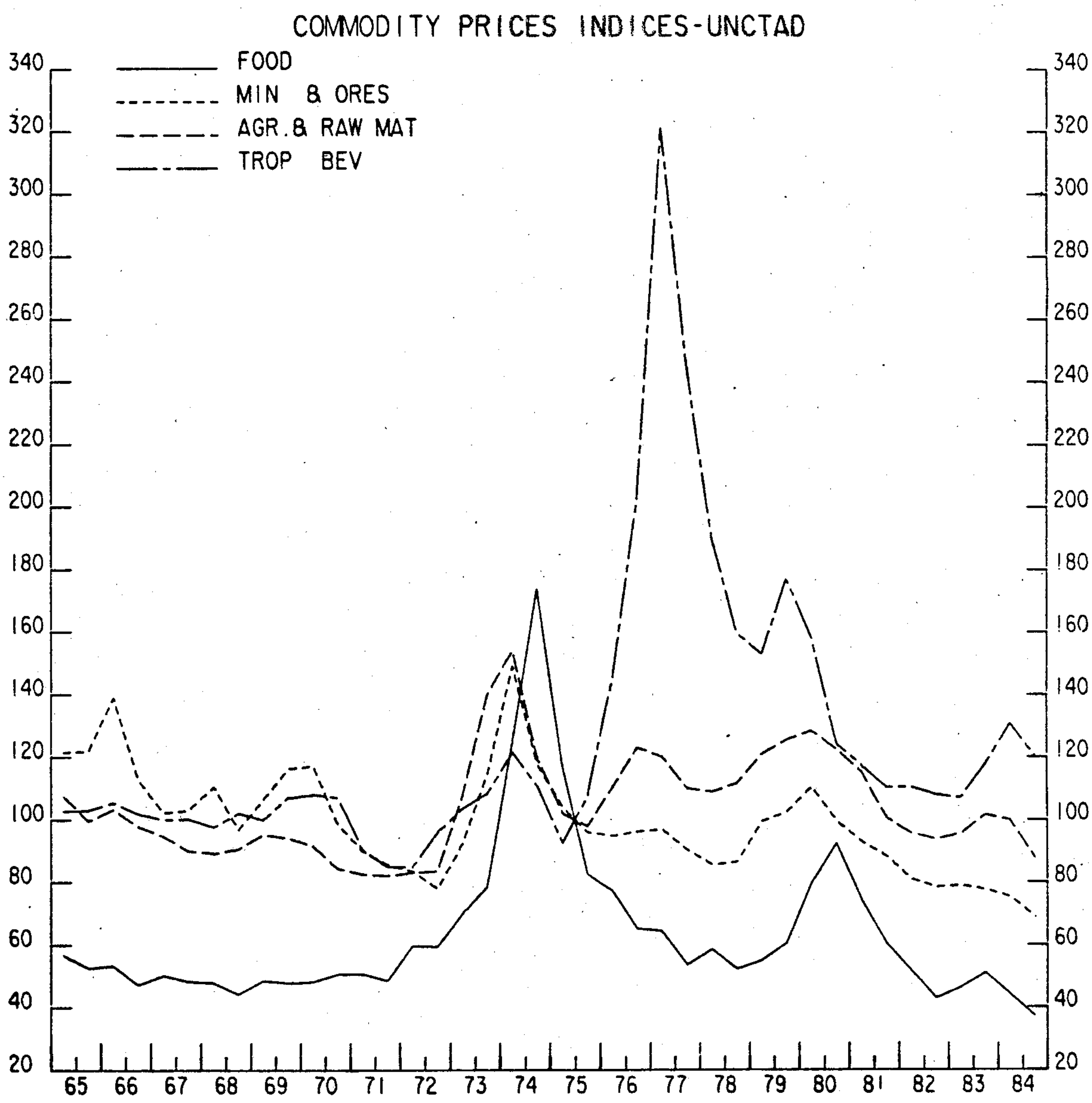


Figure 2 continued



Note: Real prices (nominal index deflated by OECD prices), base year = 1975.

were set in the light of prior knowledge and do not always coincide exactly with peaks in the series. The coffee frost, for example, struck in mid-1975. Its effects became apparent in the season March 1976 to March 1977, for which the dummies were inserted.

28. As commodity prices are often determined on speculative markets, they could turn out to be speculatively efficient and to follow a random walk. This may well hold true for daily quotations of actual commodity prices though period-average prices may show a moving-average structure as a result of time aggregation. It is unclear how aggregation across commodities into indices would affect the time series. At any rate, for all indices examined an ARIMA model was found which dominated the random walk.

29. The results for ARIMA models reported in the Annex (Table A1) relate to the UNCTAD and HWWA price indices deflated by an aggregate GDP deflator for the OECD. The HWWA indices seem to follow a first or second-order autoregressive process, whereas UNCTAD price index models are of the form of a mixed or moving average process. The fits (R^2) of the models lie between 0.65 to 0.84 in UNCTAD price index models and between 0.51 and 0.81 in the case of HWWA.

30. Univariate ARIMA models were also estimated for a series of independent variables. The residuals of the ARIMA models for commodity prices were cross-correlated with those of the other variables. The results are graphed in Figure A1 in the Annex. Significant cross-correlations can be taken to indicate that one variable is Granger-causing another. This form of "causality" test, proposed by Haugh and Pierce (10), is in some sense more severe than those proposed by Granger and Sims as independent filtering of each variable has been carried out (11). Several writers have argued that the causality test applied in this form is prone to the error of not finding a relationship between two variables, even when one exists; the test is only unbiased when a given variable, X, is uncorrelated with all other variables determining the other variable being tested, Y, which is certainly not the case here (12). The test is therefore powerful in establishing that series are not independent but the finding that series are independent cannot be treated with great confidence.

31. Annex Figure A1, showing cross correlations between commodity-price residuals and those of six of the explanatory variables, should be interpreted in the light of these warnings. The sample size of 36 is also small for this type of analysis. Here the focus is on apparent influences on commodity prices rather than the influence of commodity prices on other variables (though cross-correlations both leading and lagging are shown in the Annex charts). When identifying significant lags for the level-form equations, it is worth noting that the ARIMA models of the explanatory variable are transformed by differencing to ensure stationarity.

32. There is generally an identifiable effect of innovations in activity on commodity prices, with broadly similar effects on both indices. Interest rate effects are also usually present, but the adjustment process from interest rate changes to price changes takes longer than in the case of activity changes, presumably reflecting the fact that interest rate effects work through the commodity stock adjustment process, delaying the impact on prices. Generally, the correlation of prices and the effective exchange rate of the dollar is significant at the same intervals as those for the interest

rate. This is likely to reflect the effect of interest rates on exchange rates rather than a genuine effect of exchange rates on the commodity prices.

33. Unlike activity, interest rates and exchange rates, inflation has no clear pattern of influence on real commodity prices, reflecting the absence of money illusion in commodity spot markets. However, significant cross-correlations were found with UNCTAD mineral and HWWA raw materials indices with lags 4 and 3, respectively.

34. The interpretation of the Haugh-Pierce results concerning the real money supply is somewhat ambiguous. An acceleration in real money supply clearly has significant cross-correlations with real prices, but the sign of these changes with the lag. In most cases, correlation is negative at lags 0 to 1, but then becomes positive at longer lags (4 to 5).

35. Although the Haugh-Pierce analysis seems to shed some light on the interaction between commodity prices and some macroeconomic variables, the results must be interpreted with care. Given the degree of differencing required to induce stationarity in many of the series the implied specification of a log-level equation in commodity prices is rather complex with many of the variables appearing at a large number of lags. Other examinations, such as the spectral analysis of Labys and Granger (13), which was carried out at a higher time frequency on individual commodity prices, have reflected rather negative results. In view of these facts, the cross-correlation exercise was supplemented by an alternative approach to assessing causal ordering: that of Granger. It consisted in carrying out the regression:

$$P_t = a_0 + \sum_{j=1}^{J} a_j P_{t-j} + \sum_{j=1}^{J} b_j X_{t-j} + c.DUM + d.TIME + u_t \qquad [4]$$

and testing the hypothesis that $b_j = 0$ for all j. The test statistic, F, is calculated by estimating [4] in constrained form, omitting the X variables, and then in unconstrained form. It is given by: $F = (SSQ_c - SSQ_u)/J \,/ (SSQ_u/(T-2J-3))$, where SSQ_c and SSQ_u are the residual sum of squares of the constrained and unconstrained regressions respectively and T is the sample size. This form of test was used because for certain kinds of relationships it has been found in Monte Carlo tests to outperform others such as the Sims procedure (14).

36. A series of such bivariate regressions were run on real commodity prices to see whether any of a range of possible explanatory variables could be said to "cause" the price. All variables except interest rates were in log-level form. A time trend and dummy variables were included in both constrained and unconstrained regressions. J, the maximum lag of both dependent and independent variables was set initially at five. When a lag at t-5 was found to be significant, the regressions were repeated with a maximum lag of seven. In fact no significant lags beyond five were found. Where the F statistic indicated that the null hypothesis of no causation could be rejected with 95 per cent confidence, the variable concerned was selected for testing in multivariate regression equations. The lag structure was selected with respect to the b_js and their apparent significance.

37. The Granger tests confirmed the broad impressions of the Haugh-Pierce tests although the results of the two tests are not identical, as other researchers have found (15). Somewhat surprisingly, more significant lagged

variables are found with Haugh-Pierce than Granger. However, the Haugh-Pierce tests did not indicate much contemporaneous interaction and the Granger tests did not reflect on the influence of contemporaneous variables. Those were investigated by the usual sort of specification search with regression equations. Their inclusion, together with the move to multivariate equations, sometimes altered initial specifications based on lagged variables, as final results show.

b) Regression results for commodity prices

38. The final equations were estimated for the period 1967:2 to 1984:2. They are shown in Table 2. In a number of cases the data did not discriminate strongly between alternative specifications, with rather different simulation properties. This means that the "best" equation was not finally selected on the basis of regression statistics alone. Prior views and revealed implications in simulation testing were also important.

39. Different measures of the activity variable were tried: OECD industrial production for six of the indices and OECD consumption for food prices. Effects on the equations were marginal so GDP was retained. (Industrial production is worse-determined than GDP in INTERLINK and has larger forecast errors -- reasons to eliminate it as an explanatory variable if possible.) OECD GDP was also calculated using import weights in aggregation and this variable used in estimation. This was to investigate suggestions that the current weakness of commodity prices is owing to the regional distribution of demand and activity within the OECD, with the United States, which is nearer commodity self-sufficiency than other OECD countries, providing much demand growth. Again, the effect on equations of this change was marginal.

40. The appropriate functional specification of the activity variable was the subject of considerable experimentation. Various formulations could be found yielding a reasonable fit and forecasting ability including the level and the change at various lags. No particular formulation dominated in all equations, however. As depicted in Figure 3, deviations of GDP from its trend show the closest association with real price movements overall and were adopted as the best all-round specification. Only in the tropical beverages equations does trend GDP appear as well as the deviation. Consequently, for the other equations, the long-run elasticity of real prices with respect to GDP is zero. This property, which distinguishes these equations from other work in the field, implies that a shift in commodity demand has a temporary effect on price but that the long-run supply curve is perfectly elastic. Interest-rate effects are frequently identified though not always statistically significant.

41. Inflation was tried as an explanatory variable in all the equations and appeared to be significant, lagged three periods, in the Hamburg agricultural raw materials equation and in first-difference (acceleration) form with a negative sign in the minerals equation. Lagged inflation terms appeared for those prices also in the Granger and cross-correlation tests. However their interpretation is problematic. They were treated as spurious and dropped from equations entered in the model. Their inclusion also leads to differences in the response of different price indices that are difficult to justify.

Table 2

COMMODITY PRICE EQUATIONS

$$\underset{}{LHMR} = 7.02^{**} + \underset{(0.15)}{0.43^{*}}\ LHMR(-1) - \underset{(0.14)}{0.54^{**}}\ LHMR(-2) - \underset{(0.11)}{0.21}\ LHMR(-5)$$

$$+ \underset{(1.37)}{3.64^{**}}\ MA.DEV(-1) + \underset{(0.04)}{0.15^{**}}\ LPOILR - \underset{(0.005)}{0.03^{**}}\ TIME$$

$SEE = 0.077$, $\bar{R}^2 = 0.86$, H 1.61

$$LMINR = -0.14^{**} + \underset{(0.14)}{0.33^{*}}\ LMINR(-1) - \underset{(0.13)}{0.29^{*}}\ LMINR(-2) - \underset{(0.09)}{0.19^{*}}\ LMINR(-5)$$

$$+ \underset{(0.95)}{2.63^{**}}\ MA.DEV(-1) + \underset{(0.04)}{0.20^{**}}\ LPOILR - \underset{(0.004)}{0.025^{**}}\ TIME$$

$SEE = 0.057$, $\bar{R}^2 = 0.87$, $H = 1.39$

$$LHAR = 1.63^{**} + \underset{(0.15)}{1.10}\ LHAR(-1) - \underset{(0.16)}{0.44}\ LHAR(-2) + \underset{(0.96)}{1.33}\ MA.DEV$$

$$+ \underset{(0.01)}{0.03^{*}}\ LPOILR(-2) - \underset{(0.20)}{0.62^{**}}\ IRS(-3)$$

$SEE = 0.062$, $\bar{R}^2 = 0.87$, $H = 2.35$

$$LAGRR = -0.19^{**} + \underset{(0.19)}{1.09^{**}}\ LAGRR(-1) - \underset{(0.18)}{0.57^{**}}\ LAGRR(-2)$$

$$+ \underset{(1.04)}{1.10}\ MA.DEV + \underset{(0.05)}{0.13^{**}}\ LPOILR - \underset{(0.07)}{0.22^{**}}\ LPOILR(-1)$$

$$+ \underset{(0.06)}{0.13^{*}}\ LPOILR(-2) - \underset{(0.19)}{0.54^{**}}\ IRS(-3)$$

$SEE = 0.059$, $\bar{R}^2 = 0.87$, H-statistic cannot be calculated

Note: The real price indices in U.S. dollars (log level) are denoted by:

HWWA		UNCTAD	
LHMR:	Non-ferrous metals	LMINR:	Minerals
LHAR:	Agricultural raw materials	LAGRR:	Agricultural raw materials
LHTR:	Tropical beverages	LTBR:	Tropical beverages
LHFR:	Food	LFOOR:	Food

Table 2 continued

$$\begin{aligned} LHTR = {} & -9.0^{*} + \underset{(0.14)}{0.87^{**}}\, LHTR(-1) - \underset{(0.14)}{0.31^{*}}\, LHTR(-2) + \underset{(1.40)}{2.23}\, MA.DEV(-1) \\ & + \underset{(0.17)}{0.38^{*}}\, MA.TREND - \underset{(0.32)}{0.92^{**}}\, IRS(-2) + 0.31^{**}\, DUM.1 \end{aligned}$$

$SEE = 0.103$, $\bar{R}^2 = 0.88$, $H = -1.69$

$$\begin{aligned} LTBR = {} & -5.81 + \underset{(0.12)}{0.84^{**}}\, LTBR(-1) - \underset{(0.12)}{0.15}\, LTBR(-2) + \underset{(1.09)}{2.45^{*}}\, MA.DEV \\ & + \underset{(0.12)}{0.20}\, MA.TREND - \underset{(0.25)}{0.23}\, IRS(-1) + 0.42^{**}\, UDUM.1 \end{aligned}$$

$SEE = 0.086$, $\bar{R}^2 = 0.92$, $H = -1.11$

$$\begin{aligned} LHFR = {} & 1.78^{*} + \underset{(0.10)}{0.63^{**}}\, LHFR(-1) + \underset{(1.25)}{2.55}\, MA.DEV \\ & - \underset{(0.25)}{0.34}\, IRS(-1) + 0.26^{**}\, DUM.2 \end{aligned}$$

$SEE = 0.095$, $\bar{R}^2 = 0.78$, $H = 0.088$

$$\begin{aligned} LFOOR = {} & -0.18 + \underset{(0.05)}{0.67^{**}}\, LFOOR(-1) + \underset{(1.16)}{0.67}\, MA.DEV \\ & \underset{(0.21)}{-0.43}\, IRS + 0.63^{**}\, UDUM.2 \end{aligned}$$

$SEE = 0.086$, $\bar{R}^2 = 0.93$, $H = -0.28$

Figure 3

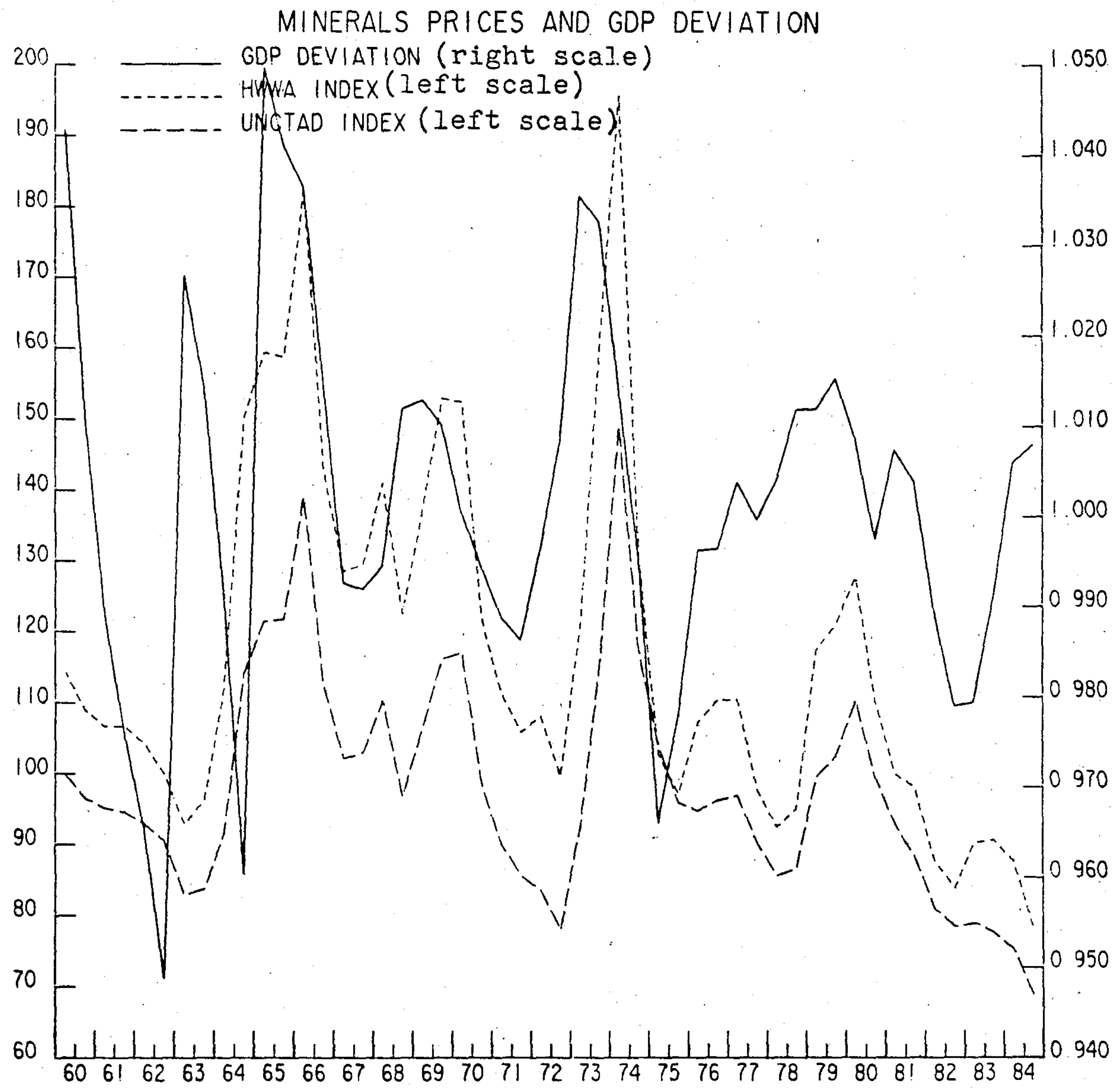

MINERALS PRICES AND GDP DEVIATION
GDP DEVIATION (right scale)
HWWA INDEX (left scale)
UNCTAD INDEX (left scale)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
1.050
1.040
1.030
1.020
1.010
1.000
0 990
0 980
0 970
0 960
0 950
0 940
60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84

Figure 3 continued

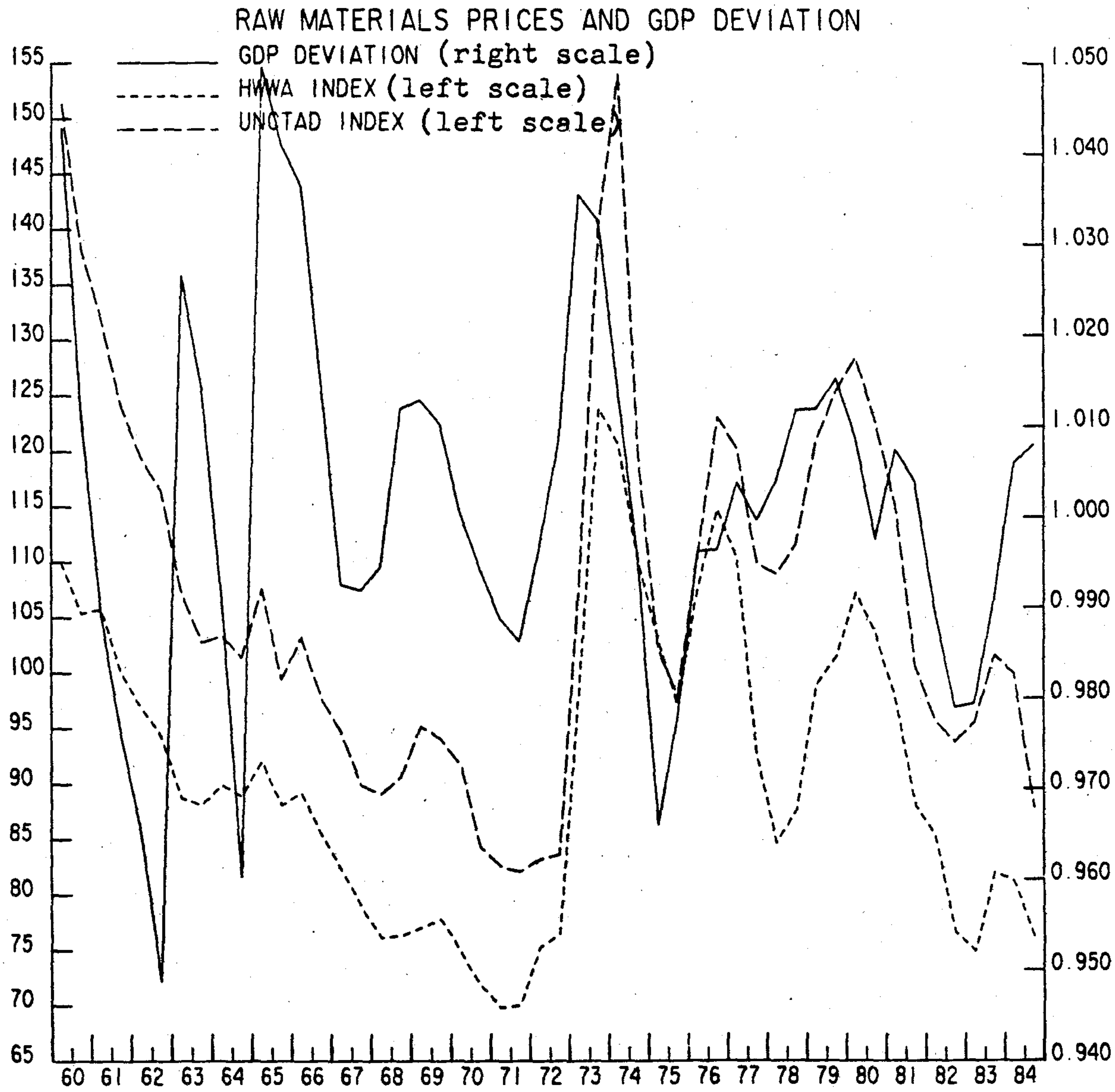


Figure 3 continued

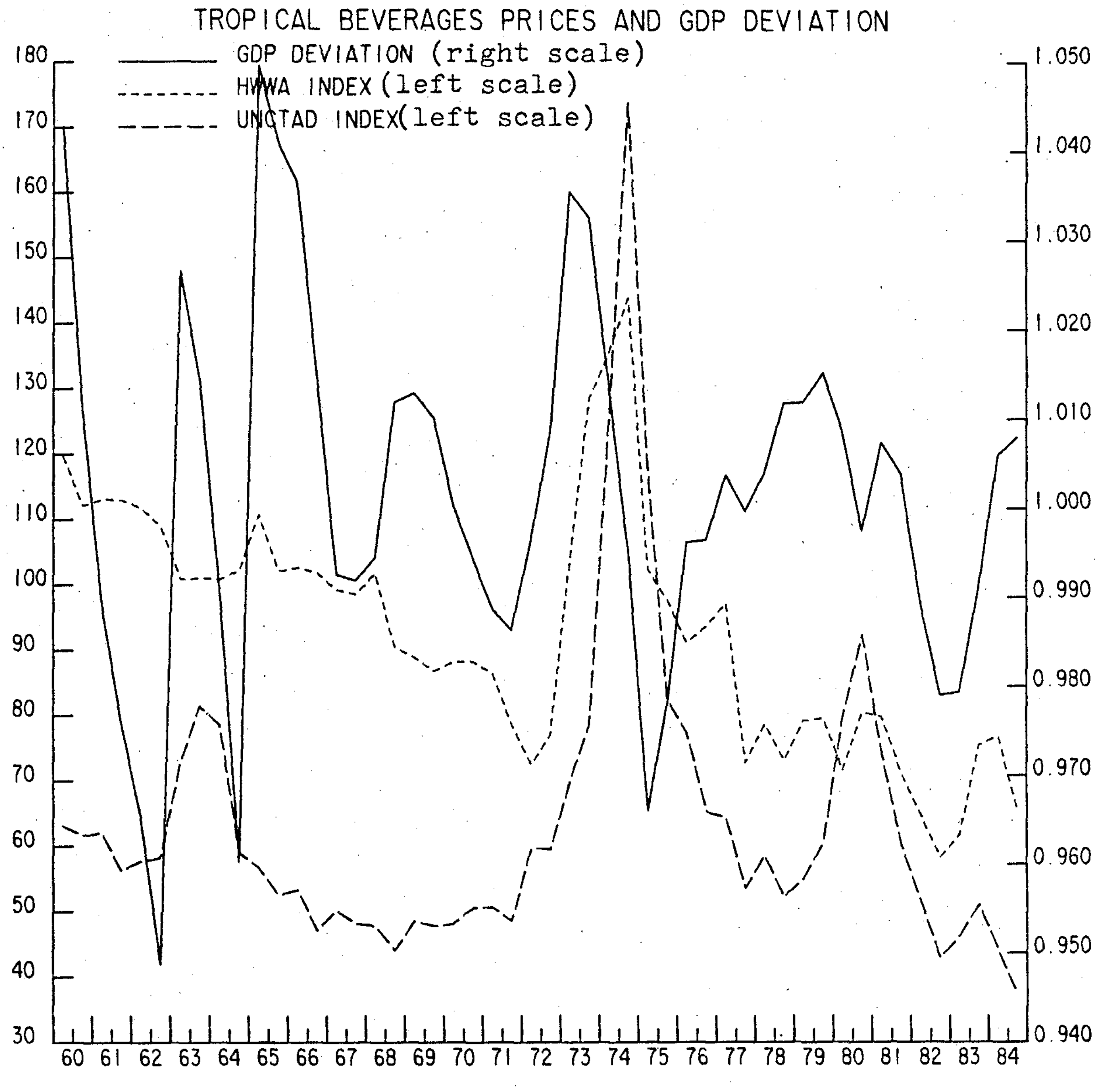
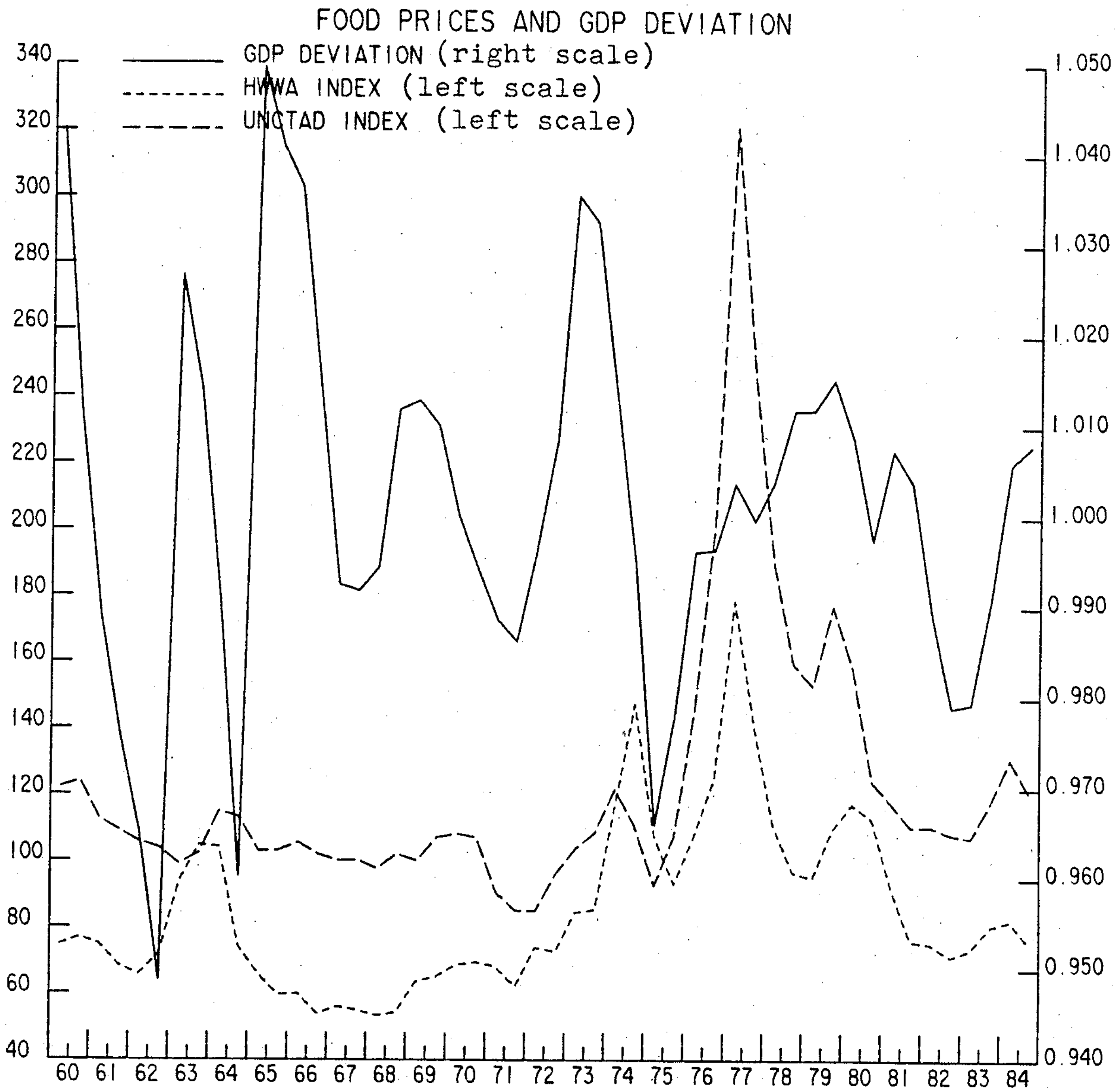


Figure 3 continued



42. The equations for the HWWA real commodity price indices are broadly similar to those for the UNCTAD indices. This is so even for the tropical beverages equations where the coverage is different: HWWA includes sugar and tobacco in tropical beverages while sugar is in the UNCTAD food group. This difference is reflected in the relative importance of the dummy variable. Both equations include a trend GDP variable which does not appear in the equations for the other commodity groups. However, the HWWA equation responds less to trend GDP and more strongly to deviations from trend GDP than does the UNCTAD equation. Interest rate effects appear in both, with a larger and much better determined coefficient in the case of Hamburg. In spite of the difference in coverage, the same lags on the dependent variable were found to be significant for both indices.

43. Dynamics were also similar for the two indices in the agricultural raw materials equations (two lags on the dependent variable) and the minerals equations. In the latter, a lag at minus five could not be excluded for either the HWWA or the UNCTAD price index. The net effect is an endogenous cycle in mineral prices whereby they overshoot in response to a disturbance and the equilibrium elasticity of mineral prices with respect to all explanatory variables is less than the impact elasticity.

44. Both minerals equations feature the current oil price but the effect is weaker for the HWWA index. Regressions on the Hamburg price with the sample period split in two (1967:2-1975:2; 1976:1-1983:2) indicate that the oil price had a much stronger influence in the latter period (coefficient 0.4 as opposed to 0.1). Both real minerals prices respond to the deviation of GDP from trend with one lag, with a larger coefficient in the Hamburg case. Split-period regressions on this equation showed a smaller effect of changes in activity in the second period. Recursive regressions also indicated that the influence of activity decreased even more markedly within the latter period. This suggests coefficients estimated over the full sample period may not be optimal for forecasting or simulation. The equations were re-estimated by discounted least squares. Comparative forecasts showed, however, that this gave little improvement (see below).

45. The current deviation of GDP from trend appears in both agricultural raw materials equations. The real oil price plays a much lesser role in the Hamburg than in the UNCTAD agricultural raw materials equation, where the current and lagged prices appear. Removal of the lagged oil prices causes the equation to deteriorate markedly.

46. Both food equations also feature the current deviation of GDP from trend. In the UNCTAD equation the coefficient is lower and poorly determined but the variable was retained to prevent simulation properties of the two food price equations diverging excessively. Interest-rate effects are comparable (stronger for UNCTAD). The dummy variables are important reflecting the poor Russian grain harvest in 1973/74 and in the case of UNCTAD, the sugar crop failure of 1980.

47. A feature of the equations for minerals is the marked time trends. As estimated these have strong implications for the steady-state properties of the equations when taken in conjunction with the absence of long-run activity effects. As the equations are estimated on semestrial data, the annual rates of decline of prices are double the coefficients on the time variable, hence some 6 per cent. If real oil prices and interest rates are constant therefore

these commodity price indices would fall at 5-6 per cent a year. In effect, the equation implies a trend fall in mineral prices quite apart from cyclical weakness, perhaps due to technical change and shifts in demand patterns.

48. The estimated equations cannot be rigorously compared to other reduced-form estimates of aggregate commodity price indices in the literature because of differences in coverage, sample period and specification. Nonetheless, some broad comparison may be helpful. Distinguishing features of these equations, compared with the equations of Chu and Morrison and Grilli and Yang (16), are: the negative coefficients on real interest rates, though not often well-determined, and the substantial long-run interest-rate semi-elasticity; the only positive effect, albeit temporary, of OECD activity except on tropical beverages prices. This latter may owe something to the different time periods over which the equations were estimated as there is some evidence that the effect of OECD activity on prices has declined over time, especially in the case of minerals. The other specifications do not allow for oil price effects, whether as a cost or as a substitute raw material, while here significant coefficients were found for the oil price in minerals and in agricultural raw materials. Long-run elasticities, however, are small. The OECD equations seem to fit relatively well in sample, but for food and tropical beverages this may be owing to the more precise specification of dummies for supply shocks. A common difficulty is the multicollinearity of explanatory variables. More detailed comparisons are not very informative as the commodity groupings are different.

c) Equation properties

49. The long-run and dynamic properties of the equations are shown in Table 3, which gives long-run elasticities, mean lags in non-oscillating equations and the phase of the price cycle in the case of oscillating processes. Mean lags are generally short, around 2 periods. In oscillating equations the phase of cycles is usually 8 to 10 periods (4 to 5 years) except in the case of the minerals prices which have a phase of 5.5 periods.

50. On *a priori* grounds, some instability of the price formation process might be expected, especially during the 1970s. Recursive regressions were run on all equations to test for instability and the CUSUM and CUSUMSQ statistics of the recursive residuals calculated. In general, the equations show reasonable stability, in the sense that the CUSUM test does not reject stability. On the other hand, the CUSUMQ test when it is run backwards indicates instability at the 95 per cent confidence level at the beginning of the estimation period for practically all UNCTAD price equations, whereas when considering the forward CUSUMQ test, instability is present only in UNCTAD raw materials equations. The chief source of that instability seems to be a gradual decrease in the size of the coefficient on the deviation of GDP from its trend. This could be owing to a shift in the composition of OECD GDP towards raw material substitutes and a consequent decline in raw material-intensive sectors (17). The CUSUMSQ test also suggests some instability in forward recursive residuals for UNCTAD food. However, the CUSUMSQ test tends to give significant results more often than other, more formal, test statistics. The coefficient on the GDP deviation in the minerals equations is negative in recent periods in backward recursive regression, and the Hamburg tropical beverages equation also indicates a diminishing role for the deviation of GDP from trend although the importance of trend GDP itself has increased. (When the equations were run with the level of GDP as an

Table 3

LONG-RUN PROPERTIES OF COMMODITY PRICE EQUATIONS

	Nature of adjustment	Long-run elasticity with respect to:			Mean lag (3)	Phase (3)
		GDP (1)	OIL	IRS (2)		
LHMR	oscillating	0	0.4	-	-	5.5*
LMINR	oscillating	0	0.17	-	-	5.5*
LHAR	oscillating	0	0.07	-1.82	-	10.6
LAGRR	oscillating	0	0.09	-1.13	-	8.3
LHTR	oscillating	0.86	-	-2.09	-	9.4
LTBR	non-oscillating	0.64	-	-0.74	2.2	-
LHFR	non-oscillating	0	-	-0.92	1.7	-
LFOOR	non-oscillating	0	-	-1.30	2.0	-

1. The GDP variable in all equations is a deviation from trend. The trend is a moving-average function of GDP so the long-run elasticity of prices with respect to GDP is zero by construction (given that the equations' dynamic properties are stable). However, for tropical beverages equations the level of trend GDP itself appears as an explanatory variable and the elasticity is calculated with respect to trend GDP.

2. Semi-elasticity.

3. In half years.

* Both mineral equations are fifth-order autoregressive processes, making analytic solution for the phase impossible. This estimate is approximate, based on simulation experiments.

explanatory variable a declining GDP coefficient was also noted, especially for minerals.) However, the coefficient on the deviation of GDP from trend is stable in the food equations and in that for UNCTAD tropical beverages. Coefficients on the real interest rate are generally stable.

51. In no case did tests lead to the conclusion that parameters of the regression model should be respecified as functions of time. Indications of instability did lead to a re-estimation by the method of discounted least squares and a comparison of forecast performance.

52. The performance of the regression equations was also evaluated by their ability to track historical real price movements. Dynamic simulations were run in-sample for the three periods 1970 to 1974, 1975 to 1979 and 1980 to 1984. The quality of the results is measured by the root mean squared error (RMSE) and Theil's inequality coefficient (THEIL) (18). The results for different commodity groups are given in Table 4. Because the dependent variables are measured in natural log levels, the RMSE is the percentage deviation from the actual value. To facilitate comparison of performance between sample sub-periods and between equations, the RMSE is standardized by dividing by the respective sample standard deviations. A rule of thumb is that the equation is satisfactory when the ratio of RMSE to standard deviation does not exceed 2. In only two cases out of 24 simulations with the UNCTAD and HWWA equations, does the value of RMSE exceed the value of sample standard deviation. The simulation errors of the HWWA equations were generally somewhat higher compared with the UNCTAD ones. Somewhat surprisingly, the equations seem to track well the real price movements during the unstable period at the beginning of the 1970s when the volatility of commodity prices increased considerably. The less impressive performance of recent years seems to a large extent to be due to the sharp decline in real commodity prices during 1984, which the dynamic simulations of the equations did not pick up adequately. The equations, however, frequently predict sharp falls in commodity prices in late 1982 or early 1983, which did not occur. One interpretation is that recent falls in commodity prices were a delayed reaction to high interest rates, lower inflation and slow growth. In the case of agricultural commodities, this delay appears to have been caused by supply shocks. Production was low in 1983 with commodities like soybeans, maize, groundnut oil, fishmeal, coffee and cocoa experiencing production declines in 1982 or 1983, owing to bad weather or government sponsored acreage reduction, especially in the United States. This supported prices. However, in 1984 production of nearly all commodities increased, contributing to price declines. The explanation for mineral price movements is less clear cut.

53. In-sample forecasting is generally satisfactory. A further test was to forecast for 1984 using the equations estimated to 1983 (see Table 5). Although the equations worked fairly well in explaining past history, price developments during 1984 remained largely unpredicted. While some of the equations forecast the fall in prices, the sharpness of the decline was not reproduced. The UNCTAD equations do predict declines in the real prices of food and of minerals in the first half of the year. The actual price level was, however, clearly lower than the forecasts. The HWWA equations (except for that for minerals, and for food in the second half of 1984) forecast rising or unchanged real prices for 1984 when the actual outcome was a sharply falling real price level especially during the second half of the year. Both UNCTAD and HWWA equations explain the 1984 price movements better than univariate ARIMA models, the exceptions being both tropical beverages

Table 4

IN-SAMPLE SIMULATION STATISTICS

	1980 - 1984			1975 - 1979			1970 - 1974		
	ROOT MSE	RMSE/ SD	Theil	ROOT MSE	RMSE/ SD	Theil	ROOT MSE	RMSE/ SD	Theil
Minerals									
HWWA	0.078	0.548	0.026	0.092	1.004	0.052	0.093	0.434	0.052
UNCTAD	0.050	0.348	0.017	0.046	0.693	0.019	0.080	0.397	0.038
Agricultural raw materials									
HWWA	0.084	0.644	0.033	0.118	1.208	0.057	0.096	0.477	0.047
UNCTAD	0.091	0.731	0.037	0.069	0.846	0.031	0.119	0.411	0.055
Tropical beverages									
HWWA	0.132	0.736	0.055	0.078	0.389	0.054	0.128	0.471	0.075
UNCTAD	0.113	0.971	0.050	0.083	0.228	0.051	0.119	0.987	0.043
Food									
HWWA	0.094	0.845	0.031	0.114	0.892	0.046	0.083	0.333	0.040
UNCTAD	0.108	0.359	0.040	0.070	0.282	0.028	0.071	0.163	0.027

Notes:
MSE: Mean square error
RMSE/SD: Root mean square error over standard deviation
Theil: Theil's inequality coefficient.

Table 5

REAL COMMODITY PRICES FORECASTS

(Percentage changes 1984I - 1984II in log-differences)

		UNCTAD					HWWA				
		Actual	Univariate ARIMA model	OLS	DLS	$\chi^2_2(2)$ (a)	Actual	Univariate ARIMA model	OLS	DLS	$\chi^2_2(2)$ (a)
Agricultural raw materials	83II	6.3	-	-	-	-	9.5	-	-	-	-
	84 I	-2.1	8.0	4.4	4.5	-	-1.3	10.6	5.0	5.9	-
	84II	-12.6	0.9	5.3	5.5	26.82	-6.2	9.2	7.0	7.4	12.38
s.e.e.				0.049					0.051		
Minerals	83II	-1.7	-	-	-	-	0.5	-	-	-	-
	84 I	-2.9	1.5	-3.2	-2.0	-	-3.8	7.3	-8.1	-5.6	-
	84II	-8.7	9.7	0.8	-0.2	2.93	-11.0	7.7	-0.4	-1.0	0.97
s.e.e.				0.056					0.077		
Food	83II	9.8	-	-	-	-	20.2	-	-	-	-
	84 I	-15.1	-1.3	-0.9	0.0	-	1.3	2.1	0.1	-2.4	-
	84II	-16.7	-5.5	-1.9	-0.5	18.98	-15.6	1.7	-0.7	0.4	2.67
s.e.e.				0.076					0.093		
Tropical beverages	83II	9.6	-	-	-	-	9.0	-	-	-	-
	84 I	10.1	4.3	2.4	4.9	-	1.8	3.7	12.1	12.2	-
	84II	-8.2	-0.6	1.5	3.8	0.85	-9.0	-1.3	2.6	3.0	5.47
s.e.e.				0.086					0.103		

a. Chi-squared statistic of parameter stability defined as:

$$\sum_{e=1\to m} e^2_{t+1}/(SSQ/N-1-k) \text{ with n degrees of freedom}$$

where e_t are forecast errors. SSQ is the sum of squared regression residuals, N observations in regression sample. k number of regressors. The joint hypothesis of parameter stability and equation adequacy can be rejected with 95 per cent confidence if the statistic exceeds 6 in this case. The χ^2-statistics refer to the OLS forecasts for the period 1984I to 1984II.

Note: Forecasts for 1984 were static extrapolations from a base of actual data for 1983II.

equations and the UNCTAD food equation. As noted above, a longer forecast starting from an earlier base gives somewhat more accurate terminal levels because underprediction in 1983 offsets the 1984 overprediction. In both minerals equations discounted least squares estimates gave slightly better forecasts but otherwise were no improvement on OLS. The discount factor used was n-1/n+1 where n is sample size and was approximately equal to 0.94.

iv) The equations in INTERLINK: simulation properties

54. The properties of the new commodities price equations were tested with a series of single-equation simulations, run over the period 1981:1 to 1986:2. They were:

i) 2 per cent per annum faster growth of the OECD GDP deflator (WPGDP);

ii) 1 per cent faster OECD GDP (volume) growth (WGDPV);

iii) the short-term U.S. interest rate (IRSUS) raised above baseline by two hundred basis points in each semi-annual period;

iv) a sustained increase of 5 percentage points in the oil price (PXED) index.

The percentage deviations from baseline are shown in Figure 4.

55. In order to use the equations in INTERLINK for forecasting and simulation purposes it was necessary to replicate trend GDP. A number of methods were tried further and experimentation is proceeding. Clearly the more flexible the trend in the sense of adapting rapidly to actual GDP the smaller will be the effect of a given shock to GDP on commodity prices, for a given parameterization of the commodity price equations. On the other hand, parameterization is not in general invariant to the specification of trend. The method provisionally selected was by a two-parameter flexible trend which allows both the level and rate of change of the trend to respond gradually to sustained shocks in output. The formula for trend is:

$$T.GDPV = 0.15*GDPV + 0.85\ [(T.GDPV(-1)*(1 + 0.30\ (\frac{GDPV(-1)}{GDPV(-2)} - 1) + 0.70\ (\frac{T.GDPV(-1)}{T.GDPV(-2)} - 1))]$$

where GDPV is OECD area real gross domestic product and T.GDPV is its calculated trend. Historical starting values are taken from a nine-period centred moving-average trend.

56. In testing the equations for world commodity prices (as opposed to export unit values) two concerns were uppermost. One was the possibly disparate response of the HWWA and UNCTAD price indices for broadly the same commodity groups, which is a consequence of differences in specification of the equations for the two indices. The HWWA aggregate indices of world commodity prices are used as explanatory variables in the export unit-value

Figure 4

SIMULATION RESPONSES TO SHOCKS

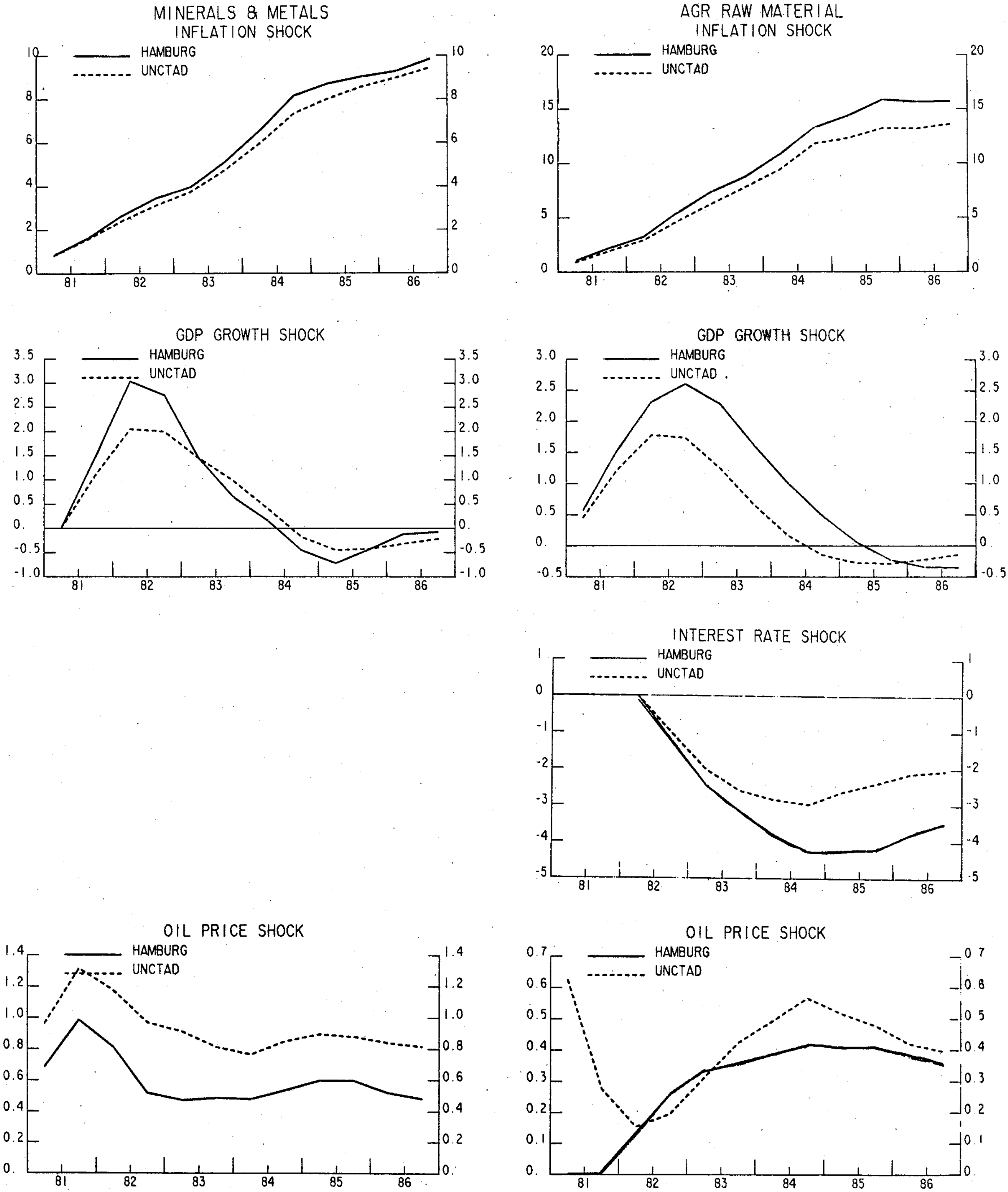
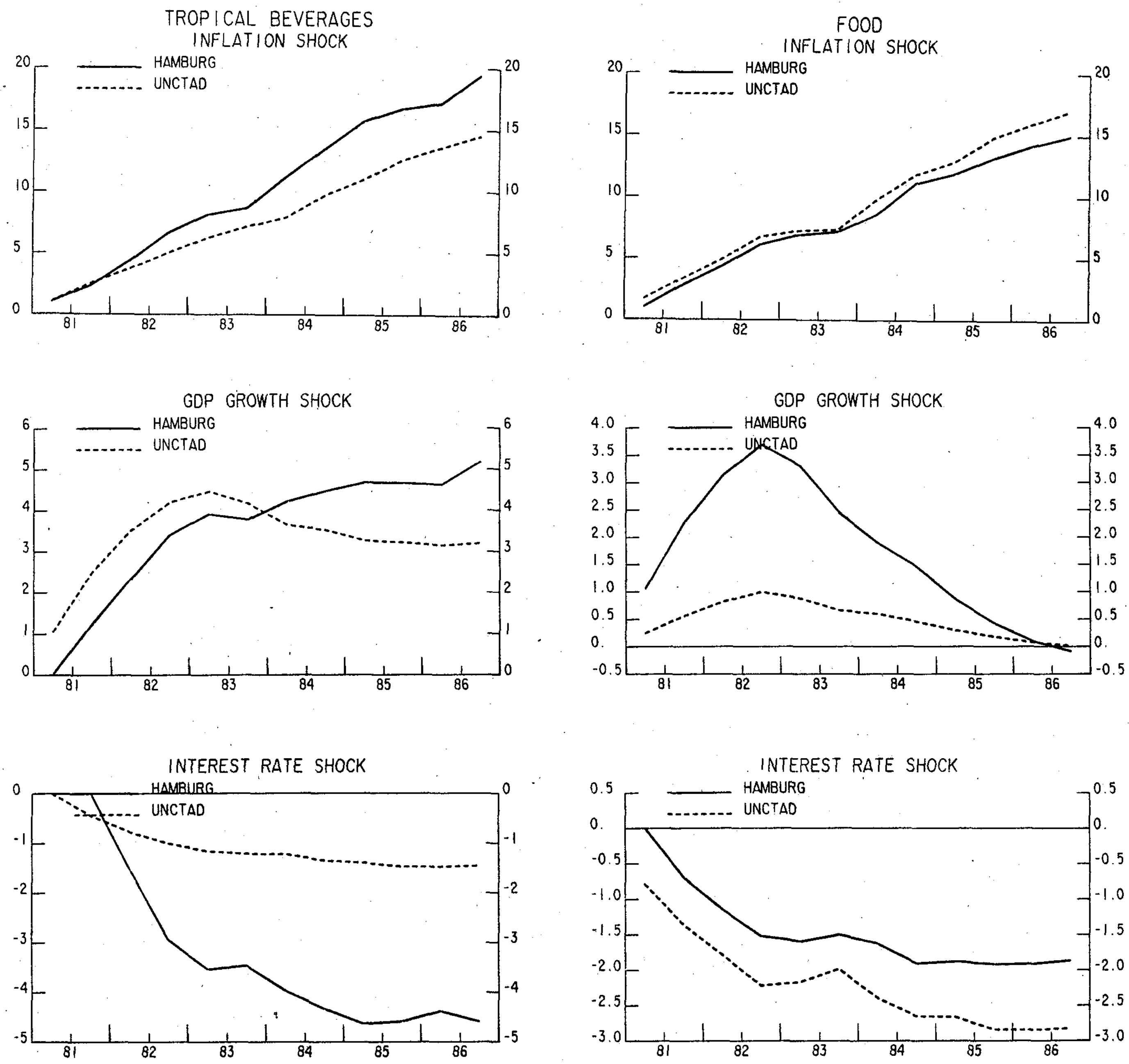


Figure 4 continued



equations of OECD countries while the UNCTAD indices are used in the export unit-value equations of non-OECD zones (19). Significant terms-of-trade movements could be implied between non-OECD and OECD zones in the model following a range of shocks. This could be explained to some extent by differences in commodity composition and commodity weights in the two indices, but large divergences could be inconvenient. A second concern was the presence of empirically-determined higher-order lags in the equations which are likely to induce cycles after shocks. While commodity price series are cyclical, pronounced and sustained cycles could give the model "black-box" properties that would be hard to explain. In the event no large disparities emerged and cycles, where they appeared, were muted.

Inflation rate

57. All the equations showed steadily increasing deviations from baseline in response to 2 per cent higher inflation. As between pairs, the response of the Hamburg index was stronger than that of UNCTAD for all categories except food, and more markedly so in the case of tropical beverages. This is reasonable as certain commodities with volatile prices (e.g. sugar) are classified with food by UNCTAD but with tropical beverages by HWWA. Given the equation specification, these differences are largely traceable to the interest-rate term. The UNCTAD food equation has a larger negative coefficient on the real interest rate than does the Hamburg food equation, so the nominal UNCTAD price rises more when the real interest rate is lowered by inflation. Nominal interest rates were held constant in this simulation but in any case neutrality of the real interest rate to inflation is not a property of INTERLINK in the medium term. The coefficient on the real interest rate is much larger in the Hamburg than in the UNCTAD tropical beverages equation. In the minerals equations, which are without interest-rate terms, the price increases follow general inflation closely.

Growth of GDP

58. Faster GDP volume growth produces broadly similar results for three of the four pairs of indices, reflecting the specification of the GDP term as the deviation from trend and the relative size of the GDP coefficients. Prices rise, with a peak response around the fourth semester, and then fade, returning to a level very close to baseline at the end of the simulation period. This conforms with the long-run properties of the equation as shown in Table 3. GDP has no long-term effect on prices; however, deviations from the trend level of GDP produce temporary price effects. A sustained shock is eventually incorporated in the trend. The size of the temporary response depends on the size of the coefficients: Hamburg minerals, raw materials and food prices all react more strongly than their UNCTAD counterparts. Continuing work suggests that better equations may be obtained with a smoother trend and that the GDP deviation effects could be understated in these equations.

59. The tropical beverages equations are exceptions, in which the trend level of real GDP appears as well as the deviation from trend. The Hamburg equation responds more strongly to the trend, and more weakly to the deviation, than does the UNCTAD equation, with the result that the UNCTAD price response is higher initially. The Hamburg deviation overtakes it in the seventh semester, rising to 5.2 per cent by the end of the period as against 3.2 per cent for UNCTAD. Thus GDP has permanent price effects only in the

case of the tropical beverage indices. Alternative formulations were tried for the sake of similarity of structure, omitting the GDP trend or replacing it with a time trend. However, the equations deteriorated markedly, so the specifications described here were retained.

Interest rates

60. In this simulation the level of the nominal interest rate is raised permanently by 200 basis points. The HWWA tropical beverages equation responds most strongly, with the nominal price 4.6 per cent lower by 1986:2 as compared with -1.5 per cent for UNCTAD. The fall is greater for the HWWA index than for UNCTAD in the case of raw materials too, but this pattern is reversed for food. Most of the deviations show slight oscillations, but the HWWA food index shows a stable deviation from baseline of -1.9 per cent in the last five periods (similar to the stability of this index subject to the shift in the deflator), while the UNCTAD food index deviates increasingly to reach -2.8 per cent in the last period. Disparities are small except for tropical beverages and are clearly related to coefficient size. The minerals equations are not affected as they have no interest-rate term.

Oil price

61. There are no oil price terms in the food and tropical beverage equations. Figure 4 shows the deviations from baseline of the price indices for minerals and raw materials in response to a 5 per cent higher level of the oil price. All four indices oscillate weakly. The UNCTAD minerals price shows the strongest response, rising to 1.3 per cent above baseline in the second semester and declining to 0.8 per cent by 1986:2.

III. EXPORT UNIT VALUE EQUATIONS

i) Specification, data and estimation

62. This section discusses equations and reports results for export unit value indices for food and beverages (SITC 0 and 1) and raw materials (SITC 2 and 4). There are numerous reasons why spot commodity price changes are not fully reflected in current-period food and raw material unit value indices. First, the commodity composition of a given world spot price index (the UNCTAD and HWWA indices, for example) may be quite different from the actual commodity composition of any country's food and raw material exports and while the former is a base-year weighted Laspeyres index, unit values of the latter have current, changing weights. Second, the existence of transportation lags and long-term contracts tends to attenuate the relationship between spot prices and export unit values (20). Finally, there are likely to be some goods within SITC 0, 1, 2 and 4 that have more processing content than the goods composing a given world spot price index (21).

63. All of these factors suggest that an explanation of export unit values for food and raw materials should include information additional to contemporary spot commodity prices. A model that has export unit value indices for food and raw materials as a function of contemporary and lagged spot price indices and a domestic cost variable would allow for transportation

lags, mismatches between spot-price index and export unit value index commodity composition, and domestic processing costs (22). This specification is similar to that currently used in INTERLINK for manufactured goods export unit values, which has as explanatory variables competitors' price (world price) and domestic cost variables such as unit labour costs and import unit values (23). Although the assumption of imperfect competition in the manufactured goods market that underlies such a model may not be valid in many food and raw materials markets, there is probably enough product differentiation in semi-processed and processed food and raw materials industries to invalidate the assumption of perfect competition.

64. The OECD maintains current and historical export unit value data from national sources for food and raw materials for almost all OECD countries (24). For non-OECD regions, a data set provided by the World Bank contains the same information for groups that closely parallel the INTERLINK newly-industrialising country (NIC), non-OPEC oil producing (OOP), and other low- and middle-income developing (LMI) groups. The OECD export unit value indices are available at the traditional INTERLINK semi-annual frequency, while the World Bank indices are annual data. To obtain semi-annual non-OECD region indices, the World Bank indices have been interpolated using closely-matching concepts, e.g. the non-OECD region food export unit value indices are interpolated using semi-annual OECD food import unit value indices as a reference. The HWWA commodity price indices are used in the OECD export unit value equations, and the UNCTAD commodity price indices are used in the non-OECD region export unit value equations. Since the HWWA indices use an OECD import, not export, weighting scheme, there remains a problem of mismatch between spot-price indices and export unit value indices. However, the HWWA OECD import-weighted indices are preferable to the UNCTAD developing country export-weighted indices, since most OECD food and beverage imports (66 per cent in 1981) and raw material imports (64 per cent in 1981) come from within the OECD (25).

65. Several domestic cost pressure concepts have been tested. Unit labour cost data are not available across all countries for sufficiently long time periods. For this reason, the GDP deflator, an output price, which performs as well as unit labour costs, has been used as a proxy. To account for the effect of energy import prices upon food and raw material production costs, energy (SITC 3) import unit values were tested as an explanatory variable. The energy price term does not turn out to be significant, however, possibly due to correlation with another key explanatory variable, namely spot commodity prices. All variables are indices of dollar prices.

66. The basic model, referring to the variables mentioned above, is:

$$\Delta PX = a + \sum_{i=1}^{n} b_i * \Delta PW_i + \sum_{i=1}^{n} c_i * \Delta PGDP_i \qquad [5]$$

That is, the change in the export unit value index (PX) is equal to a constant plus the sum of current and lagged changes in the world spot price index (PW) and changes in the domestic cost variable (PGDP). All equations have been estimated on semi-annual data over the period 1971:2 to 1982:2, or the longest subset of that interval permitted by the data.

67. Several modifications have been made to the basic equation [5]. First, the variables are represented in log-difference form. Second, the constant term is suppressed and the sum of coefficients restricted to unity, i.e. we

assume homogeneity of degree one. In principle, for a given increase in world (or competitor) prices, one would expect a country's export prices to rise in step with domestic prices; hence:

$$\Delta \ln PX = \sum_{i=1}^{n} b_i * \Delta \ln PW_i + \sum_{i=1}^{n} c_i * \Delta \ln PGDP_i, \quad \sum_{i=1}^{n} b_i + \sum_{i=1}^{n} c_i = 1 \quad [6]$$

68. As it turns out, estimating equation [5] using ordinary least squares and equation [6] using a linear minimum-distance technique imposing coefficient restrictions yields quite similar results for most countries and regions. Several types of distributed lag schemes have been tried, including polynomial distributed lags and Pascal lags. In addition, a lagged dependent variable was tested for all countries but was found to be significant in very few cases. None of the distributed lag methods yielded great improvements. It should be noted that because of the limited numbers of degrees of freedom available, longer lags cannot be tested.

69. Another restriction has been imposed in order to ensure sensible long-term model properties. As equation [6] is specified, it is possible for a country's export price growth rate to diverge indefinitely from the world spot price growth rate by having its domestic cost variable grow at a rate different from the world spot price. Adding a constant term and an error correction term prevents the export unit value index from diverging from the world spot price in the long run. This modification yields the model:

$$\Delta \ln PX = a \sum_{i=1}^{n} b_i * \Delta \ln PW + \sum_{i=1}^{n} c_i * \Delta \ln PGDP + d * \ln(PW_{-1}/PX_{-1}), \quad [7]$$

$$\sum_{i=1}^{n} b_i + \sum_{i=1}^{n} c = 1$$

where d is expected to have a positive coefficient. This specification was tested for both food and raw materials, but only the raw material equations yielded significant coefficient estimates for d. Thus, equation [6] was used for the food export unit value equations and equation [7] for the raw material export unit value equations.

70. Both sets of commodity price indices, HWWA and UNCTAD, include two indices for the SITC 0+1 category -- food and tropical beverages/tobacco -- and two for the SITC 2+4 category -- non-ferrous metals and agricultural raw materials. In some cases the correspondence between the commodity-price indices and the SITC categories is not perfect; for example the non-ferrous metals index contains prices for goods at a stage of processing that would put them in SITC 6 rather than SITC 2. The two world food price indices have been tested as separate independent variables in the OECD country equations, but, due perhaps to multicollinearity, they do not yield significant coefficient estimates. The same holds for the raw materials equation. In order to eliminate the problem of multicollinearity, the food and tropical beverage/tobacco world price indices are combined using each country's export value shares of food and tobacco/tropical beverages. The same is done for raw materials.

71. The non-OECD regions have been treated differently from the OECD countries for two reasons. First, non-oil developing country food and raw

material exports generally have a lower processing content than corresponding OECD exports, thus obviating the need for a domestic cost of processing variable such as unit labour costs. Second, domestic cost variables such as unit labour costs or even the GDP deflator are not available in INTERLINK for non-OECD regions. Instead, export unit value indices for food and raw materials have been modelled using lagged world price indices as the only explanatory variable. Another difference is that the UNCTAD spot food price index and the UNCTAD spot tropical beverage/tobacco price index, when included separately, both have a significant effect upon the non-OECD region food export unit value indices. So the two UNCTAD SITC 0+1 indices are included separately in the non-OECD region food equations. The raw materials equation, on the other hand, uses the trade-weighted combination as is the case with the OECD countries.

72. A final issue related to the proposed model is single equation versus system estimation. The error terms of the individual country and region equations are related through the feed-in from other-country export unit values into own import prices and hence into own costs (even though one would assume that the food and raw material import content of food and raw material production is small). In such a case, a systems form of estimation may be called for in order to increase efficiency through information contained in other-equation residuals. It is assumed here that the potential gain in efficiency from using a systems form of estimation is not large. This is an issue, however, that could be further researched.

ii) Results

73. Table 6 presents the estimation results for the food and raw material export unit values for the non-OECD regions. The raw materials equations are quite similar across the three regions, with about two-thirds of current-period world spot prices reflected in current-period export unit values. In the food equations, the non-OPEC oil-producing (OOP) countries and low and middle-income developing (LMI) countries are found to have SITC 0+1 export unit value indices that are much more dependent upon tropical beverage prices than on food prices. The opposite is true for the NICs. This has implications for the export revenues of the OOPs and LMIs, since tropical beverage prices were the most unstable of all raw material prices (including oil) during the period 1972-1982 (26) and have continued to be unstable in recent years. It should be noted that the three non-OECD regions cited above depend upon food and raw materials to widely differing degrees. For the LMIs, about three-quarters of export revenue is accounted for by goods in SITC 0, 1, 2, and 4: the corresponding figure is 40 per cent for OOPs and 25 per cent for NICs (27). It is thus not surprising that the terms-of-trade of LMI countries have shown the greatest fluctuation of any of these INTERLINK groups over the past several years.

74. Estimation results for equation [7] for OECD raw materials export unit value indices are shown in Table 7. For the majority of countries, the total spot price coefficient is less than 0.5, thus leaving domestic costs as the key explanatory factor. The precise commodity composition of each country's raw material exports would have to be studied in order to explain the relative influence of world price versus domestic price. The ratio of raw material export value to total export value in each country and the ratio of own raw material export value to total OECD raw material export value have been

Table 6

NON-OECD REGIONAL EQUATIONS

	PF	PF(-1)	PTB	PTB(-1)	PRAW	PRAW(-1)	PRAW(-2)	CCSQ	SEE
<u>Food & Tropical Beverages</u>									
OOP	0.222		0.514	0.264				0.760	0.060
	(4.7)		(8.1)						
NIC	0.460	0.149	0.391					0.630	0.070
	(6.3)		(6.9)						
LMI	0.321		0.428	0.251				0.870	0.040
	(9.2)		(9.1)						
<u>Raw Materials</u>									
OOP					0.765	0.235		0.740	0.050
					(8.9)				
NIC					0.648	0.352		0.720	0.050
					(7.8)				
LMI					0.613	0.316	0.071	0.780	0.040
					(8.3)	(3.4)			

<u>Notes</u>: PF = UNCTAD spot food price index,
PTB = UNCTAD tropical beverage spot price index.
PRAW = UNCTAD weighted raw material spot price index,
CCSQ = correlation coefficient squared.
Dependent variable: export unit value index, dollars. SITC 0 + 1 (food and tropical beverages).
" " " " " SITC 2 + 4 (raw materials).
Estimation is by minimum-distance algorithm; t-statistics in parentheses.

Table 7

RAW MATERIALS UNIT VALUES

	Constant	PHWWA	PHWWA(-1)	PHWWA(-2)	PGDP	PGDP(-1)	Log ratio	CCSQ	SEE
United States	-1.420	0.369	0.096		0.535		0.292	0.500	0.066
	(-1.7)	(2.8)	(0.6)				(1.7)		
Japan	-0.955	0.322	0.398		0.280		0.190	0.780	0.055
	(-1.3)	(3.4)	(3.2)				(1.3)		
Germany	-1.470	0.209	0.131		0.660		0.298	0.870	0.035
	(-2.9)	(3.1)	(1.7)				(2.9)		
France	-0.150*		0.191		0.809		0.029*	0.880	0.028
	(-0.6)		(4.4)				(0.5)		
United Kingdom	-1.850	0.297	0.004		0.699		0.372	0.740	0.049
	(-2.6)	(3.1)	(0)						
Italy	-1.466	0.227			1.240	-0.467	0.298	0.740	0.070
	(-3.1)	(2.3)			(6.3)		(3.1)		
Canada	-1.149	0.204	-0.013		0.809		0.228	0.720	0.033
	(-2.8)	(3.2)	(-0.1)				(2.8)		
Austria	-1.930	0.365	0.136		0.499		0.393	0.870	0.044
	(-2.8)	(4.0)	(1.5)				(2.8)		
Belgium	0.256*	0.081			0.919		-0.055*	0.810	0.037
	(0.8)	(1.3)					(-0.8)		
Denmark	-0.075*	0.386	0.196		0.418		0.020*	0.460	0.075
	(-0.2)	(2.6)	(1.4)				(0.3)		
Finland	-0.905		0.343		0.657		0.183	0.920	0.029
	(-3.3)		(4.4)				(3.3)		
Greece	-1.544	0.518			0.482		0.308	0.510	0.082
	(-1.9)	(4.0)					(1.9)		
Ireland	-1.069	0.194	-0.012		0.908		0.212	0.760	0.038
	(-3.6)	(2.9)	(-0.2)				(3.6)		
Netherlands	-1.117	0.163	0.082		0.755		0.228	0.890	0.029
	(-3.3)	(2.8)	(1.3)				(3.2)		
Norway	-0.920	0.166	0.119	0.101	0.614		0.185	0.870	0.036
	(-2.6)	(2.8)	(1.5)	(1.5)			(2.6)		
Portugal	-0.449*	0.253		0.248	0.499		0.091*	0.750	0.035
	(-0.9)	(3.1)		(2.5)			(0.9)		
Sweden	-1.652		0.147	0.130	0.723		0.338	0.750	0.058
	(-2.7)		(1.1)	(1.1)			(2.8)		
Switzerland	-0.213*	0.163			0.837		0.041*	0.920	0.024
	(-1.3)	(4.9)					(1.3)		
Turkey	0.250*	0.258		0.377	0.365		-0.050*	0.700	0.044
	(0.5)	(3.2)		(3.9)			(-0.5)		
Australia	-0.410*	0.239			0.761		0.081*	0.450	0.079
	(-0.6)	(1.6)					(0.6)		
New Zealand	-1.530	0.656			0.344		0.316	0.590	0.102
	(-1.7)	(3.1)					(1.8)		

Notes: PHWWA = HWWA spot raw materials price index,
PGDP = GDP deflator,
CCSQ = correlation coefficient squared,
Log ratio = $LN(PHWWA_{-1}/PX_{-1})$ where PX = dependent variable.
Dependent variable is export unit value index, dollars, SITC 2 + 4.

examined to see if they match with coefficient size. However, a strong relationship between relative influence of domestic cost and size of market share does not seem to exist (and similarly for the importance of raw materials in total exports). There are several cases where estimates of the constant term and/or the error correction term are either insignificant or incorrect in sign. In these cases, and in cases where data for a country are not available, coefficient values taken from an average of neighbouring countries have been imposed for the constant and the error correction term. The original estimation results are shown in Table 7, with asterisks next to those coefficients that will have imposed values in model simulation runs.

75. The non-EEC food price results shown in Table 8 reveal a stronger influence of world price versus domestic costs for the United States, Canada, and Australia, and a stronger influence of domestic cost for the other non-EEC countries. Grain prices figure heavily in the HWWA spot price index, and the United States, Canada and Australia are big grain exporters. The relatively weak influence of world spot prices in other non-EEC countries may be explained by the usual index composition problem but also by the widespread existence of domestic agricultural support programmes.

76. The EEC presents a separate case owing to the Common Agricultural Policy (CAP), which sets import levies on certain products and export subsidies on others (28). In cases where the domestic price of a particular exportable product is above the world price, a refund is given to the exporter to compensate for the loss taken from selling at below domestic price. The effect of the export subsidy is to maintain the wedge between world price and domestic price for many exported products, but the effect upon export unit values is less clear. Not all exportable EEC agricultural products have a domestic price above the world price, and during the period 1973 to 1975 world prices were above EEC domestic prices for many goods, leading in some cases to export taxes and import subsidies. One might expect to find a weak, and very much lagged relationship between world spot prices and EEC food export unit values. This is indeed the case: inclusion of the world spot price index in the EEC food export unit value equations yields coefficient estimates (on the HWWA price index) that are statistically insignificant and close to zero in value, even when several lags are included.

77. A number of alternative specifications were tried in order to improve the EEC country food export unit value index equations. Using Eurostat farm producer price data, an index of EEC farm producer prices was constructed and tested, both as a separate independent variable and as part of a ratio between world spot price and EEC farm producer price. In neither form did this index yield significant coefficient estimates in more than a couple of cases. This is probably due to insufficient commodity coverage of the constructed index as well as the problem of export destination; as mentioned above, export subsidies apply only to goods going to third countries, whereas export unit value indices apply to products regardless of export destination.

78. Another alternative approach is to consider the overall purpose of the system of CAP import levies, government purchases of commodities, and export subsidies, which is to maintain real farm income. By moderating fluctuations in the price of inputs and outputs, governments aim at preventing large changes in nominal farm income. Assuming that the net outcome of CAP policies is indeed to stabilize nominal farm income, changes in real farm income are determined by fluctuations in the cost of living. Thus the cost of living, or

Table 8

NON-EEC EXPORT UNIT VALUES

Country	PHWWA	PHWWA(-1)	PHWWA(-2)	PXF(-1)	PGDP	PGDP(-1)	CCSQ	SEE
United States	0.264	0.414			0.322		0.750	0.047
	(3.7)	(5.6)						
Japan		0.176		0.550	0.274		0.340	0.063
		(1.7)			(1.7)			
Canada	0.302	0.215	0.090		0.393		0.680	0.059
	(3.3)	(2.3)	(1.0)					
Austria		0.194			0.806		0.300	0.086
		(1.4)						
Finland		0.192	0.202		0.606		0.610	0.051
		(2.1)	(2.4)					
Greece	0.281				0.719		0.290	0.096
	(1.7)							
Norway	0.273				0.727		0.620	0.063
	(2.8)							
Portugal	0.145	0.079		0.290	0.486		0.750	0.037
	(2.5)	(1.2)			(4.1)			
Sweden	0.086	0.242	0.128		0.544		0.680	0.054
	(1.0)	(2.7)	(1.8)		(4.4)			
Switzerland		0.122			0.878		0.880	0.030
		(2.8)						
Turkey	0.238	0.200			0.259	0.303	0.650	0.051
	(2.8)	(2.2)				(2.3)		
Australia	0.330	0.208			0.462		0.670	0.066
	(2.9)	(2.0)						
New Zealand	0.093				0.807	0.100	0.830	0.032
	(1.7)				(7.8)			

Notes: PHWWA = weighted HWWA food and tropical beverage spot price index.
PXF(-1) = export unit value index, dollars, SITC 0 + 1 (lagged dependent variable).
PGDP = GDP deflator.
CCSQ = correlation coefficient squared.

consumer price index, can be seen as a proxy measuring the extent to which the CAP, in combination with domestic agricultural policies, must further increase farm earnings in order to prevent real income loss. And since the CAP is an EEC-wide phenomenon, it makes sense to look at an EEC-wide cost of living measure. A trade-weighted average of EEC private consumption deflators, expressed in dollars, when added to equation [6], yields a range of coefficient estimates of between 0.27 and 0.65 (see Table 9). France, Belgium and Denmark are at the high end of this range, and Italy, Germany and the United Kingdom are at the low end. The world spot price index has a smaller effect, even when lagged values are included. The close linear relationship between own GDP deflator and own consumption deflator makes use of both variables infeasible for most countries, but the trade-weighted EEC-wide consumption deflator avoids this problem to a large extent. To take account of cross-country differences in inflation (and, correspondingly, differences in bilateral exchange rate changes), the EEC-wide private consumption deflator has been adjusted for each country by subtracting the own inflation rate from the EEC-wide inflation rate, but this modification did not yield satisfactory results. Certainly, the EEC food export unit value index equation needs more research. Nonetheless, the trade-weighted EEC private consumption deflator is a convenient proxy that avoids the complications of modelling CAP distortions.

IV. CONCLUSIONS

79. The work reported above has resulted in the endogenization of aggregate commodity prices in the INTERLINK system. The usefulness of the system in analysing the macroeconomic issues referred to in the introduction has still to be fully tested in practice. One drawback already encountered is that the full extent of the current commodity-price slump remains unexplained by the equations. In principle, this might suggest a rebound in prices was likely. In fact, on the basis of market information this seems unlikely, tending to reinforce findings that parameters have been changing in the recent past. A trend decline in metals and minerals prices and in their responsiveness to activity is established.

80. Preliminary investigations using the system encourages scepticism about some of the stronger claims made for the role of commodity prices in the world economy. It seems improbable that they are an important autonomous source of activity fluctuations in the OECD. This finding would seem to be robust to substantial variation in the parameters of reported equations but it is the subject of continuing work.

Table 9

EEC FOOD EXPORT UNIT VALUES

Country	HWWA	HWWA(-1)	PCPD	PGDPD	CCSQ	SEE
Germany	0.045	0.068 (1.6)	0.285 (1.3)	0.602 (2.8)	0.880	0.026
France	0.104 (2.8)	0.113 (3.6)	0.547 (2.5)	0.236	0.950	0.018
United Kingdom	0.029	0.061 (1.7)	0.271 (2.7)	0.639 (7.0)	0.910	0.023
Italy		0.124 (1.5)	0.217	0.659 (2.0)	0.670	0.053
Belgium	0.183 (4.8)	0.181 (4.8)	0.636		0.890	0.024
Denmark		0.054	0.471 (1.3)	0.475 (1.4)	0.720	0.041
Ireland	0.127 (3.5)	0.098 (2.6)	0.353	0.422 (2.6)	0.920	0.022
Netherlands	0.067 (1.8)	0.069 (1.8)	0.351	0.513 (2.4)	0.900	0.023

Notes: HWWA = weighted HWWA spot food price index (food, tropical beverages, tobacco).
PCPD = trade-weighted EEC private consumption deflator.
PGDPD = own-country gross domestic product deflator.
CCSQ = corelation coefficient squared.

t-statistics in parentheses.

Greece not included since it joined EEC during estimation period, dependent variable is export unit value index, dollars, SITC 0 + 1.

NOTES AND REFERENCES

1. See Kaldor, N., "Inflation and Recession in the World Economy", Economic Journal, Vol.86, No.344, December 1976, pp.703-714; and "The Role of Commodity Prices in Economic Recovery", Lloyds Bank Review, July 1983.

2. Beckerman, W., "How the Battle for Inflation was Really Won", Lloyds Bank Review, January 1985; Beckerman, W. and Jenkinson, T., "Commodity Prices, Import Prices and the Inflation Slowdown: A Pooled Cross-country Time Series Analysis", unpublished mimeo.

3. A previous attempt to endogenise commodity prices in the context of a world model was the COMLINK project. A series of 28 commodity market models ranging from two to over 30 equations were integrated into the Project Link system. This was a more elaborate and ambitious approach than the present one. See F.G. Adams, "Integrating Commodity Markets into LINK" in I.A. Sawyer (Ed.) Modelling the International Transmission Mechanism, North Holland, New York 1979, pp. 273-294. Partial endogenisation was carried out in the UNCTAD World Trade and Development Model. There 28 "mini" commodity models were used to obtain an intial set of prices which were inserted as exogenous into the world model. Successive iterations were then possible.

4. See V.L. Hemphill, "Estimation of the Timing Asymmetry in International Trade", IMF Staff Papers, March 1980 and E. Veil, "The World Current Account Discrepancy", OECD Occasional Studies, June 1982.

5. A description of the INTERLINK trade model is given in the OECD INTERLINK manual: OECD Interlink System, Vol. 1, Structure and Operation.

6 Coe, D.T. (1985), "Nominal Wages, the NAIRU and Wage Flexibility", OECD Economic Studies (Autumn).

7. See "A New HWWA Raw Material Price Index", Hans-J. Timm, Intereconomics, September 1980, Hambourg. Monthly prices are based on daily computations and they are averaged to give semestrial series.

8. The two indices differ in coverage as sugar and tobacco are included in tropical beverages in the HWWA index.

9. See M.R. Wickens, "The Efficient Estimation of Econometric Models with Rational Expectations", Review of Economic Studies, 1982.

10. Pierce, D. and Haugh, L., "Causality in Temporal Systems: Characterisations and a Survey", Journal of Econometrics 5 (1977), pp. 265-293.

11. Alternative regression-based techniques were first proposed by C.W.J. Granger, "Investigating Causal Relationships by Econometric Methods and Cross Spectral Methods", Econometrica 36 (May 1969) and C. Sims, "Money, Income and Causality", American Economic Review 62 (September 1972).

12. Sims, in "Comment on Pierce", Journal of the American Statistical Association 72.357 (March 1977), pp. 23-24.

13. W. Labys and C.W.J. Granger, Speculation, Hedging and Commodity Price Forecasts, Lexington, Mass. 1970, Chapter 3.

14. See D.K. Guilkey and M.K. Salemi, "Small Sample Properties of Three Tests for Granger-Causal Ordering in a Bivariate Stochastic System", Review of Economics and Statistics, November 1982.

15. See, for example, E.L. Feige and D.K. Pearce: "The Casual Causal Relationship between Money and Income: Some Caveats for Time Series Analysis", Review of Economics and Statistics 1978.

16. Chu, Ke-Young and Thomas K. Morrison (1984), "The 1981-82 Recession and Non-oil Primary Commodity Prices", IMF Staff Papers (March). Grilli, Enzo R. and Maw-Cheng Yang (1981), "Real and Monetary Determinants of Non-oil Price Movements", Division Working Paper No. 1981-6, Commodities and Export Projections Division, The World Bank (December).

17. Economic Outlook 36, December 1984, p.60.

18. See, for example, H. Theil, Applied Economic Forecasting, Amsterdam 1966, pp.26-32.

19. Both sets of commodity price indices have been tested for both OECD country and non-OECD region equations. The HWWA indices yield more significant and sensible coefficients than do the UNCTAD indices in OECD country export unit value equations; the reverse is true for non-OECD region equations.

20. Adams, Gerard F. and Marquez, Jaime, "The Impact of Petroleum and Commodity Prices in a Model of the World Economy", in B. Hickman, ed., Global International Economic Models, North Holland, 1983.

21. Deppler, Michael and Ripley, Duncan, "The World Trade Model: Merchandise Trade", IMF Staff Papers, March 1978, Vol.25, No.1.

22. Ripley, Duncan, "The World Model of Merchandise Trade: Simulation Applications", IMF Staff Papers, June 1980, Vol.27, No.2.

23. Turner, Philip, "International Aspects of Inflation", in OECD Occasional Studies, Paris, June 1982.

24. Export unit value data for food and raw materials were not available for Iceland and Spain.

25. Both sets of commodity price indices have been tested for both OECD country and non-OECD region equations. The HWWA indices yield more significant and sensible coefficients than do the UNCTAD indices in OECD country export unit value equations; the reverse is true for non-OECD region equations.

26. Chu and Morrison, op. cit.

27. These ratios apply to the NIC, OOP and LMI groups as they are currently constituted in INTERLINK. Changes in the country composition of these groups to be incorporated in the next version of INTERLINK will cause these ratios to change.

28. Harris, S., Swinbank, A, and Wilkinson, G. The Food and Farm Policies of the European Community, Wiley & Sons, 1983.

Annex

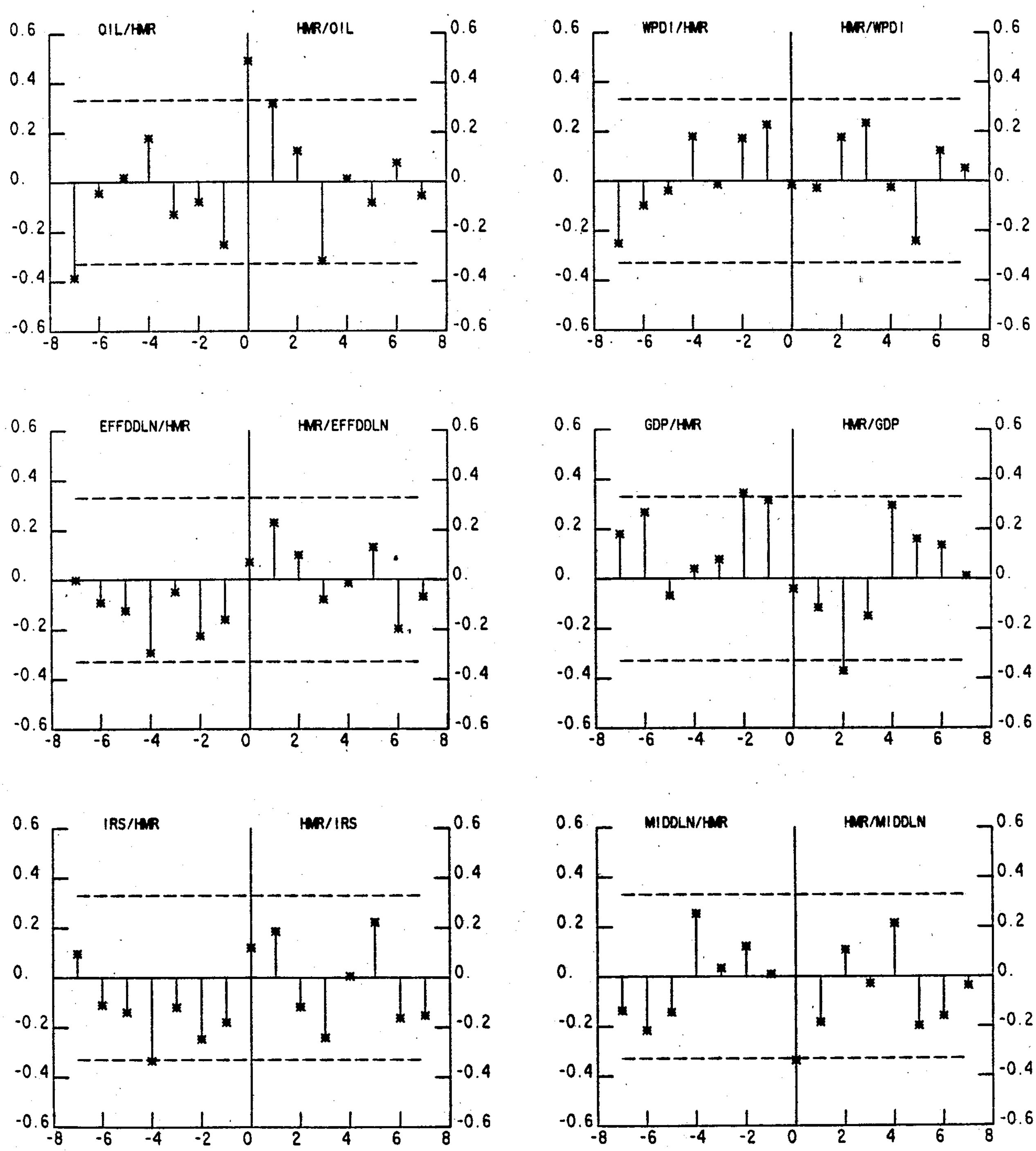
COMMODITY PRICES, SUPPORTING MATERIAL

CROSS-CORRELATIONS

The following figures (A1) depict pairwise cross-correlations between residuals of ARIMA models for commodity price indices and a number of other variables. The definition of the variables is in the text of the main paper, as is a discussion of these results. The specifications of the various ARIMA models are noted in Table A1.

Figure A1

CROSS-CORRELATIONS OF COMMODITY PRICES
AND EXPLANATORY VARIABLES



Note: Vertical axis measures correlation coefficient, horizontal axis lead (+) or lag (–) of commodity price on explanatory variable. Dotted lines indicate 95 per cent confidence intervals.

Figure A1 continued

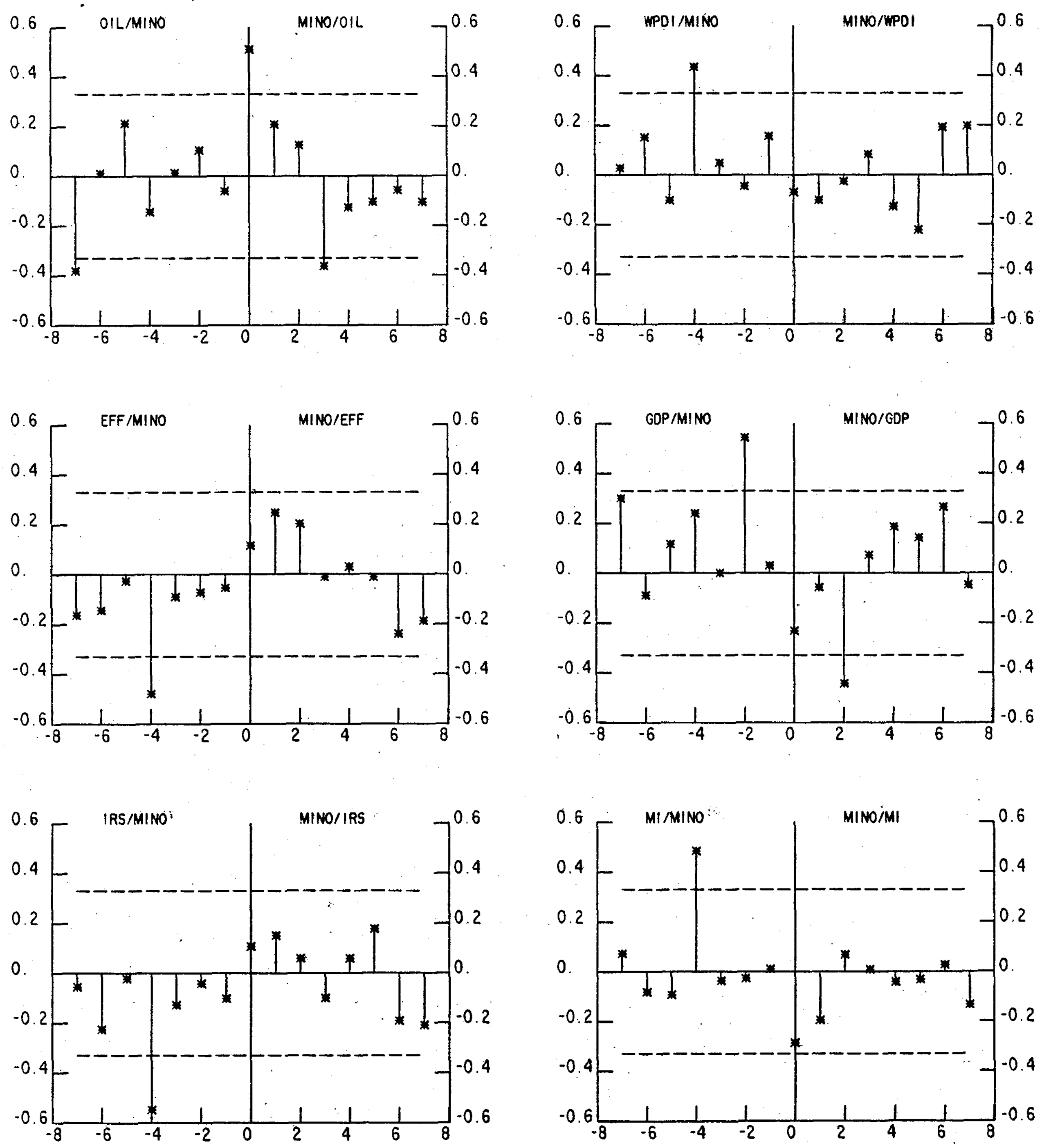


Figure A1 continued

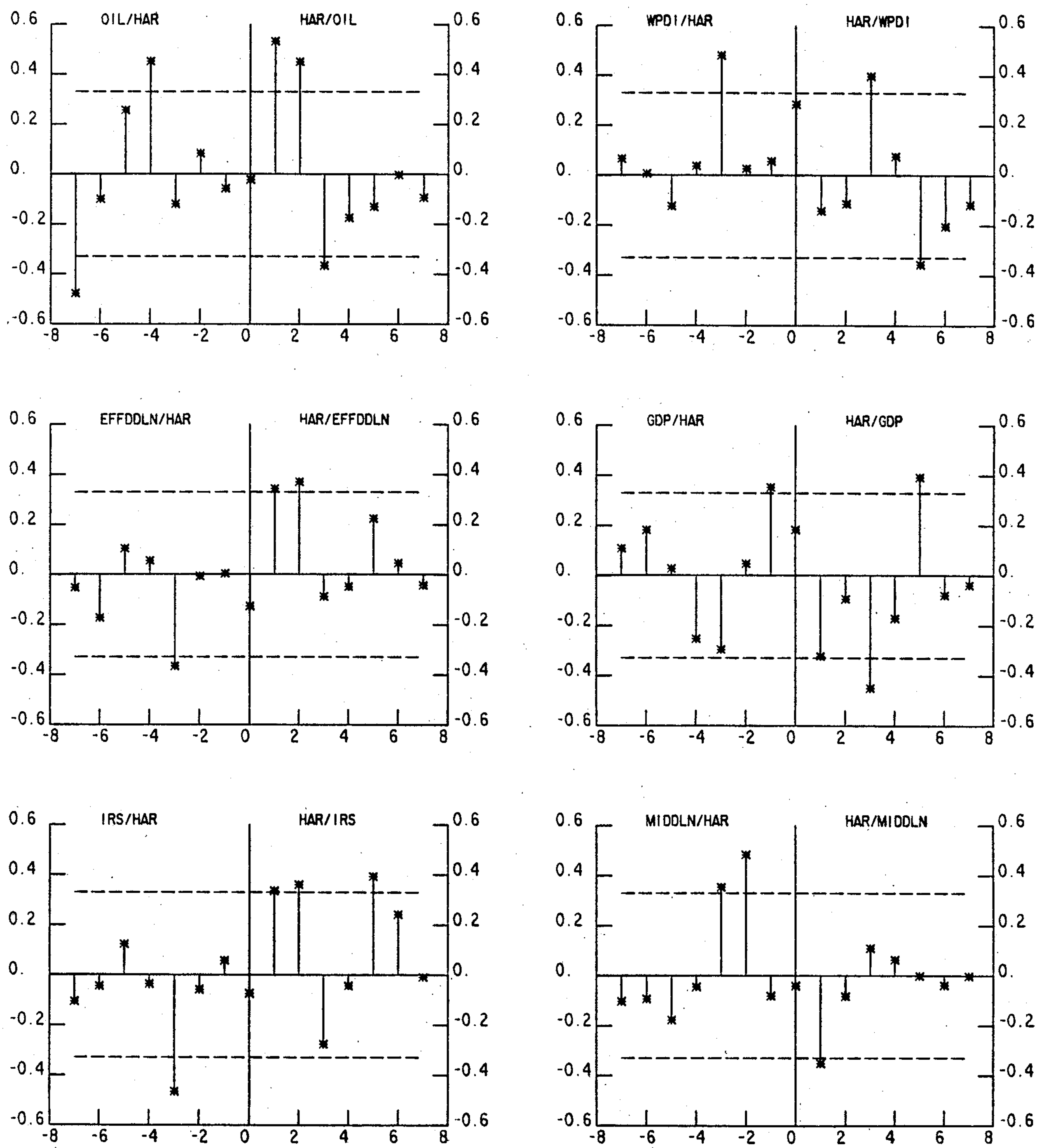


Figure A1 continued

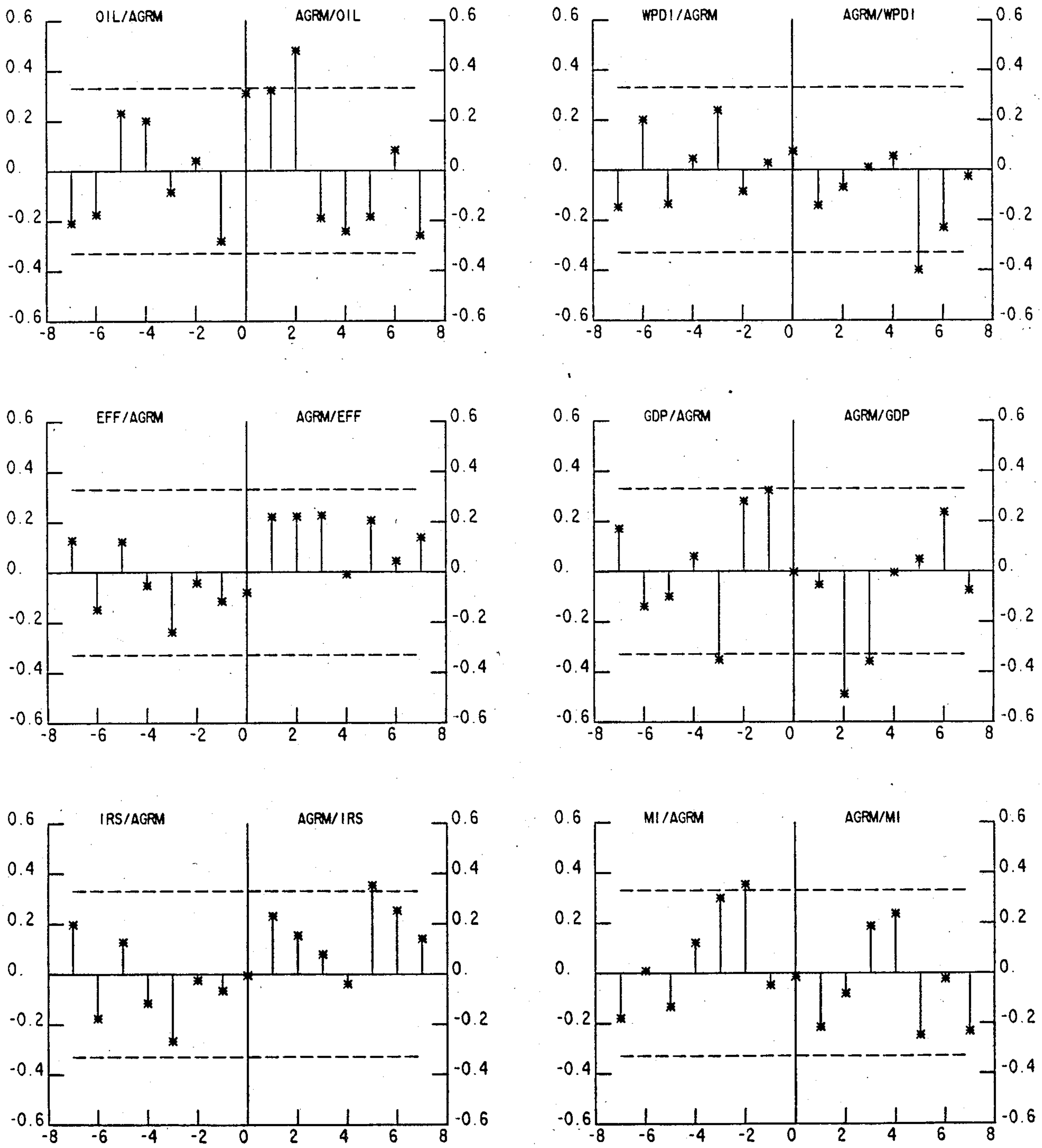


Figure A1 continued

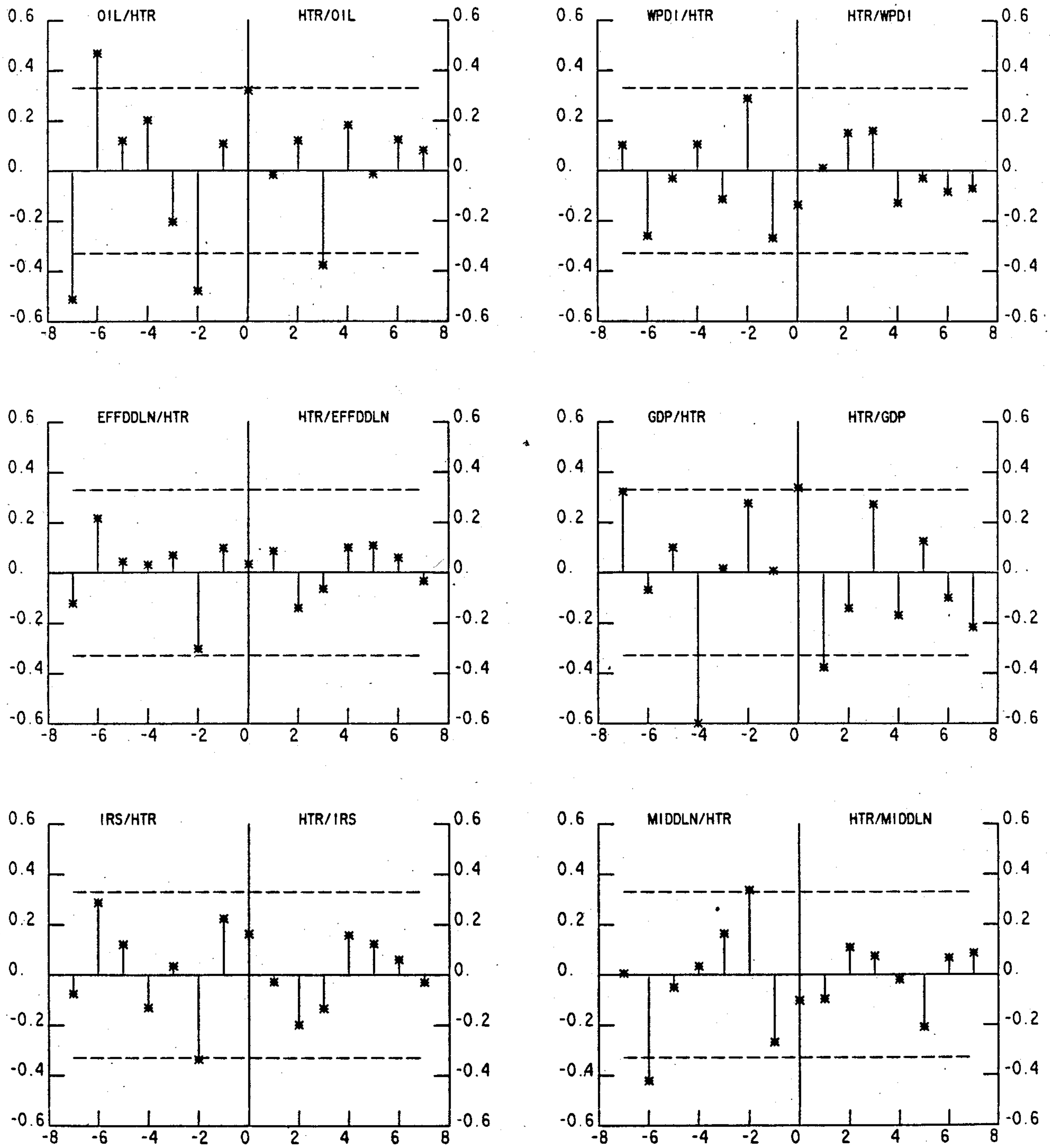


Figure A1 continued

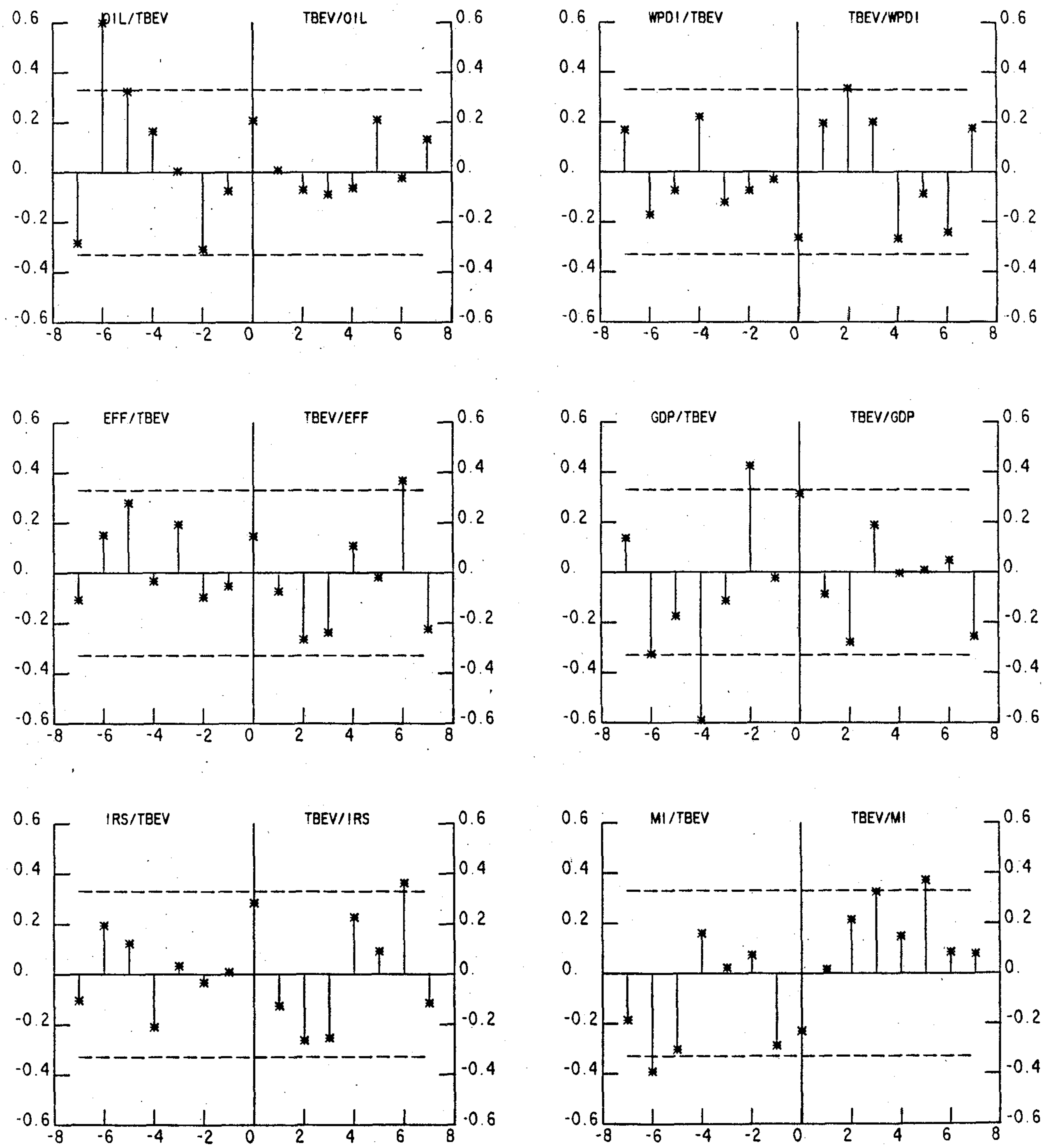


Figure A1 continued

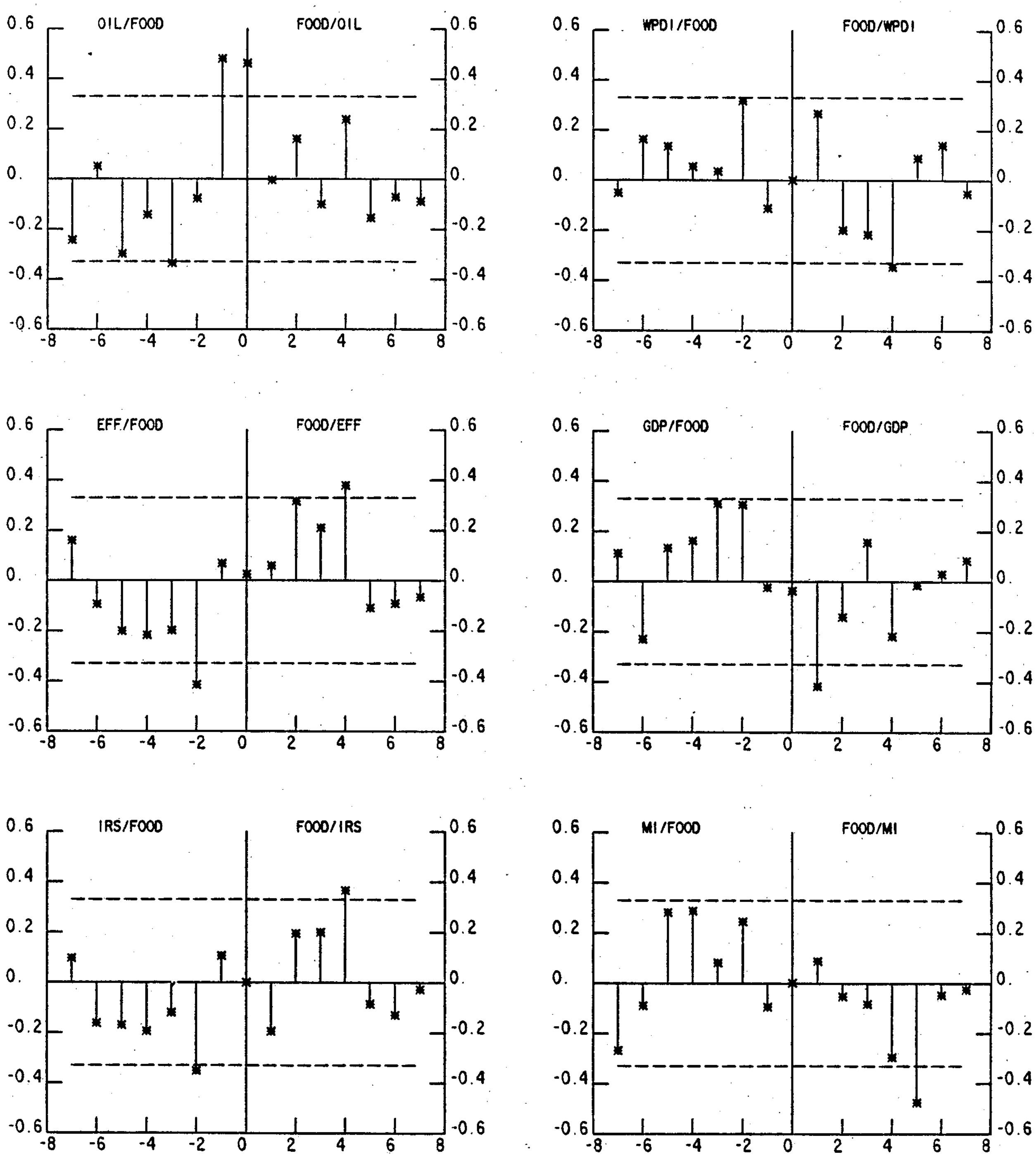
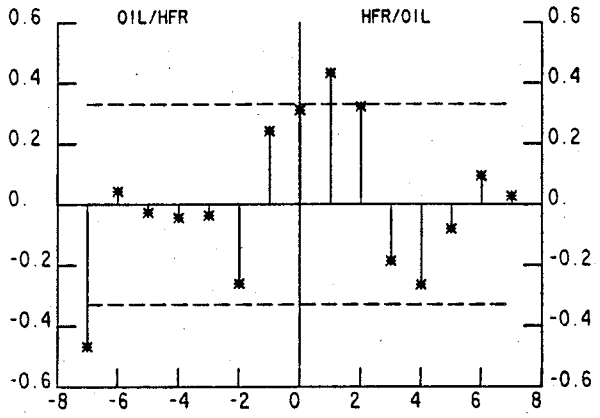
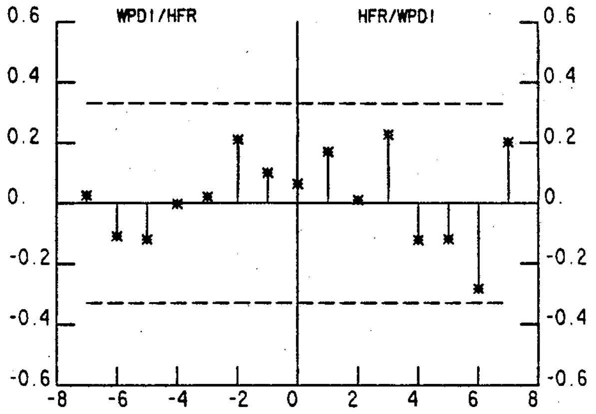
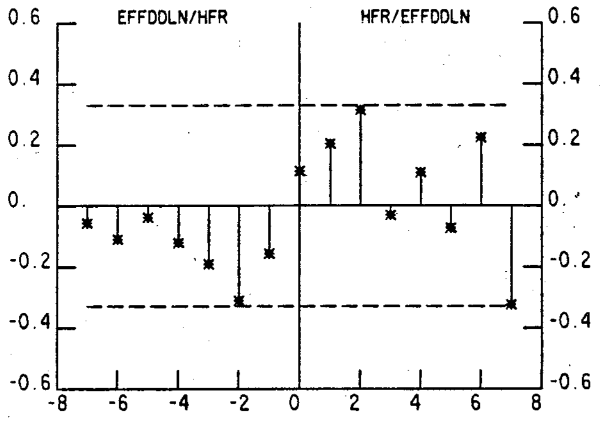
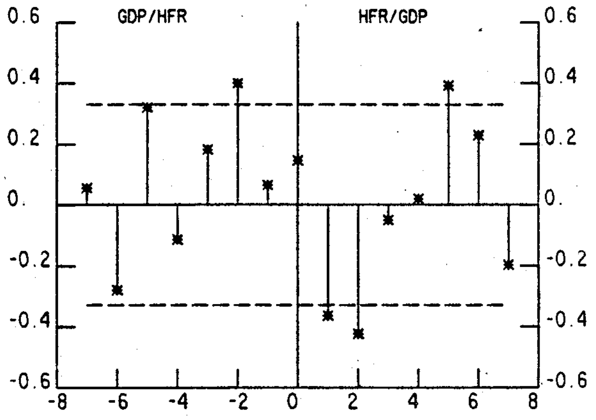


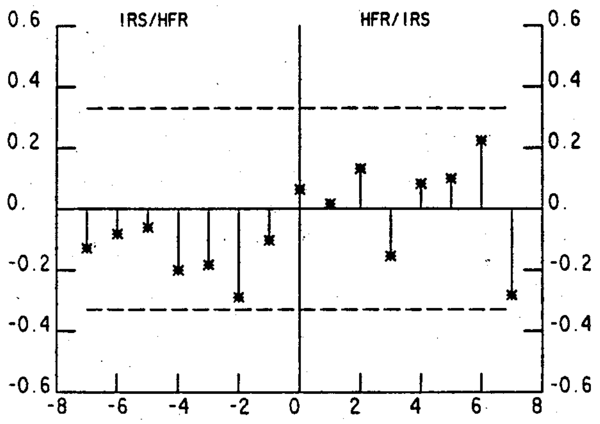
Figure A1 continued











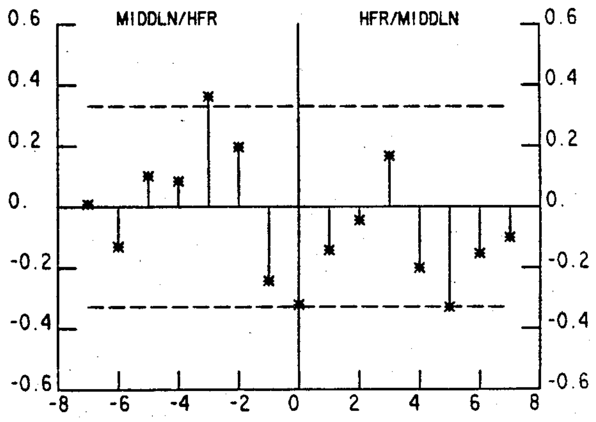


Table A1

ESTIMATED ARIMA EQUATIONS FOR COMMODITY PRICE EQUATION VARIABLES (1)

1966I to 1983II	Constant (2)	ϕ_1	ϕ_2	θ_1	θ_2	R^2 (3)	Box-Pierce χ^2	Box-Pierce d.f
AGRM, log level, AR1 MA2	0.52 (3.08)	0.47 (2.73)		-1.24 (10.07)	-0.79 (6.27)	0.84	3.88	3
MINO, log level, MA2	0.96 (22.41)			-1.23 (18.63)	-0.89 (15.75)	0.65	1.95	4
FOOD, log level, AR1 MA1		0.93 (29.65)		-0.38 (2.41)		0.69	2.27	5
TBEV, log level, AR1 MA1	0.24 (1.86)	0.77 (6.50)		-0.54 (3.43)		0.80	5.31	4
LHAR, log level, AR2	1.12 (2.95)	1.37 (9.21)	-0.59 (3.97)			0.82	3.57	3
LHMR, log level, AR2	2.10 (3.33)	1.09 (6.82)	-0.50 (3.07)			0.61	4.04	3
LHFR, log level, AR1	0.87 (1.71)	0.82 (8.02)				0.64	7.28	4
LHTR, log level, AR2		1.94 (22.27)	-0.95 (11.24)			0.51	9.25	4
B7IP, 1 diff., AR2		0.77 (4.71)	-0.28 (1.71)			0.17	4.41	5
USAIRSREAL, Δ %, MA1				0.57 (4.08)		0.23	1.53	6
EFFEX, 2.diff., AR2		-0.63 (3.93)	-0.45 (2.65)			0.30	4.74	4
OECDCPV, 1.diff., AR1		0.88 (16.09)				0.30	6.18	6
OECDM1, 2.diff., MA1				0.97 (34.98)		0.32	3.91	5
B7GDPV, 1.diff., AR1	0.008 (2.61)	0.51 (3.41)				0.25	5.69	5
WPGDPD, 1.diff., AR1	0.019 (2.77)	0.38 (2.28)				0.10	3.13	5
POILR, 1.diff., random walk	-	-	-	-	-	-	2.88	7

1. Semi-annual data 1966-1983, for HWWA commodity prices 1967II to 1983II. Statistics in parentheses are t-values. For variable definitions see main paper, p.14.

2. To ensure that the residuals (a_t) of the ARIMA models in log-transformed form have a mean not significantly different from zero, a constant was introduced where necessary, as the mean of the original log-transformed series (μ) was significantly different from zero.

   i.e. $\mu > 2\sigma/\sqrt{N}$

   where μ = mean of the log-transformed series,
   σ = standard deviation,
   N = number of observations.

3. For the models, the statistic R^2 is defined as: $1 - \hat{V}(a_t)/\hat{V}(Z_t)$.

   where $\hat{V}(a_t)$ and $\hat{V}(Z_t)$ denote estimated variances of a_t and Z_t. It is comparable with R^2 in standard multiple regression.

Independent variables (all in logs except the interest rate):

B7IP:	industrial production of the seven largest economies.
USAIRSREAL:	U.S. three-month Treasury bill real interest rate (nominal rate minus actual inflation rate), first difference.
EFFEX:	U.S. effective exchange rate in dollars, MERM weights, second difference.
OECDCPV:	OECD consumption in volume terms.
OECDM1:	Money stock (M1) of seven largest OECD economies, second difference.
B7GDPV:	GDP of the seven largest OECD countries, 1980 prices and dollars, first difference.
WPGDPD:	GDP price deflator in dollars of the seven largest OECD economies, weighted by GDP shares, first difference.
POILR:	Spot price for oil in Rotterdam market, deflated by OECD price deflator, first difference.