Currencies and commodities: modeling the impact of exchange rates on commodity prices in the world market

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Abstract:

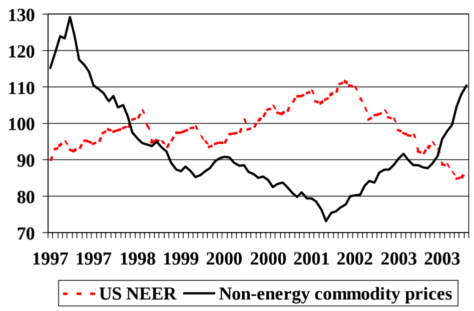
Prices of internationally traded commodities are notoriously volatile, due in part to market fundamentals, but also in part to exchange rate movements. It is useful to understand the latter clearly as these can both influence and obscure commodity market outcomes. The paper develops a comprehensive model based on a simple, equilibrium approach which, though well known, has not previously been implemented on the present scale. Estimated using pooled regressions, the model incorporates trade of over 200 countries in 33 commodities comprising most of the weight of the World Bank's primary commodity coverage. A freely available excel version also computes terms of trade and balance of payments impacts at both country and regional levels. Several applications are presented, such as exploring the impact of the euro's recent appreciation.

Exchange rates and commodity prices

1. Introduction

Primary commodity prices are notoriously volatile and recent history is no exception. Between 1997 and early 2004, the World Bank's index of dollar-denominated commodity prices first fell by 43%, then rebounded by 51% (figure 1). In real terms (deflated by the US GDP deflator), the decline was even larger. But, the US accounts for only around 15% of total world commodity trade and for producers and consumers of commodities elsewhere real and nominal dollar price movements may be quite misleading. German construction firms buy copper or wood with euros; cocoa farmers in Côte d'Ivoire are paid in CFA francs. Local currency commodity prices in these countries would have been more stable to the extent exchange rates moved in an offsetting direction. And, indeed, over the course of the recent commodity price cycle this was generally the case, as evidenced by the IMF's nominal effective exchange rate index of the dollar which first rose by 24% and then fell by 22%. In other words, at least part of the story of the recent commodity price cycle was more about the numeraire currency than commodity prices.

Figure 1 – Commodity prices and US NEER



Source: IMF IFS and World Bank

[1] I am grateful to Hans Timmer for encouraging this research and for many useful discussion which have improved the quality of this paper. All remaining errors and omissions are mine.

Nevertheless, volatile exchange rates do more than just obscure commodity market outcomes. A change in any country's exchange rate affects the price of tradables there, commodities included, which in turn affects supply and demand both in that country and the world at large and thus displaces the global market equilibrium. The appreciation of the dollar in 1997-01 made commodities such as coffee and wheat appear cheap to American buyers and sellers, inducing endogenous supply and demand responses and displacing the global market equilibrium. Or to give a more focused example, in 2001 the price of gold fell by 2.9% in dollars, but due to a sharp depreciation of the rand it rose 35% in South Africa. Thus, what seemed a weak market for gold in many countries must have looked very strong in South Africa. Indeed, much of the decline in the dollar denominated world gold price in 2001 is explained by South African producers moving up their supply curves.

In brief, exchange rate fluctuations introduce noise into the analysis of global commodity markets on the one hand, and on the other they have real effects. With commodities accounting for a quarter of merchandise trade and merchandise trade accounting for a quarter of world GDP, it is clearly of practical importance to understand as much as possible about the determinants of prices. This is especially true for many clients of the World Bank which depend on one or a few commodities for the bulk of their export earnings. For these, commodity price volatility can have a major impact on terms of trade, hence financing needs and debt servicing capacity.

From an empirical standpoint, both the theory and data needed for a modeling exercise are readily available. Over the years, the link from exchange rates to commodity prices has been explored in a small literature.[2] But, the empirical applications in this literature have tended to focus on particular historical episodes or on markets with special characteristics, or have dealt at a highly aggregate level, or in some way limited the generality and applicability of results to practical analysis and forecasting. For instance, Gilbert 1989 applied the approach to explaining commodity price declines in the early 1980s and argued that the debt crisis had shifted supply curves outward as suppliers faced a critical need for foreign exchange. Similarly, Borensztein and Reinhart 1994 put forward the breakup of the Soviet Union as an explanation for price weakness in the late 1980s. Sjaastad and Scacciavillani 1996 studied the gold market using sophisticated econometric techniques, but conceded their approach could not be replicated more widely because it depended on peculiar characteristics of the market (large, widely held inventories) and the availability of high-frequency futures data.

By contrast, what distinguishes the present paper is its generality. Subject to data availability, the model described here incorporates over 200 countries and 31 individual commodities, comprising most of the weight of the World Bank's index of non-energy commodities. Pooled regressions find that foreign exchange rates can explain up to 30-40% of commodity price movements. Of course, in addition commodity market equilibria reflect various financial, political and technical "fundamentals." However, these are not modeled explicitly and are assumed to be orthogonal to any impacts of exchange rates.

[2] For pioneering contributions and other variants of the approach, see Chambers and Just 1972, Ridler and Yandle 1979, Gilbert 1989, Borensztein and Reinhart 1994 and Sjaastad and Scacciavillani 1996.

The remainder of the paper is structured as follows. Section 2 derives a simple, theoretical model relating (dollar) commodity prices to domestic prices, incomes and exchange rates in countries which supply or demand the commodity in international trade. Section 3 then describes the empirical implementation of the model to 31 primary commodities (10 metals and minerals; 21 agricultural),[3] plus manufactures. A working version of the model in excel incorporating some additional features is described in section 4. Section 5 describes an out of sample test of model performance.

2. An equilibrium model of international commodity prices

Conceptually, the model calculates comparative static displacements of global market equilibrium, commodity by commodity. Individual countries' supplies and demands for each commodity are given by simple and uniform specifications in which income and relative prices are arguments. The basic structure is then replicated across commodities.

Three key assumptions underpin the model: (i) market clearing – prices change until global market excess demand is eliminated; (ii) the law of one price – commodity prices in local currency fully reflect exchange rate changes. Thus, the analysis disregards differences in quality and timing, transportation costs and non-competitive behavior which could affect exchange rate pass through; (iii) zero cross-price elasticities between commodities – enabling individual commodity markets to be estimated and solved separately.[4]

For simplicity (to avoid unnecessary subscripting), the model is derived here for a single commodity. Assume the world price of the commodity is quoted in dollars and write the price as $P_{\$}$. Suppose N countries, j=1,…,N potentially trade the commodity. Each country's real net demand, written Q_j, is the difference between consumption and production. Thus, $Q_j > 0$ if j is a net demander/importer and $Q_j < 0$ if j is a net supplier/exporter. Let country j's exchange rate in LCU/$ be E_j and its domestic price level in LCU be P_j. Then the local currency price in each country is $P_{\$}E_j$ and the real or relative price, which from an economic standpoint determines net supply or demand, is $R_j = P_{\$}E_j / P_j$. Demands are also assumed to depend on income, Y_j. Even if country j is a net supplier on world markets, i.e. $Q_j < 0$, home consumption and hence exports are functions of income. Thus net excess demand for both exporters and importers is a function of home income.

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[3] Metals: aluminum, copper, gold, iron ore, lead, nickel, silver, steel, tin, zinc; agricultural: bananas, beef, cocoa, coffee, copra, cotton, ground nut meal, ground nut oil, maize, oranges, palm kernels, palm oil, wood pulp, rice, rubber, sorghum, soy meal, soybean oil, soy beans, sugar, tea, tobacco, wheat.

[4] Chambers and Just 1979 critique this assumption, arguing it confounds price and exchange rate changes, though they concede its appeal for empirical work. For many primary commodities, particularly those relevant to developing countries, substitution possibilities in production and consumption seem likely to be small.

Total market or world equilibrium requires that global net excess demand is equal to zero:

$$Q = \sum_{j=1}^{N} Q_j (R_j , Y_j) = 0 \qquad (1)$$

To derive the comparative statics of market equilibrium, totally differentiate (1):

$$dQ = \sum_{j=1}^{N} [(\partial Q_j / \partial R_j) dR_j + (\partial Q_j / \partial Y_j) dY_j] = 0$$

where $(\partial Q_j / \partial R_j) < 0$ and $(\partial Q_j / \partial Y_j) > 0$, assuming the local equilibrium in each country is stable and the good is normal. Next, substitute: $dR_j = R_j * \hat{R}_j = R_j * (\hat{P}_\$ + \hat{E}_j - \hat{P}_j)$ where ^ indicates a growth rate; $\partial Q_j / \partial R_j = \eta_j^P Q_j / R_j$ where $\eta_j^P = (R_j / Q_j)(\partial Q_j / \partial R_j)$ is the price elasticity of excess demand; and $\partial Q_j / \partial Y_j = \eta_j^Y Q_j / R_j$ where $\eta_j^Y = (Y_j / Q_j)(\partial Q_j / \partial Y_j)$ is the income elasticity of excess demand, to rewrite equation (2) as:

$$dQ = \sum_j [\eta_j^P Q_j (\hat{P}_\$ + \hat{E}_j - \hat{P}_j) + \eta_j^Y Q_j \hat{Y}_j] = 0$$

Finally, solve for $\hat{P}_\$$ to get:

$$\hat{P}_\$ = \sum_j [(\frac{Q_j \eta_j^P}{\sum_i Q_i \eta_i^P})(\hat{P}_j - \hat{E}_j) - (\frac{Q_j \eta_j^Y}{\sum_i Q_i \eta_i^P})\hat{Y}_j] = \sum_j [\omega_j^P (\hat{P}_j - \hat{E}_j) + \omega_j^Y \hat{Y}_j] \qquad (2)$$

where $\omega_j^P = Q_j \eta_j^P / \sum Q_i \eta_i^P$ and $\omega_j^Y = -Q_j \eta_j^Y / \sum Q_i \eta_i^P$, and $(\hat{P}_j - \hat{E}_j)$ is the rate of change of country j's price level denominated in dollars. The terms are shares in weighted sums of elasticities and represent each country j's weight in price determination. If country j has a big share in world trade or has a high price elasticity of net demand, ω_j^P is big. Likewise, if country j has a big share in world income and a high income elasticity of demand, ω_j^Y is big. Note that the net excess demand price elasticities $\eta_j^P < 0$ if demand curves are more steeply sloped than supply curves. Thus, inspection shows that $\omega_j^P > 0$ whether country j is a net exporter or importer. Further, the price elasticities are constrained to sum to one, $\sum_j \omega_j^P = 1$, since the same terms appear in the numerator and denominator. If the commodity is normal, income elasticies are positive and $\omega_j^Y > 0$.

Any number of countries may feature in the analysis, but Ridler and Yandle 1979 suggest a useful simplification which assumes that price elasticities are uniform across all suppliers and all demanders. That is, $\eta_j^P = \eta_S$ if j is a net supplier and $\eta_j^P = \eta_D$ if j is a net demander. Income elasticities are also assumed to be the same everywhere, $\eta_j^Y = \eta_Y$. Then noting that $Q_S = Q_D$ equation (2) simplifies to:

$$\hat{P}_\$ = \frac{\eta_S}{\eta_S + \eta_D}(\hat{P}_S - \hat{E}_S) + \frac{\eta_D}{\eta_S + \eta_D}(\hat{P}_D - \hat{E}_D) + \omega_W \hat{Y}_W \qquad (3)$$

where each country's weight in its respective index, $(\hat{P}_S - \hat{E}_S)$ or $(\hat{P}_D - \hat{E}_D)$, is simply its share in net exports or imports $Q_j / \sum Q_i$. The introduction argued that dollar denominated commodity prices are not representative of experiences of typical buyers and sellers of commodities. By contrast, $(\hat{P}_S - \hat{E}_S)$ and $(\hat{P}_D - \hat{E}_D)$ more legitimately reflect changes in "typical" market participants' price levels and the indexes $P_\$ E_D / P_D$ and $P_\$ E_S / P_S$ computed from these changes are the relevant real or relative prices on which buyers and sellers base their supply and demand decisions.

Example: To illustrate the model, consider the aggregate case. Suppose real income is fixed and the US is not a significant participant in the market. If the dollar depreciates equally against both currencies (i.e. the cross rate remains constant), then $P_\$$ must rise by exactly the amount to offset the depreciation, leaving relative prices in both countries and the volume of trade unchanged. Suppose S currencies are pegged to the dollar ($\hat{F}_S$ = 0) and let $\eta_S = 2$ and η_D = 0.5. Then a 10% depreciation of the dollar against the basket of D currencies will raise the dollar price by 0.5/2.5*10 = 2%. In the new equilibrium, $P_\$ F_D$ is 8% lower, so Q_D rises by 4% (= 0.5*8). $P_\$ F_S$ is 2% higher so Q_S also rises by 4% (=2*2). Alternatively, suppose a 10% depreciation against S's currency with D's currency pegged to the dollar. $P_\$$ must rise by 2.0/2.5*10 = 8% at which point $P_\$ F_D$, is 8% higher and $P_\$ F_S$ is 2% lower. Q_D and Q_S are both 4% lower, while the cost of imports, is 2% lower is 4% lower.

3. Implementing the model

The expression for $\hat{P}_\$$ in (3) is a reduced form equation with two structural parameters, η_S and η_D, which evidently are not identified. A possible strategy would be to estimate the structural parameters by choosing suitable instruments. For instance, an appealing choice would be to use R_D as an instrument for the supply equation, ($d\log(Q) = \beta_0 + \beta_1 d\log(R_S) + \beta_2 d\log(Y_S) + \varepsilon$), and likewise to use R_S for the demand equation. If domestic inflation is uncorrelated between supply and demand countries, then IV estimates of β_1 would be consistent. Unfortunately, however, this did not yield very satisfactory results. But in any case, if the objective is to map exchange rates to commodity prices, the structural model is not required. Accordingly, the strategy adopted here is to estimate equation (3) directly.

Commodity coverage: The set of commodities in the model was chosen from the universe of the World Bank's commodity coverage and the current version of the model comprises 31 commodities representing around 90% of the weight of the Bank's aggregate, non-energy commodity price index. An equation was also fitted for manufactures, using the World Bank's manufacturing unit value (MUV) index as a price series. An initial plan to extend the model to energy was abandoned as no satisfactory fits could be obtained – energy market outcomes do not seem to reflect economically meaningful supply and demand responses to costs and prices, probably because of non-competitive behavior by suppliers and long lags in demand.

Data sources: A base period of 1995-97 was chosen to calculate trade shares as this was a relatively stable period with no dramatic supply or demand shocks in commodity markets. Commodity trade was sourced from the UN's COMTRADE commodity trade database accessed through WITS. The World Bank's World Development Indicators were used for GDP and GDP deflators, and the IMF's International Financial Statistics were used for balance of payments flows and exchange rates.

The commodity trade data needed are total net trade (both exports and imports) between each country and the rest of the world. COMTRADE allows users to select values reported either by exporters or importers. For instance, Côte d'Ivoire's exports of cocoa may be calculated by summing the Ivoirien authorities' reported exports to the US, Japan and Germany, or alternatively summing US, Japanese and German reported imports from Côte d'Ivoire. Not infrequently the estimates will be very different. A decision was made to sum importer reported data for exports and exporter reported data for imports, the rationale being to rely on developed country data sources as much as possible. That is, the bulk of raw commodity trade is from developing countries to developed ones, which will rely on importer recorded data. While the approach depends on commodity exporters' reports for some exports of developed countries, these will rarely have a significant impact on world markets.

A problem arises because summing world exports and imports of any commodity will typically give different tallies. To get around this, the market *shares* were computed by dividing each country's exports or imports of a given commodity by the respective world total. For instance, world exports of cocoa are computed as \$5.7 and imports are \$5.1 billion. German exports are given as \$235 million, or 4.1% of the world total, while imports are \$670 million or 13.7% of the world total. Thus, Germany is identified as an a cocoa importer because net imports are 13.7 – 4.1 = 9.6%.

Next, for each commodity lists of importers and exporters must be compiled. Countries are defined as exporters if their net export position calculated in terms of market shares is positive. For instance, Germany is a net cocoa importer, since net imports are 13.7% – 4.1% = 9.6%. An arbitrary cut off point of 0.1% of the market was adopted for computing the indexes to avoid some messy data problems (especially exchange and inflation rates) for some small countries. Some experimentation with the cut off point (0.1%, 0.25,..., 5%) found the precise value didn't matter much. These lists were then used to compute weighted indexes of inflation rates of dollar-denominated GDP deflators as per equation (4): $(\hat{P}_S - \hat{E}_S) = \sum_{j \in X} (\frac{X_j}{\sum_i X_i})(\hat{P}_j - \hat{E}_j)$ and $(\hat{P}_D - \hat{E}_D) = \sum_{j \in M} [(\frac{M_j}{\sum_i M_i})(\hat{P}_j - \hat{E}_j)$ where M refers to the net imports of importers and X refers to net exports of exporters. Note that since X and M refer to *net* flows, the shares will sum to one only if no country both exports and imports the commodity, which is unlikely. Thus, the weights must be scaled to ensure they add to one. For instance, the sum of shares of net cocoa importers was 0.664.[5] Thus, Germany

[5] The alternative would be to use gross rather than net flows, but this would weight more heavily countries such as Belgium and the Netherlands which have large gross flows and small net flows, and whose trade is unlikely to have a significant impact on the world price.

(and all other cocoa importers) were scaled by dividing by 0.664 so that finally Germany was given a weight of 0.096/0.664 = 0.145 in computing the index P_D / E_D.

The approach with manufactures is slightly different since intraindustry trade is extensive – countries typically both import and export differentiated products within the same SITC categories. Thus, price indices for manufactures were using gross rather than net trade positions so that countries appear as both exporters and importers. In other respects, however, manufactures were handled in the same way as other commodity categories.

The indexes are now ready for use in estimating equation (3). For many individual commodities, meaningful fits could not be obtained for equations of the form: $\hat{P}_{\$} = \alpha(\hat{P}_S - \hat{E}_S) + (1-\alpha)(\hat{P}_D - \hat{E}_D) + \beta\hat{Y}_W$ because the constraint, $0 \le \alpha \le 1$, was violated, or coefficients were not statistically significant. As an alternative, commodities were pooled. After some experimentation the universe of non-energy commodities was divided into two pools: (1) agricultural commodities, including such things as pulp and rubber, and (2) metals and minerals (table 1).

Table 1 – Commodity pools for model estimation

Pool	Components
Agriculture	bananas, beef, cocoa, coffee, copra, cotton, groundnut oil, maize, palm oil, oranges, rice, rubber, sorghum, soybeans, soybean oil, soy meal, sugar, tea, tobacco, wheat, woodpulp
Metals and minerals	aluminum, copper, gold, lead, iron ore, nickel, silver, steel, tin, zinc
Manufactures	Manufactures

Coefficient estimates for these pools are shown in table 2.[6] The greater weight for exporters than importers conforms to the expectation that supplies are more elastic than demands. The magnitudes of the income impacts for agriculture and metals and minerals are surprising high, implying relatively high income elasticities of demand, though empirically commodity prices are known to be highly sensitive to global business cycles. For manufactures, the weight on income is very small and in some specifications was negative, suggesting more or less constant returns to scale and few constraints to increasing production. By contrast, the positive weights in the commodity pools indicate supply curves which rise steeply.

Table 2 – Pooled estimates

Coefficient	Agriculture	Metals & minerals	Manufactures
Exporter weight	0.86	0.68	0.59
Importer weight	0.14	0.32	0.41
Income weight	5.45	7.07	0.10
Observations in pool	600	238	30
R^2	.096	.197	.424

[6] Estimates included, where significant, both contemporaneous and one-year lagged values of independent variables. The values used in the model, as shown in table 2, are the summations of these.

Commodity prices and terms of trade

In addition the impacts of exchange rates on commodity prices, a second aim of the exercise is to estimate the terms of trade and financing (balance of payments) impacts of price volatility, of particular interest for developing countries and regions. Having estimated the model, computing these impacts is straightforward. Let A be a matrix with countries as rows and commodity exports and imports as columns. Computing the price impacts of exchange rates was achieved by normalizing elements of A by dividing through by column sums, then calculating net flows, separating net importers and exporters and renormalizing by column sums. To compute terms of trade impacts, gross imports and exports for each country are normalized by that country's total exports and imports (i.e. row sums), to ensure a 10% price rise for all traded goods in the model will raise total export and import price deflators by 10%. Note that the calculations can be based on dollar prices without converting to local currency, since the ratio of export to import prices is not affected by scaling both the numerator and denominator. To compute terms of trade changes as a percentage of income, the overall percentage price changes are multiplied by current account merchandise credits (exports) and debits (imports) and divided by GDP.[7]

4. The model in excel

Since the model has no endogeneity or dynamics, solving it in excel is straightforward. For each commodity, the price impacts are calculated by multiplying a vector of price impacts, $(\hat{P}_j - \hat{E}_j)$, times vectors of export and import shares, then multiplying these by the relevant coefficients in table 1 above. Thus, for instance, for tin:

$$\hat{P}_{tin} = 0.68 * \sum_{j \in X,tin} \left(\frac{X_{j,tin}}{\sum_i X_{i,tin}}\right)(\hat{P}_{j,tin} - \hat{E}_{j,tin}) + 0.32 * \sum_{j \in M_{tin}} \left(\frac{M_{j,tin}}{\sum_i M_{i,tin}}\right)(\hat{P}_{j,tin} - \hat{E}_{j,tin}) + 7.1 * \hat{Y}_{world}$$

The price impacts determined by these calculations are then multiplied by shares of each country's trade to calculate terms of trade and balance of payments impacts.

The excel workbook contains three worksheets. The first, labeled "Model" is set up to enter shocks and display results (figure 2). The second, labeled "Commodity shares" contains a matrix of country shares in net exports and imports of each commodity (that is, columns sum to 1). The third worksheet, labeled "Country shares," contains row shares of exports and imports, as well as data on merchandise exports and imports, and GDP needed for calculating terms of trade impacts. All calculations are performed by formulas embedded in the worksheet (the file contains no macros).

[7] Note that if all prices rise by 10%, there is no impact on a country's terms of trade, but there will be a terms of trade loss as a percentage of GDP if the country has a trade deficit.

Figure 2 -- The model in excel

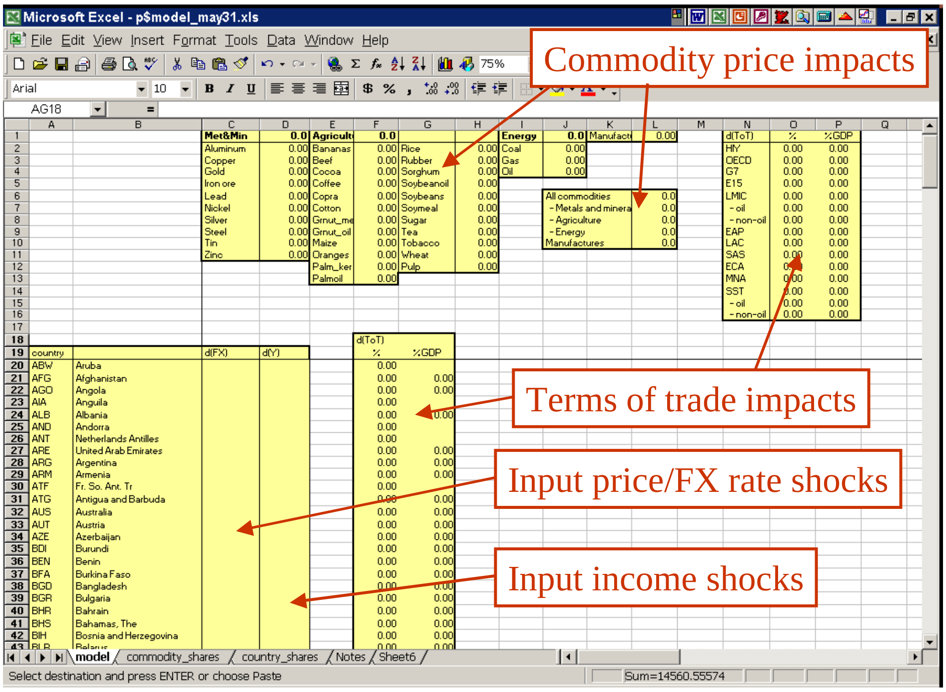
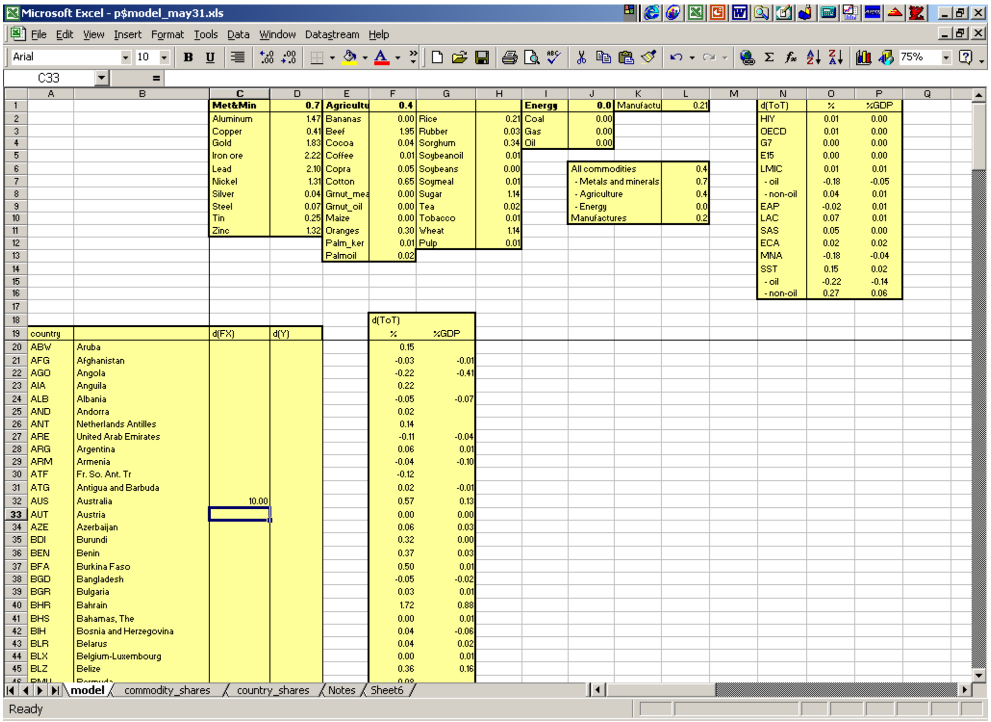


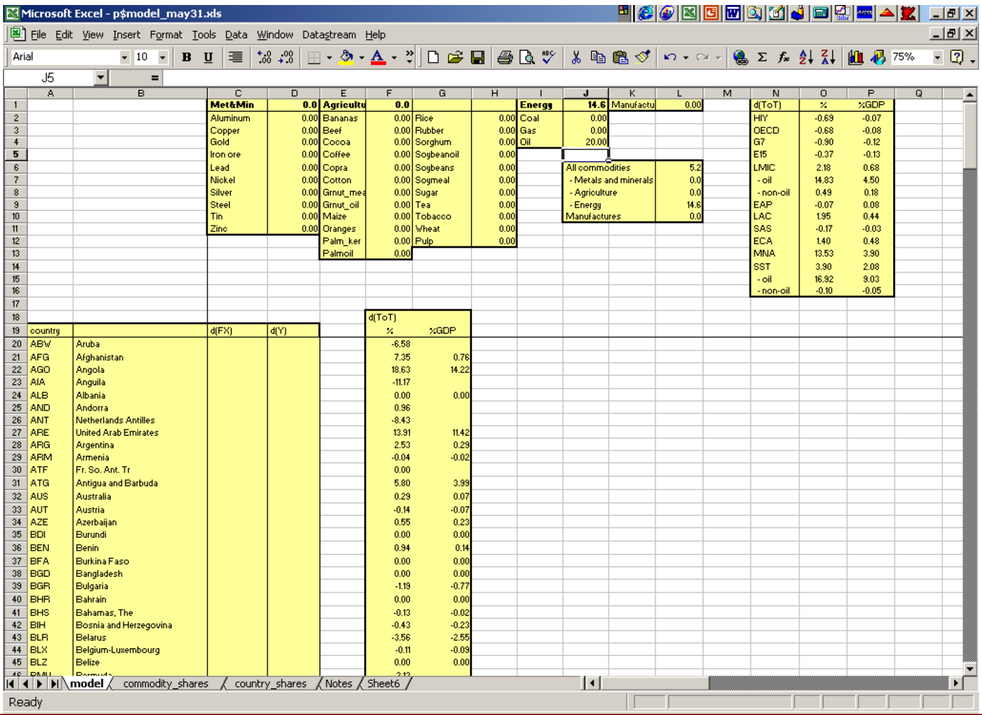
Figure 3 – Simulating a 10% A$ appreciation



Entering a positive number for an exchange rate in the column headed d(FX) is equivalent to an appreciation. Thus, for instance, to simulate a 10% appreciation of the Australian dollar, enter "10" in the appropriate position in the column headed "d(FX)." Figure 3 shows the output from this experiment. Several metals prices are affected – aluminum (+1.5%), iron ore (+2.2%), etc. – as well as some agricultural commodities – beef (+2%), wheat (+1.1%), etc. Manufactures prices rise by 0.2%. The impact on Australia's terms of trade is +0.6% and low income non-oil exporters also benefit.

The primary logic of the model flows from exchange rates to commodity prices to terms of trade impacts. However, the excel version is set up to allow this logic to be short circuited by entering commodity price changes directly. Entering "20" in the cell for the oil price generates the result shown in figure 4.[8] The results indicate sharp terms of trade gains for countries such as Angola which rely heavily on oil exports (terms of trade up 18.6%, or 14.2% of GDP). Meanwhile, high income countries as a group experience a terms of trade deterioration of 0.7% (0.1% of GDP). Low income countries are net oil exporters and have a net terms of trade gain of 2.2% or 0.7% of GDP.

Figure 4 – Simulating a 20% oil price shock



[8] The example of an oil price shock is straightforward as energy prices are not endogenous to the model. However, entering a non-energy price directly will overwrite a formula in the cell which must be re-entered to restore the link from exchange rates to commodity prices (either by clicking "undo", or by reloading the model).

5. Model evaluation

The model was estimated over the period 1970-2000. Feeding in subsequent exchange rate and price data from 2001-03 allows an out of sample evaluation of predictive power. Figure 5 compares the model's predictions with actual outcomes at an aggregate level. The model tracks the general direction of aggregate price movements reasonably well, which is notable in given the sharp turnaround in commodity prices during this period and strong gains in 2003 which took many observers by surprise.

Figure 5 -- Actual and predicted exchange rate impacts

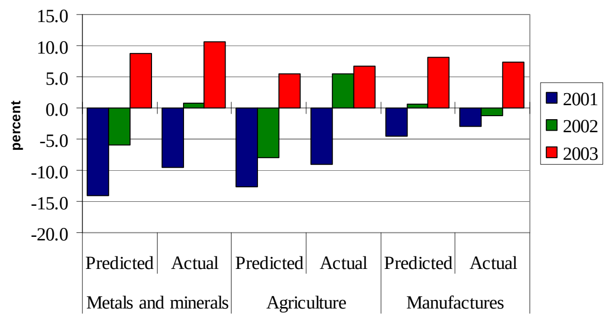


Table 4 provides further data on the forecasts. The first two panels contain the data in the graph. The bottom two panels show the root mean squared forecast error for individual commodities within each category and the ratio of the RMSE to the mean. In general, the model performed relatively well in 2001 and 2003, but did not adequately anticipate the the turning point in 2002. The most serious prediction error was for agriculture in 2002 where the prediction was –8% and the actual +5.5%. A closer examination of individual commodities shows that many forecasts are reasonably good, but there were some spectacular failures. For instance the model forecasts in 2002 a cocoa price rise of 0.6% whereas the actual outcome was a 66.4% rise. However, since this was the result of drought and civil strife in Cote d'Ivoire, it is not surprising that exchange rates failed to capture it.

Table 3 – Out of sample model performance

	2001	2002	2003
		Predicted	
Metals and minerals	-14.1	-5.9	8.8
Agriculture	-12.7	-8.0	5.5
Manufactures	-4.5	0.6	8.1
		Actual	
Metals and minerals	-9.6	0.7	10.7
Agriculture	-9.1	5.5	6.7
Manufactures	-2.9	-1.3	7.4
		RMSE	
Metals and minerals	3.98	3.08	3.19
Agriculture	4.95	5.78	4.57
Manufactures	1.54	1.84	0.74
		RMSE/Mean	
Metals and minerals	-0.42	4.15	0.30
Agriculture	-0.55	1.06	0.68
Manufactures	-0.52	-1.47	0.10

Source: own calculations; Note: index weights based on trade shares rather than World Bank index weights.

References

Borensztein, Eduardo and Carmen M. Reinhart 1994, "The macroeconomic determinants of commodity prices," *IMF Staff Papers* 41:236-61.

Chambers, Robert G. and Richard E. Just 1972, "A critique of exchange rate treatment in agricultural trade models," *American Journal of Agricultural Economics* :249-57.

Clements, Kenneth W. and Meher Manzur 2002, "Notes on exchange rates and commodity prices," in Meher Manzur (ed.) *Exchange rates, interest rates and commodity prices* (Northampton, MA: Edward Elgar), pp. 145-56.

Gilbert, Christopher L. 1989, "The impact of exchange rates and developing country debt on commodity prices," *Economic Journal* 99: 773-784.

Ridler, Duncan and Christopher A. Yandle 1979, "A simplified method for analyzing the effects of exchange rate changes on exports of a primary commodity," *IMF Staff Papers* 19:559-77.

Sjastaad, Larry and Fabio Scacciavillani 1996, "The price of gold and the exchange rate," *Journal of International Money and Finance,* 15:879-97.