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# OECD Economic Activity and Non-Oil Commodity Prices: Reduced-Form Equations for INTERLINK

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

This paper gives an overview of the determination of non-oil commodity prices in the Economics and Statistics Department's INTERLINK world model. The practical problems which have been encountered, in particular in the context of full simulations are discussed. Based on a number of statistical tests, a new specification of the commodity price block is proposed. Indices of nominal commodity prices measured in dollars are estimated as functions of OECD economic activity and inflation, U.S. interest rates and oil prices. Compared to the previous system, the new equations are better behaved in a number of respects.

* * *

Cet article rappelle comment les prix des produits de base sont déterminés dans le modèle INTERLINK du Département des Affaires Economiques et Statistiques de l'OCDE et analyse les difficultés rencontrées, en particulier dans le cadre de simulations de chocs exogènes. A cet égard, après la conduite de plusieurs tests statistiques, une nouvelle spécification du bloc des prix produits de base est proposée: les indices de prix nominaux mesurés en dollars sont exprimés en fonction d'une part de la croissance et de l'inflation de la zone OCDE, et d'autre part du taux d'intérêt américain et du prix du pétrole. A divers égards le système d'équations ainsi éstimé est plus satisfaisant que le précedent.

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# OECD ECONOMIC ACTIVITY AND NON-OIL COMMODITY PRICES: REDUCED-FORM EQUATIONS FOR INTERLINK

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# OECD ECONOMIC ACTIVITY AND NON-OIL COMMODITY PRICES: REDUCED-FORM EQUATIONS FOR INTERLINK

by

Gerald Holtham and Martine Durand

## INTRODUCTION

The endogenous determination of non-oil commodity prices in a multi-country model facilitates the analysis of a number of issues which are important to the work of the Economics and Statistics Department. The steep decline in commodity prices in recent years, for example, has been credited with a major role in the slowing of OECD inflation. At the same time, primary product exporters are among the countries with the most severe problems of external indebtedness, so the level of real commodity prices, i.e. their terms of trade, is an important issue in any analysis of the international debt crisis. More generally, both the disinflation of the early-1980s and the LDC debt problem underline the important effects that changes in economic policy in OECD Member countries can have on non-OECD economies, and their multiple feedbacks on OECD activity and inflation. Finally, the endogenous determination of commodity prices facilitates the preparation of the Economics and Statistics Department's biannual forecasts published in the Economic Outlook.

Reduced-form equations for commodity price indices were first introduced in INTERLINK -- the Economics and Statistics Department's world econometric model -- in 1985 (Holtham et al., 1985). Subsequent experience with full-model simulations and forecasts revealed a number of difficulties with the initial specification. This paper reports the results of a re-estimation of the commodity price block. Part I gives a brief overview of the previous model and the practical problems which were encountered. Part II describes the respecification of the commodity price block and reports estimation and simulation results.

## I. SPECIFICATION ISSUES

### A. Description of the original commodity price equations

The determination of commodity prices and the way in which the commodity price block was integrated into the structure of INTERLINK is described in Holtham et al (1985). There are separate price indices for four commodity groups: agricultural raw materials, food, beverages, and metals and minerals. There are two indices for each group, one in which commodities are weighted according to their importance in the exports of developing countries (the UNCTAD indices), the other in which the weights reflect the importance of commodities in OECD trade (the Hamburg (HWWA) indices) (see Annex Table 1). These "global" commodity price indices are explanatory variables in country-specific export unit value equations, with the UNCTAD indices driving the export unit values of non-OECD regions and the HWWA indices driving the export unit values of the OECD countries.

A reduced-form equation for each index was derived from a simple theoretical model of the market for a storable commodity. Given that the reduced forms summarised a complex underlying structural system, few theoretical priors were imposed beyond the selection of the range of explanatory variables to be tested in equations. Much exploratory data analysis was carried out before equations were estimated, including filtering of all series to obtain white noise series and cross-correlations of these to elucidate causal relationshsips. The final specifications were substantially data-guided. The lag distributions in the reduced-form equations are assumed to reflect expectations formation processes as well as lagged adjustments owing to transactions costs.

The "price" determined in a simple partial-equilibrium model is a relative or "real" price. In the case of indices of nominal commodity prices measured in dollars, an important issue is how to model the effects of macroeconomic phenomena, in particular, OECD inflation and the dollar exchange rate. In line with the presumption that relative prices should be homogenous of degree zero with respect to the absolute price level, commodity price indices are normally specified to move one for one with some measure of the OECD general price level. The appropriate partial-equilibrium response of an index of commodity prices expressed in dollars to the dollar exchange rate was derived by Ridler and Yandle (1972) (1). Their results imply that, for a unit percentage change in an index of the real dollar exchange rate against all other currencies, dollar commodity prices should change in the opposite direction by less than 1 per cent (2).

In INTERLINK, the general OECD price level is defined in terms of a dollar index, which itself varies with the dollar exchange rate. If the dollar appreciates against all other currencies by 1 per cent in real terms, the OECD price index falls by one minus the current weight of the United States in OECD real GNP. If commodity price indices are specified so as to be homogenous of degree one with respect to this index, reasonable commodity-price behaviour with respect to exchange rates is assured. The specification then amounts to a special case of the Ridler and Yandle system where the relative importance of each country in commodity consumption and production is assumed to be reflected by its relative GNP weight.

The original estimation of the commodity price equations assumed that the adjustment of commodity prices to OECD inflation and exchange-rate changes would be complete within a half year. Equations for a semi-annual model like INTERLINK could therefore be specified as "real" price equations. In the final equations, commodity prices were specified as functions of the deviation of OECD real GNP from its long-run trend, the real oil price, real interest rates and, in the case of metals prices, a time trend.

## B. Practical difficulties with the commodity price equations

The first problem encountered related to the oscillatory nature of the equations in response to shocks. There is no shortage of reasons why commodity prices may cycle in response to shocks. Production/inventory cycles may exist at one periodicity and investment cycles at another periodicity. A shock to demand which depresses prices may lead to expectations of continued low prices, leading to cut-backs in inventory investment and in investment in capacity. Even with no recovery in demand, a period of low prices could be followed by a period of high prices.

Reduced-form price equations, lacking explicit variables for levels of stocks or for the available capacity of commodity producers, are likely to have auto-correlated errors unless they include lagged dependent variables. All of the estimated equations contained at least one lagged dependent variable. The food-price equations were first-order processes, (i.e. one lagged dependent variable), agricultural materials and beverages prices were second-order processes, and the minerals price equation had the lagged dependent variable at lags one, two and five. Five of the eight equations implied oscillatory adjustment of prices to a new equilibrium after a shock (3).

The practical problem arises because the cyclical behaviour is merely observed and calibrated, rather than explained; it is not possible, therefore, to say why any particular cycle is occurring. When commodity prices cycle markedly in response to a shock, no explicit explanation can be given and the model becomes a "black box". In the context in which the model is used, this is regarded as a serious disadvantage.

Reduced-form equations are often rather unstable when estimated across different data sets. While the equations were subjected to a number of stability tests on the estimation sample, and passed them, they failed to forecast well out of sample (4). The simulation properties of such equations may therefore reflect the noise characteristics of a particular data set rather than any intrinsic features of commodity markets.

These problems were compounded by the fact that the two parallel sets of price indices often had substantially different long-run elasticities and dynamics (5). Although in principle, there is nothing surprising or inappropriate about this result -- just as the commodity composition of different countries' exports differs, it is reasonable to suppose that the response of their export prices to a common shock would also differ -- it implied movements in the terms of trade between groups of countries for which no clear explicit reason could be given beyond a general reference to the commodity composition of exports. It was not possible to say which specific commodities were the source of the divergences.

The estimated equations generally had very good in-sample dynamic simulation properties. The estimation period ended in 1983 and as data for 1984 became available, however, it became clear that the equations' out-of-sample forecasts for that year were very inaccurate. Errors ranged from about 6 per cent (HWWA minerals) to nearly 25 per cent (UNCTAD agricultural raw materials). Because the commodity-price equations in INTERLINK have not played a primary role in the preparation of short-term forecasts, the failure of the equations to track the developments of 1984 and 1985 was not critical. Commodity price projections continued to be made judgementally, and the need for extensive add-factoring was accepted.

The forecasting role of the equations, however, became more important in the case of medium-term projections. In general, the more distant is the projection, the more one would want to rely on the model rather than on judgement, or leading indicators. Large initial add factors which are retired, progressively or all-at-once can interact with the cyclical dynamics of the equations and this may result in substantial, apparently arbitrary cycles in the projection for which no rationalization can be given -- as neither the initial add factor nor the equations' cyclical dynamics are fully understood. The problem is particularly acute if GNP of the larger countries is projected to be growing regularly (6).

## II. REDUCED-FORM COMMODITY PRICE EQUATIONS

### A. Estimation results

Some of the difficulties discussed above are inherent in the reduced-form approach and cannot be resolved without moving to a more structural, disaggregated modelling of commodity markets. Even then, it is not clear that all the problems would be resolved; the forecasting record of larger models of commodity markets is not uniformly impressive and problems of functional instability and the difficulty of modelling expectations formation are still encountered. In view of this, the basic structure of the block has been retained.

The intention was to simplify dynamics, to more closely align parameter estimates for the pairs of indices (HWWA and UNCTAD) and, if possible, to reduce the size of out-of-sample forecast error. Expectations were realistic as to the last objective but some progress appears to have been made.

The innovations in specification were to drop the formulation for the OECD GNP term as a deviation from a flexible trend, and to derestrict the dynamics of the response of commodity prices to OECD inflation and exchange rates. Equations were estimated for nominal commodity prices with the OECD dollar price index and other price and exchange-rate terms appearing as right-hand-side variables. There were two innovations in terms of econometric techniques: co-integration tests were carried out to elucidate whether variables should enter in level or change form; and the equations were estimated simultaneouly, imposing cross-equation parameter restrictions.

#### 1. Co-integration tests

Most of the variables in the commodity price equations are integrated of order one (7). This permits co-integration tests for long-run relationships between the levels of the series; if individual variables are co-integrated of order n, a linear combination of those variables is integrated of order n-1. The usual procedure is to regress unlagged variables (the so-called "staticized" regression) and test whether the residuals are a random walk. If the null hypothesis that the residuals are a random walk cannot be rejected, the variables are not co-integrated and any levels relationship between them is tenuous. Under the null, the Durbin-Watson statistic from the regression is zero (Sargan and Barghava, 1983).

Tests carried out on the commodity price data set indicated that the null hypothesis of random walk residuals could never be rejected at the 5 per cent level when the nominal commodity price was regressed on OECD prices and real GNP. Only when oil prices were added to the vector of variables did the Durbin-Watson statistic move into the indeterminate range.

Those results suggest that the supply of commodities is elastic in the long run and hence that the real price of commodities is not a function of the level of OECD activity. This conclusion is supported by the fact that real commodity prices, ignoring problems of assessing quality and other index-number difficulties, are not higher than they were several decades ago, while the level of OECD GNP is a multiple of what it was then.

2. Initial regressions and specification search

Initial ordinary least squares regression analysis on semi-annual data followed the "general to simple" search method. Each commodity price index was regressed on its own values lagged one and two periods and current and four lagged values of OECD GNP, the OECD dollar price deflator, the United States effective exchange rate, the U.S. GNP deflator, U.S. short-term interest rates and an index of traded oil prices. Log-linear and quadratic time trends were also tried in each equation. All variables except interest rates and time were in natural logarithms. Regressions were run over two samples 1960I to 1985II and 1970I to 1985II. For about half the commodity price indices, Chow tests revealed a break in the relationship at the end of the 1960s so regression analysis concentrated on the shorter sample period (8).

Simplifications of the most general equation were then sought which lowered, or did not raise, equation standard errors. In the case of the UNCTAD food equation and the HWWA beverages equation, the estimated coefficients on OECD GNP activity were so ill-determined and sensitive to the data sample that the terms were dropped. Interest-rate effects were also insignificant and not robust and were eliminated in all but three equations. Impact effects are negative, as expected, indicating that commodity demand is reduced by higher interest rates. If the equations are interpreted as depicting an elastic long-run supply curve for commodities, long-run interest-rate effects must result from shifts in the supply curve rather than the demand curve. If investment in commodities production is more (less) discouraged by rises in interest rates than is investment generally in the OECD area, the relative price of commodities could be raised (lowered) in the long run by interest rate increases. A tiny long-run positive effect from interest rates is incorporated in the agricultural raw materials equations, but the effect in the UNCTAD food equation remains negative (see Table 3).

In all equations, the long-run elasticity of commodity prices with respect to the OECD dollar price deflator was close to unity. The equations were constrained to have a unit elasticity with an "error-correction" specification. The sum of the estimated coefficients on the real GNP terms generally added up to around zero, consistent with the results of co-integration tests implying that GNP growth rates were the relevant explanatory variable.

The OLS regression results are reported in Annex Table 2. Contemporaneous values of U.S. prices and exchange rates are not retained in any of the equations. For both food equations and the UNCTAD tropical beverages equation, even the OECD dollar price index (embedding an exchange-rate effect) only enters with a lag, implying that an exchange rate change has no effect for six months.

Finally time trends have been retained in all equations except for tropical beverages. While this is reasonable in the light of recent commentary about technical progress in agricultural production (the green revolution, etc.) and the declining metal-intensity of OECD GNP, the size of the trends is disturbing and is probably sample-specific. Time-squared terms were retained for the metals and minerals equations since they made a substantial improvement to the standard error of the equations. Their inclusion resulted in only small changes to the value of other estimated coefficients.

### 3. Simultaneous estimation results

The pairs of equations for the same commodity price indices (UNCTAD and HWWA) were then estimated simultaneously and the null hypothesis that the coefficients were identical in both equations was tested (Table 1). Despite the different commodity composition of the agricultural raw materials indices, the hypothesis of identical coefficients was accepted for these equations. For the minerals equations, complete identity was rejected. However, the

Table 1

TEST OF IDENTICAL PARAMETERS IN PAIRS OF EQUATIONS

| | Chi-squared statistics (a) | | | |
|---|---|---|---|---|
| | Complete identity | Identical long-run elasticity w/r OECD growth | Identical (b) short-run impact of OECD inflation | Identical long-run elasticity w/r oil price |
| Agricultural raw materials | 6.9* | n.a. | n.a. | n.a. |
| Metals and minerals | 63.5 | 0.4* | 0.1* | 8.4 |

* indicates that the null hypothesis of identical parameters was accepted at the 90 per cent level.

a. These Chi-squared test statistics are derived from log-likelihood ratio tests. The pairs of equations were first estimated freely. Identical parameters were then imposed in both equations. The Chi-squared statistic is minus twice the ratio of the log-likelihood functions.

b. Identical long-run elasticity is imposed in all cases.

restrictions that both the long-run elasticity with respect to GNP growth and the short-run impact of OECD inflation were the same were accepted. An identical long-run elasticity with respect to oil prices in the minerals equations was rejected, but because the commodity composition of the two indices is similar, this restriction, suggested by OLS results (see Annex Table 2), was imposed particularly as it did not increase the standard errror of the regression. Because the composition of the food and beverage indices is so different, similar pairwise tests were not conducted for these indices. In particular the HWWA index includes sugar in the beverages index with a weight of 40 per cent (see Annex Table 1) while sugar is in the UNCTAD food index, also with a weight around 40 per cent.

Equation errors might be correlated across all eight commodity-price equations, in which case a Zellner seemingly-unrelated-regression estimator is appropriate. All eight equations incorporating all parameter restrictions were therefore re-estimated simultaneously with the "SURE" estimator.

Table 2 reports the results of the simultaneous estimation of the whole system (9). Table 3, panel A, reports the calculated long-run elasticities of the price indices with respect to explanatory variables. Panel B reports the coefficients on lagged dependent variables and the dynamic characteristics of the estimated equations. Of the six equations with two lagged dependent variables, two (the UNCTAD food and the HWWA tropical beverages) have associated eigen values with modulus close to unity. Of the two, one, the UNCTAD food equation has complex eigen values and it has a cycle of eight semesters. The equations for agricultural raw materials and minerals show cycles of shorter periods; their associated eigen values have rather small modulus, implying that, for this group of indices, the cycles are small and short-lived.

To test the stability of the new set of commodity price equations, the system of equations was estimated to 1983II and out-of-sample forecasts were made for 1984 and 1985 -- two years when commodity price developments were difficult to track. Table 4 reports the mean absolute errors and root-mean-squared errors which resulted, and a portmanteau Chi-squared test for parameter stability and equation adequacy (Davidson <u>et al</u>., 1978). With the exception of the food indices, root-mean-squared percentage errors are in single figures and all equations except that for the HWWA food index pass the portmanteau test comfortably with forecast errors low in relation to regression standard errors.

Table 2

SIMULTANEOUS ESTIMATION RESULTS

---

$$\text{HF-HF(-1)} = \underset{(0.06)}{0.07} + \underset{(0.07)}{0.28}*\text{(PG(-1)-HF(-1))} + \underset{(0.85)}{1.43}*\text{(GDPV-GDPV(-1))}$$

$$+ \underset{(0.03)}{0.10}*\text{POIL} + \underset{(0.05)}{0.20}*\text{DWHEAT} - \underset{(0.004)}{0.016}*\text{T}$$

SEE = 0.092 DH = 0.26

---

$$\text{UF-UF(-2)} = \underset{(0.05)}{0.03} + \underset{(0.06)}{1.40}*\text{(UF(-1)-UF(-2))} + \underset{(0.06)}{0.52}*\text{(PG(-1)-UF(-1))}$$

$$- \underset{(0.006)}{0.02}*\text{USIRS} + \underset{(0.05)}{0.32}*\text{POIL(-1)} + \underset{(0.05)}{0.20}*\text{DWHEAT} - \underset{(0.005)}{0.03}*\text{T}$$

SEE = 0.122 DH = -0.21

---

$$\text{HB-HB(-2)} = \underset{(0.02)}{0.01} + \underset{(0.07)}{0.97}*\text{(HB(-1)-HB(-2))} + \underset{(0.05)}{0.24}*\text{(PG(-2)-HB(-2))}$$

$$+ \underset{(0.06)}{0.28}*\text{(POIL(-1)-POIL(-2))} + \underset{(0.3)}{0.80}*\text{(PG-PG(-1))} + \underset{(0.04)}{0.30}*\text{DTBEV}$$

SEE = 0.092 DH = -1.58

---

$$\text{UB-UB(-1)} = \underset{(0.02)}{-0.03} + \underset{(0.03)}{0.20}*\text{(PG(-1)-UB(-1))} + \underset{(0.7)}{2.40}*\text{(GDPV-GDPV(-1))}$$

$$+ \underset{(0.06)}{0.31}*\text{(POIL-POIL(-1))} + \underset{(0.04)}{0.35}*\text{DTBEV}$$

SEE = 0.074 DH = 0.72

---

$$\text{HA-HA(-2)} = \underset{(0.04)}{-0.28} + \underset{(0.06)}{1.19}*\text{(HA(-1)-HA(-2))} + \underset{(0.05)}{0.72}*\text{(PG(-1)-HA(-1))}$$

$$+ \underset{(0.26)}{1.48}*\text{(GDPV-GDPV(-3))} - \underset{(0.002)}{0.007}*\text{USIRS}$$

$$+ \underset{(0.003)}{0.020}*\text{USIRS(-3)} + \underset{(0.02)}{0.22}*\text{POIL} + \underset{(0.2)}{0.97}*\text{(PG-PG(-1))} - \underset{(0.002)}{0.021}*\text{T}$$

SEE = 0.054 DH = 2.86

---

$$UA-UA(-2) = \underset{(0.04)}{-0.28} + \underset{(0.06)}{1.19}*(UA(-1)-UA(-2)) + \underset{(0.05)}{0.72}*(PG(-1)-UA(-1))$$

$$+ \underset{(0.26)}{1.48}*(GDPV-GDPV(-3)) - \underset{(0.002)}{0.007}*USIRS$$

$$+ \underset{(0.003)}{0.020}*USIRS(-3) + \underset{(0.02)}{0.22}*POIL + \underset{(0.2)}{0.97}*(PG-PG(-1)) - \underset{(0.002)}{0.021}*T$$

SEE = 0.042 DH = 1.31

---

$$HM-HM(-2) = \underset{(0.03)}{0.25} + \underset{(0.05)}{1.23}*(HM(-1)-HM(-2)) + \underset{(0.05)}{0.90}*(PG(-1)-HM(-1))$$

$$+ \underset{(0.26)}{1.37}*(GDPV(-1)-GDPV(-3)) + \underset{(0.03)}{0.34}*POIL$$

$$+ \underset{(0.23)}{0.52}*(PG-PG(-1)) - \underset{(0.002)}{0.088}*T + \underset{(0.0001)}{0.001}*T^2$$

SEE = 0.058 DH = -0.83

---

$$UM-UM(-2) = \underset{(0.03)}{0.03} + \underset{(0.05)}{1.13}*(UM(-1)-UM(-2)) + \underset{(0.05)}{0.59}*(PG(-1)-UM(-1))$$

$$+ \underset{(0.26)}{0.82}*(GDPV(-1)-GDPV(-3)) + \underset{(0.03)}{0.22}*POIL$$

$$+ \underset{(0.23)}{0.52}*(PG-PG(-1)) - \underset{(0.004)}{0.039}*T + \underset{(0.0001)}{0.0004}*T^2$$

SEE = 0.053 DH = -0.73

---

<u>Notes</u>: Standard errors are shown in brackets.
Variables are all in natural logarithms except for dummies, interest rates and time:

- HF: HWWA food price index
- UF: UNCTAD food price index
- HB: HWWA beverages price index
- UB: UNCTAD beverages price index
- HA: HWWA price index for agricultural raw materials
- UA: UNCTAD price index for agricultural raw materials
- HM: HWWA price index for metals and non-fuel minetals
- UM: UNCTAD price index for metals and non-fuel minerals
- PG: Dollar price deflator for OECD activity (see (1) for precise definition); basic data source OECD
- GDPV: OECD aggregate GDP at constant prices; source OECD
- POIL: index of a basket of oil prices quoted on Rotterdam spot market; source OECD
- USIRS: United States three-month Treasury bill interest rate
- DWHEAT: Dummy variable, Russian grain harvest failure and purchases 1973
- DTBEV: Dummy variable for Brazilian coffee frost 1976 and 1977I
- T: Time

Table 3

LONG-RUN ELASTICITIES AND DYNAMICS

A) Long-run elasticities

| With respect to: | | POIL | $\dot{POIL}$ | WPGDP | GDPV | $\dot{GDPV}$ | IRS* |
|---|---|---|---|---|---|---|---|
| Food | (H | 0.4 | - | 1 | 0 | 5.1 | 0 |
| | (U | 0.6 | - | 1 | 0 | 0 | -0.038 |
| Tropical beverages | (H | 0 | 1.16 | 1 | 0 | 0 | 0 |
| | (U | 0 | 1.55 | 1 | 0 | 12 | 0 |
| Agricultural raw materials | (H | 0.3 | - | 1 | 0 | 2.1 | 0.018 |
| | (U | 0.3 | - | 1 | 0 | 2.1 | 0.018 |
| Metals and minerals | (H | 0.4 | - | 1 | 0 | 1.5 | 0 |
| | (U | 0.4 | - | 1 | 0 | 1.5 | 0 |

* Semi-elasticity.

B) Dynamics

| | | Coefficient on lag 1 | Coefficient on lag 2 | Mean lag in semesters | Nature of associated eigen values | Modulus of eigen values | Phase of cycle in semesters |
|---|---|---|---|---|---|---|---|
| Food | (H | 0.72 | - | 2.60 | Real | 0.72 | |
| | (U | 0.88 | -0.4 | - | Complex | 0.63 | 8 |
| Tropical beverages | (H | 0.97 | -0.21 | 0.96 | Real | 0.65 | |
| | (U | 0.80 | - | 4 | Real | 0.80 | |
| Agricultural raw materials | (H | 0.47 | -0.19 | 0.39 | Complex | 0.44 | 6.5 |
| | (U | 0.47 | -0.19 | 0.39 | Complex | 0.44 | 6.5 |
| Metals and minerals | (H | 0.33 | -0.23 | 0.30 | Complex | 0.48 | 5.2 |
| | (U | 0.54 | -0.13 | 0.70 | Complex | 0.36 | 6.7 |

Note: "H" refers to the HWWA indices and "U" to the UNCTAD indices.

Table 4

OUT-OF-SAMPLE FORECAST PROPERTIES
1984-85

| | | SD | RMSE (per cent) | MAE (per cent) | RMSE/SD | $\chi^2_4$ |
|---|---|---|---|---|---|---|
| Food | (H | 0.036 | 17.7 | 17.2 | 5.1 | 11.6 |
| | (U | 0.068 | 10.3 | 7.8 | 1.2 | 2.4* |
| Tropical beverages | (H | 0.034 | 3.7 | 4.8 | 1.4 | 0.4* |
| | (U | 0.029 | 7.5 | 7.5 | 3.0 | 1.1* |
| Agricultural raw materials | (H | 0.069 | 4.0 | 3.2 | 0.5 | 1.5* |
| | (U | 0.039 | 4.6 | 3.8 | 1.1 | 5.7* |
| Metals and minerals | (H | 0.051 | 7.4 | 5.9 | 1.4 | 2.5* |
| | (U | 0.045 | 5.3 | 3.7 | 1.1 | 2.3* |

* indicates that the joint hypothesis of parameter stability and equation adequacy cannot be rejected at the 95 per cent confidence level.

Note:

RMSE = Root mean square error
MAE = Mean absolute error
SD = Standard deviation of actual series over forecast period
$\chi^2_4$ is a portmanteau statistic of equation adequacy and parameter stability defined as:

$$\sum_{i=1}^{m} e^2_{t+i}/(SSQ/N-1-k)$$

where $e_t$ are forecast errors, SSQ is the sum of squared regression residuals, N is the number of observations in the regression sample, k is the number of regressors and m is the length of forecast horizon (see Davidson et al., 1978).

## B. Simulation results

Table 5 reports the results of simulated shocks to a number of explanatory variables. The shocks have been performed in full-model linked mode. This allows feedback effects from all variables in the INTERLINK model to be taken into account. The simulations, which were run over a seven-year period, are:

i) 1 per cent per annum increased OECD real GDP growth;

ii) 1 per cent per annum increased inflation in OECD GDP deflator;

iii) a sustained rise of 100 basis points in the U.S. short-term interest rate;

iv) a sustained decrease of 10 percentage points in the oil price index;

v) a 10 per cent depreciation of all currencies against the U.S. dollar with fixed interest rates.

For shocks i) to iv) a fixed exchange rate regime was assumed (10).

Faster growth in the OECD area gives rather similar results for all four pairs of indices, although short-term responses vary. The UNCTAD tropical beverages and both agricultural raw materials indices react most rapidly. The UNCTAD food index and Hamburg tropical beverages index equation have no activity growth terms. Hence, the growth rate impact only occurs after two or three years because of side-effects coming through OECD inflation.

The long-run homogeneity with respect to OECD inflation, which has been imposed in all equations, is reflected in the simulation results of higher OECD inflation. The responses are very similar across indices with the differences explained by different lag structures and different responses to induced changes in activity.

Direct interest-rate effects are only present in the UNCTAD food and in both agricultural raw materials equations. The UNCTAD food index responds most strongly to the simulated increase in the U.S. interest rate. The interest rate in the UNCTAD food equation presumably reflects stockholding costs. For agricultural raw materials prices, the very small positive long-run effect (presumably due to relatively greater input or investment financing costs) is outweighed in full-system simulation by negative indirect effects. In the other equations interest rates affect commodity prices only through indirect effects on activity and prices.

There is an oil price term in all equations and, with the exception of tropical beverages, the response of commodity prices to a sustained oil price decrease is quite substantial, reflecting estimated long-run elasticities of around 0.3 to 0.4. In the case of the tropical beverages indices, long-run elasticities are present only with respect to the change in the oil price. The impact of a sustained oil shock is thus concentrated on the first periods and tends to zero towards the end of the simulation period.

As mentioned above, an appreciation of the U.S. dollar is transmitted in the estimated equations through the dollar OECD GNP deflator. The dollar exchange rate as such does not appear as a separate explanatory variable. Except for the food and the UNCTAD tropical beverages indices, other indices roughly show a two-thirds pass-through of a change in the exchange rate after two semesters. The overshooting of the UNCTAD food index comes from the dynamics of the equation and the somewhat different responses of the two identical agricultural raw materials equations comes from the different values taken by the two indices in the two half-years preceding the beginning of the simulation period.

These simulation results are more well-behaved than those given by the earlier system. With the exception of the UNCTAD food equation, they do not show substantial oscillatory movements in response to exogenous shocks; this was a problem with the previous equations and was one of the main reasons for undertaking the re-estimation of commodity price equations. In addition, the cross-equation parameter restrictions guarantee more similar simulation properties across pairs of indices. In this sense, the new equations represent a clear improvement to the model. Indeed, the intention was less to find good forecasting equations than equations whose essential simulation properties were robust to changes in sample and as transparent as data-consistency permits.

Table 5

SIMULATION PROPERTIES OF INTERLINK WITH
NEW COMMODITY PRICE EQUATIONS

Percentage difference from baseline

| | | Years | Shock 1 OECD growth | Shock 2 OECD inflation | Shock 3 US interest rate | Shock 4 oil price | Shock 5 US exchange rate |
|---|---|---|---|---|---|---|---|
| Food | H | 1 | 1.1 | 0.3 | -0.1 | -1.5 | -2.4 |
| | | 2 | 1.6 | 1.1 | -0.3 | -2.2 | -4.7 |
| | | 3 | 2.0 | 2.0 | -0.2 | -2.5 | -5.6 |
| | | 4 | 2.9 | 3.1 | -0.2 | -3.1 | -6.6 |
| | | 5 | 4.2 | 4.0 | -0.3 | -3.3 | -8.4 |
| | | 6 | 5.6 | 4.7 | -0.4 | -3.2 | -9.7 |
| | | 7 | 6.9 | 5.2 | -0.5 | -2.9 | -9.9 |
| | U | 1 | 0.0 | 0.1 | -3.2 | -1.9 | -3.2 |
| | | 2 | 0.0 | 1.0 | -4.6 | -6.9 | -11.3 |
| | | 3 | 0.5 | 2.3 | -4.0 | -7.4 | -12.1 |
| | | 4 | 1.4 | 3.3 | -3.7 | -6.3 | -10.0 |
| | | 5 | 3.6 | 4.9 | -4.0 | -6.4 | -11.4 |
| | | 6 | 7.0 | 6.5 | -4.0 | -6.1 | -15.8 |
| | | 7 | 8.8 | 7.1 | -3.5 | -5.1 | -15.4 |
| Tropical beverages | H | 1 | 0.0 | 0.6 | -0.0 | -1.5 | -5.6 |
| | | 2 | 0.2 | 1.3 | -0.0 | -2.4 | -6.1 |
| | | 3 | 0.7 | 2.1 | -0.1 | -1.1 | -5.4 |
| | | 4 | 1.6 | 3.4 | -0.2 | -0.6 | -5.6 |
| | | 5 | 2.8 | 4.1 | -0.2 | -0.4 | -6.2 |
| | | 6 | 4.6 | 5.0 | -0.3 | -0.2 | -7.8 |
| | | 7 | 7.1 | 6.6 | -0.4 | -0.2 | -8.2 |
| | U | 1 | 1.6 | 0.4 | -0.2 | -1.6 | -2.2 |
| | | 2 | 3.0 | 1.5 | -0.5 | -2.2 | -4.2 |
| | | 3 | 3.9 | 2.6 | -0.5 | -1.2 | -4.1 |
| | | 4 | 5.3 | 3.9 | -0.4 | -0.8 | -4.3 |
| | | 5 | 3.8 | 2.7 | -0.2 | -0.3 | -3.4 |
| | | 6 | 4.6 | 2.8 | -0.3 | -0.2 | -4.6 |
| | | 7 | 6.4 | 3.6 | -0.4 | -0.2 | -5.0 |
| Agricultural raw materials | H | 1 | 1.4 | 1.0 | -0.0 | -3.0 | -8.9 |
| | | 2 | 3.4 | 2.9 | -0.3 | -3.4 | -8.7 |
| | | 3 | 3.9 | 4.5 | -0.1 | -3.2 | -7.6 |
| | | 4 | 5.3 | 5.8 | -0.1 | -3.5 | -7.9 |
| | | 5 | 5.9 | 5.2 | -0.1 | -2.6 | -8.5 |
| | | 6 | 6.4 | 4.7 | -0.1 | -2.1 | -8.2 |
| | | 7 | 7.8 | 5.0 | -0.2 | -2.0 | -8.0 |
| | U | 1 | 1.3 | 1.0 | -0.0 | -2.9 | -8.8 |
| | | 2 | 3.1 | 2.7 | -0.3 | -3.2 | -8.1 |
| | | 3 | 3.9 | 4.4 | -0.1 | -3.2 | -7.4 |
| | | 4 | 5.1 | 5.5 | -0.1 | -3.3 | -7.5 |
| | | 5 | 5.7 | 5.0 | -0.1 | -2.6 | -8.2 |
| | | 6 | 5.9 | 4.4 | -0.1 | -1.9 | -7.5 |
| | | 7 | 7.1 | 4.6 | -0.2 | -1.9 | -7.4 |
| Metals and minerals | H | 1 | 0.4 | 0.6 | -0.0 | -4.4 | -8.3 |
| | | 2 | 1.7 | 1.9 | -0.3 | -3.7 | -8.5 |
| | | 3 | 2.3 | 3.5 | -0.4 | -3.9 | -8.2 |
| | | 4 | 3.4 | 4.5 | -0.2 | -3.9 | -8.1 |
| | | 5 | 5.0 | 5.0 | -0.3 | -3.3 | -9.8 |
| | | 6 | 6.3 | 5.3 | -0.4 | -2.9 | -10.2 |
| | | 7 | 8.4 | 6.1 | -0.5 | -3.0 | -10.5 |
| | U | 1 | 0.2 | 0.5 | -0.0 | -2.8 | -6.4 |
| | | 2 | 1.3 | 1.6 | -0.2 | -3.4 | -7.9 |
| | | 3 | 2.0 | 3.1 | -0.3 | -3.6 | -8.0 |
| | | 4 | 3.0 | 4.1 | -0.3 | -3.5 | -7.7 |
| | | 5 | 4.4 | 4.7 | -0.3 | -3.2 | -8.9 |
| | | 6 | 5.7 | 5.0 | -0.4 | -2.7 | -9.3 |
| | | 7 | 7.5 | 5.6 | -0.5 | -2.6 | -9.6 |

NOTES

1. General equilibrium extensions are cited and discussed in Gilbert (1986).

2. The precise percentage change is one minus the average weight of the United States in the consumption and production of the commodity in question, divided by the sum of the overall -- weighted average -- supply and demand elasticities for the commodity.

3. Any equation with more than one lagged dependent variable may display cyclical dynamics (see Deleau and Malgrange, 1978).

4. See Holtham et al. (1985) pp.26-30.

5. A sustained change in the growth rate of OECD GNP of 1 per cent, for example, raised the HWWA agricultural raw material price index by over 2 1/2 after two years while the UNCTAD index was up by only 1 1/2 after the same period. The HWWA index returned to baseline only after some 4 1/2 years while the UNCTAD index was back after 3 1/2 years. The difference in the reaction of the food price indices was even greater (3 1/2 per cent for HWWA, less than 1 per cent for UNCTAD after the same period to the same shock).

6. Another difficulty stemmed from the two-parameter double-exponential-smoothing specification of OECD trend GNP. "Trend" GNP thereby adjusts recursively to actual GNP. If the growth rate of actual GNP falls durably, the trend adjusts progressively in both level and growth rate terms (see Holtham et al . (1985)). That reduced the transparency of the commodity price equations in simulation exercises, as sustained changes in GNP affected trend and hence deviations from it. Commodity-price responses could not then be inferred from the parameters of the commodity-price equations alone. This measure of trend GNP also adjusted too rapidly to actual GNP, which partly explains why the estimated equations overpredicted commodity prices in the most recent period: in 1986, for example, OECD GNP was at or above its "trend" according to the measure. As this particular measure of OECD trend GNP was different from the country-specific measures of potential output based on production functions in INTERLINK, it had an awkward status in the model. It was best thought of as the OECD GNP expected by commodity producers, on average, at the time they were making decisions about investment and productive capacity.

7. For definition of co-integration and discussion of co-integration tests and their interpretation, see Granger and Engle (1985) and Granger (1986).

8. The UNCTAD food equation and both minerals equations generated 'F' statistics substantially above the 95 per cent significance level for rejection of the null hypothesis of equation stability (2.4, 3.3 and 3.1 respectively against a critical value of 2.05). The HWWA beverage equation was more borderline ($F = 1.9$) while HWWA food ($F = 0.3$), UNCTAD beverages ($F=0.2$) and both ARM equations ($F = 1.7$ in both cases) were stable.

9. Taken at face value, estimated time polynomials in the minerals equations imply that the HWWA minerals prices have stopped their secular decline at the end of 1986 and that the UNCTAD minerals prices would stop declining around 1994. A polynomial in time does not, of course, constitute an explanation of commodity price developments and, in the context of forecast projections the estimated time trends need to be monitored closely. One possibility is to assume no time trend in both equations from 1987 onwards. At the end of 1986 the tangents to the polynomials estimated in the HWWA and UNCTAD minerals equations have a slope of 0 and -0.01 respectively.

10. For simulations i), ii), iv) and v), an accommodating monetary policy has been assumed, i.e. nominal interest rates are held constant. For simulations ii), iii), iv) and v), government non-wage expenditure is assumed fixed in real terms. In simulation i), government non-wage expenditure is used as an instrument to achieve targeted real growth and in simulation ii), the GNP deflator has been add-factored.

Annex 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, sunflower oil | 9.2 |
| Wheat | 5.9 | Others | 2.7 |
| Others | 6.5 | | |
| **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 | 34.2 |
| 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 |

## Annex Table 2

### OLS REGRESSION RESULTS

---

HF-HF(-1) = 0.06 + 0.30*(PG(-1)-HF(-1)) + 1.31*(GDPV-GDPV(-1))
(0.09) (0.12) (1.36)

+ 0.09*POIL + 0.26*DWHEAT - 0.015*T
(0.05) (0.08) (0.006)

SEE = 0.100   DH = -0.01   $\bar{R}^2$ = 0.45

---

UF-UF(-2) = 0.01 + 1.54*(UF(-1)-UF(-2)) + 0.66*(PG(-1)-UF(-1))
(0.08) (0.13) (0.11)

- 0.02*USIRS + 0.42*POIL(-1) + 0.20*DWHEAT - 0.04*T
(0.013) (0.09) (0.10) (0.009)

SEE = 0.130   DH = -1.46   $\bar{R}^2$ = 0.85

---

HB-HB(-2) = 0.01 + 0.94*(HB(-1)-HB(-2)) + 0.30*(PG(-2)-HB(-2))
(0.03) (0.12) (0.07)

+ 0.38*(POIL(-1)-POIL(-2)) + 0.96*(PG-PG(-1)) + 0.29*DTBEV
(0.09) (0.56) (0.06)

SEE = 0.099   DH = -2.60   $\bar{R}^2$ = 0.84

---

UB-UB(-1) = -0.02 + 0.19*(PG(-1)-UB(-1)) + 1.67*(GDPV-GDPV(-1))
(0.02) (0.05) (1.02)

+ 0.25*(POIL-POIL(-1)) + 0.40*DTBEV
(0.07) (0.05)

SEE = 0.078   DH = 0.37   $\bar{R}^2$ = 0.76

---

HA-HA(-2) = -0.29 + 1.24*(HA(-1)-HA(-2)) + 0.57*(PG(-1)-HA(-1))
(0.09) (0.14) (0.12)

+ 1.41*(GDPV-GDPV(-3)) - 0.004*USIRS
(0.57) (0.006)

+ 0.011*USIRS(-3) + 0.21*POIL + 1.38*(PG-PG(-1)) - 0.021*T
(0.009) (0.05) (0.2) (0.005)

SEE = 0.056   DH = 2.26   $\bar{R}^2$ = 0.90

---

$$\text{UA-UA(-2)} = \underset{(0.08)}{-0.29} + \underset{(0.11)}{1.38}*\text{(UA(-1)-UA(-2))} + \underset{(0.10)}{0.74}*\text{(PG(-1)-UA(-1))}$$

$$+ \underset{(0.55)}{1.27}*\text{(GDPV-GDPV(-3))} - \underset{(0.005)}{0.001}*\text{USIRS}$$

$$+ \underset{(0.005)}{0.051}*\text{USIRS(-3)} + \underset{(0.02)}{0.21}*\text{POIL} + \underset{(0.3)}{1.10}*\text{(PG-PG(-1))} - \underset{(0.002)}{0.019}*\text{T}$$

SEE = 0.046 DH = -0.55 $\bar{R}^2 = 0.95$

---

$$\text{HM-HM(-2)} = \underset{(0.07)}{0.26} + \underset{(0.11)}{1.31}*\text{(HM(-1)-HM(-2))} + \underset{(0.09)}{0.95}*\text{(PG(-1)-HM(-1))}$$

$$+ \underset{(0.59)}{1.25}*\text{(GDPV(-1)-GDPV(-3))} + \underset{(0.06)}{0.42}*\text{POIL}$$

$$+ \underset{(0.36)}{0.64}*\text{(PG-PG(-1))} - \underset{(0.017)}{0.16}*\text{T} + \underset{(0.003)}{0.002}*\text{T}^2$$

SEE = 0.060 DH = -3.35 $\bar{R}^2 = 0.93$

---

$$\text{UM-UM(-2)} = \underset{(0.03)}{0.02} + \underset{(0.05)}{1.14}*\text{(UM(-1)-UM(-2))} + \underset{(0.05)}{0.68}*\text{(PG(-1)-UM(-1))}$$

$$+ \underset{(0.26)}{0.83}*\text{(GDPV(-1)-GDPV(-3))} + \underset{(0.03)}{0.32}*\text{POIL}$$

$$+ \underset{(0.23)}{0.67}*\text{(PG-PG(-1))} - \underset{(0.004)}{0.072}*\text{T} + \underset{(0.0001)}{0.001}*\text{T}^2$$

SEE = 0.054 DH = -2.81 $\bar{R}^2 = 0.92$

---

Notes: Standard errors are shown in brackets.
Variables are all in natural logarithms except for dummies, interest rates and time:

HF: HWWA food price index
UF: UNCTAD food price index
HB: HWWA beverages price index
UB: UNCTAD beverages price index
HA: HWWA price index for agricultural raw materials
UA: UNCTAD price index for agricultural raw materials
HM: HWWA price index for metals and non-fuel minetals
UM: UNCTAD price index for metals and non-fuel minerals
PG: Dollar price deflator for OECD activity (see (1) for precise definition); basic data source OECD
GDPV: OECD aggregate GDP at constant prices; source OECD
POIL: index of a basket of oil prices quoted on Rotterdam spot market; source OECD
USIRS: United States three-month Treasury bill interest rate
DWHEAT: Dummy variable, Russian grain harvest failure and purchases 1973
DTBEV: Dummy variable for Brazilian coffee frost 1976 and 1977I
T: Time

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