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The Macroeconomic Determinants of Commodity Prices

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Abstract

The "traditional structural approach" to the determination of real commodity prices has relied exclusively on demand factors as the fundamentals that explain the behavior of commodity prices. This framework, however, has been unable to explain the marked and sustained weakness in commodity prices during the 1980s and 1990s. This paper extends that framework in two important directions: First, it incorporates commodity supply in the analysis, capturing the impact on prices of the sharp increase in commodity exports of developing countries during the debt crisis of the 1980s. Second, we take a broader view of "world" demand that extends beyond the industrial countries and includes output developments in Eastern Europe and the former Soviet Union (FSU). The empirical results support these extensions, as both the fit of the model improves substantially and, more importantly, its ability to forecast increases markedly.

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I. Introduction

Commodity markets play a central role in transmitting disturbances internationally by linking industrial commodity-importing countries to developing commodity suppliers. Given the marked fluctuations in both prices and volumes in recent years, this role as a conduit of shocks suggests that a comprehensive analysis of the macroeconomic factors having an impact on this market must be incorporated in the design of policy, particularly for those countries that rely heavily on primary commodity exports and that are facing substantial terms-of-trade shocks. Further, the need to understand the factors that influence the behavior of commodity prices has taken on a new urgency in recent years, as non-oil commodity prices have fallen sharply and persistently in real terms since the early 1980s. While this decline affects all commodity-producing countries in some measure, those with the least diversified production structure suffer the largest impact. 1/ Moreover, this latter group of countries tends to have less flexible economic systems, making substitution away from commodity production more difficult or costly, and encompasses many of the poorest countries in the world.

The conventional analysis of commodity markets mimics the empirical strategy applied to other key macroeconomic variables--namely, to try to identify a stable and predictable relationship between commodity prices and two or three macroeconomic variables. While markets for individual commodities are affected by a variety of specific factors in their day-to-day evolution, the aggregate index of non-oil commodities has been treated as a macroeconomic variable whose movements, on a quarterly or annual basis, are related to prevailing macroeconomic conditions. Studies that have stressed a structural approach to commodity price determination have found that two (demand-side) variables did well in explaining the variation of commodity prices: the state of the business cycle in industrial countries and the real exchange rate of the U.S. dollar. 2/ This line of research, including the work of Dornbusch (1985), Morrison and Chu (1984 and 1986) and, more recently, Gilbert (1989), generally involve partial equilibrium models that treat the determinants of commodity prices (both conceptually and empirically) as exogenous. During the early 1980s, industrial production in the industrial countries was weak, as several countries experienced prolonged and deep recessions, and the dollar appreciated by nearly 50 percent in real terms. In this setting, the "demand-driven" framework explained much of the observed weakness in real commodity prices. 3/ In the post-1984 period, however, despite a weakening dollar and a substantial rebound in the growth of output of several of the major industrial countries, real commodity prices remained soft, puzzling many commodity market analysts and further worsening the predicament of the large

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1/ See for example, Reinhart and Wickham (1993).

2/ The role of the real exchange rate of the U.S. dollar in this framework is to correct for the fact that commodity prices are measured by a dollar-denominated index and deflated by a dollar-denominated price index, whereas the relevant measure for the non-U.S. industrial countries is the price of commodities relative to output prices in those countries.

3/ Real commodity prices fell by 31 percent in that period.

number of developing economies that are primary commodity exporters (see Morrison and Wattleworth, (1987)). By late 1984, the "demand-driven" framework began to systematically overpredict real commodity prices by wide margins and the forecasts have continued to be off-track up to the present. This persistent overprediction, in turn, suggested that one or more important variables were being left out of the analysis.

A number of reasons have been put forward to explain the persistent weakness in commodity prices in the post-1984 period, essentially on the basis of anecdotal evidence rather than on the basis of a formal systematic approach. For instance, the response in developing countries to the debt crisis of the 1980s and the economic developments in the economies in transition in Eastern Europe and the former Soviet Union (FSU) more recently stand out as major shocks that are thought to have had considerable impact on international commodity markets. Specifically, it has been argued that the acceleration in primary commodity supplies since the mid-1980s has been a byproduct of the debt crisis, as developing countries expanded commodity exports in an attempt to service burgeoning debt obligations (see, for instance, Aizenman and Borensztein (1988) and Gilbert (1989)). With respect to the economies in transition, the impact on the international commodity market has come through two channels: weaker demand, as incomes and consumption have fallen dramatically in recent years, and a sharp increase in the supply of several primary commodities. The contraction in demand is reflected in the sharp declines in imports of a broad spectrum of commodities, while the supply effect is evident in the staggering increases in FSU exports of various metals. 1/

The purpose of this paper is to identify the main economic fundamentals that lie behind the behavior of commodity prices, particularly the recent weakness, and quantify how the relative importance of each of these factors has evolved over time. We extend the "traditional structural approach" described above by incorporating these two important developments in international commodity markets of the 1980s and 1990s. The empirical analysis is based on quarterly data for 1970:1-1992:3. As in the theoretical model outlined in Reinhart (1991), we incorporate commodity supplies as a determinant of commodity prices, thus capturing the impact on prices of the sharp increase in the commodity exports of the developing countries. In addition, we take a broader view of "world" aggregate demand that extends beyond the major industrial countries and includes output developments in Eastern Europe and the FSU.

The main results can be summarized as follows: first, as predicted by theory, the constructed commodity supply index affects commodity prices in a negative and predictable manner. The inclusion of this measure of supply markedly improves the fit of the structural model and, more importantly, significantly reduces the out-of-sample overprediction of real commodity

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1/ Other less quantifyable factors depressing real commodity prices, such as the breakdown of numerous international commodity agreements are discussed in Reinhart and Wickham (1993).

prices that have plagued "demand-driven" structural models since the mid-1980s. In effect, supply developments appear to account for the bulk of the variation in real commodity prices during the 1985-1988 period. Secondly, while output in Eastern Europe and the FSU appears to have played a relatively minor role over the entire sample period (1971-1992), adding little to the overall fit of the model or to the model's predictive ability prior to 1989, these developments acquired an increasingly important role in the more recent period. When this broader measure of world demand is employed the problem of systematic overprediction disappears altogether. In addition, decompositions confirm that the relative importance of developments in the transition economies in accounting for the variability in real commodity prices more than quadrupled in the post 1988 period. More generally, estimates using quarterly data suggest that while the full structural model does not outperform a random walk forecast of real commodity prices for ***short-term*** forecast horizons (one- to four-quarters ahead), the structural model outperforms the random walk predictions over a ***longer-term*** forecast horizon (five to 31 quarters) and captures the major turning points in real commodity prices during the 1985-1992 period.

The paper proceeds as follows: Section II summarizes some of the stylized facts on recent developments in commodity prices and their potential determinants; the focus is on documenting supply conditions and discussing the relevant developments in Eastern Europe and the Soviet Union. Section III provides the theoretical structure that forms the basis for the empirical part of the analysis, which is presented in Section IV. The empirical section discusses some of the problems of the earlier models. It is shown that the single equation approach adopted by Dornbusch (1985 and 1986) and others (see Englander (1985) for a review of this literature) suffers from both misspecification and simultaneity bias. Proxies for world commodity supply and for demand in the transition economies are then included as determinants of real commodity prices. The section assesses the robustness of the proposed structural model by comparing its out-of-sample forecasting performance to a "naive" model a la Meese and Rogoff (1983) and concludes by examining how the relative importance of the macroeconomic determinants has evolved over time.

II. Developments in Commodity Prices

The decline in the prices of non-oil commodities in real terms in the past decade has been remarkable. By mid 1993, the relative price of non-oil commodities had declined 42 percent relative to 1980, and 63 percent relative to its peak in early 1974 (top panel, Chart 1). 1/ From an historical perspective, the decline is also exceptional. In 1982, the relative price of non-oil commodities went below its previous historical

1/ We measure the relative price of non-oil commodities as the IMF all-commodity index deflated by the U.S. GNP deflator. Both indices are in U.S. dollars. Different measures of the commodities price index or the deflator do not alter the outlook significantly.

minimum of 1932, and presently is at its lowest level in over ninety years. While market conditions vary from one commodity to another, Reinhart and Wickham (1994) show that the downward trend has been quite generalized, which suggests that common factors have been responsible for the price decline.

As the top panel of Chart 1 illustrates, the other prominent development in the recent evolution of commodity markets is that the decline in prices has been accompanied by a vigorous growth in the *volume* of imports of non-oil commodities by industrial countries. 1/ Since 1983, this volume index has almost doubled, even though, during the same period, GDP of the industrial nations grew less than 30 percent. 2/ Imports of non-oil commodities also grew faster than those of other goods, as world imports of all types of goods increased by approximately 70 percent in real terms during the same period. This large increase in the volume of commodity production and trade suggests the importance of supply-side factors in explaining price developments. A perusal of Chart 1 suggests that the decline in prices of the 1980s and 1990s cannot be explained by an inward shift in the demand for commodities alone, and that the rapid outward shifts in available supply must have played an important role.

In the case of developing countries, a number of factors contributed to the expansion in supply. The unfolding of the debt crisis in the early 1980s confronted many developing countries with considerably more restricted borrowing opportunities in international financial markets. This situation required balance of payments adjustments, which brought about policies geared to encouraging exports, expanding commodity supplies in many developing countries. During the midst of the debt crisis, (1984-88) world commodity supply grew at an annual rate of 13 percent, or about three times as fast as the 4.8 percent annual rate of growth of the previous ten years. Moreover, the process of structural reforms started by many developing countries in the later part of the 1980s also had a positive impact on commodity supplies. In particular, countries opened their economies to international trade and adjusted their economic policies in a more market-

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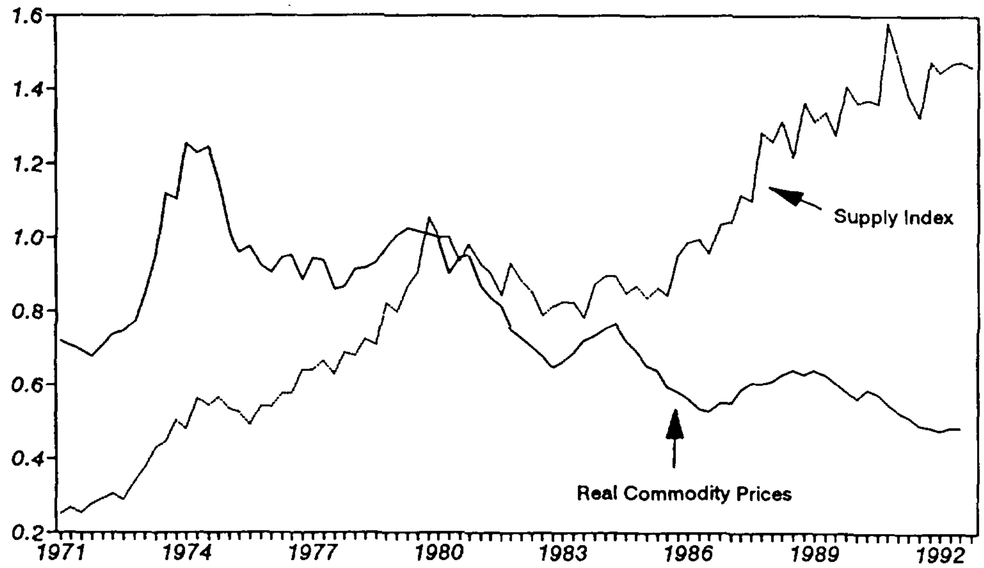
1/ World commodity supply is an unobserved variable, and most likely, any constructed proxy for it (including the one used here) is subject to measurement error. However, the principal reason for using an index of the volume of commodity imports of the industrial countries as a measure of supply rather than, say, recorded exports of primary commodities from developing countries is the accessibility and reliability of the data. According to the country classification strategy used in the World Economic Outlook, there are 130 developing countries (of which 68 are non-oil commodity exporters). Since both the timeliness and reliability of the data vary markedly across such a large set of countries, especially at quarterly frequencies, it is expected that this diversity will exacerbate the measurement error problem.

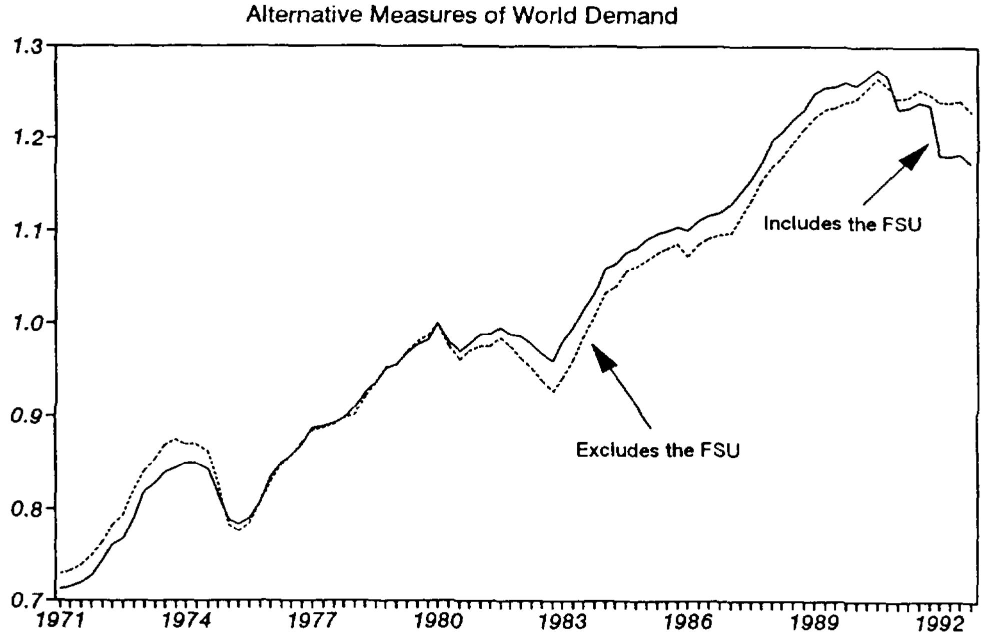
2/ This increase in world commodity supplies is further corroborated by the sharp increase in agricultural yields in both developed and developing countries in recent years (see Reinhart and Wickham (1993)).

Chart 1. Factors Affecting Commodity Markets

Commodity Prices
and World Commodity Supply



Alternative Measures of World Demand



Sources: Commodity Research Bureau, International Financial Statistics, World Economic Outlook, and the authors.

oriented direction. Resources have flowed towards productive sectors with comparative advantage, which include exportable goods and, in the case of many developing countries, primary products. Further, as noted earlier, technological developments also appear to have played a key role in boosting primary-commodity output, particularly of several agricultural commodities.

Since 1990, a second major shock affected commodity markets, namely, the aftermath of economic developments in Eastern Europe and, particularly, the FSU. Taken together these countries are large participants in commodity markets both in the demand side (mostly grains and other foodstuffs) and the supply side (especially in metals). Their demand for imported commodities fell concomitantly with the fall in output and aggregate demand that followed the collapse of their centrally-planned economic systems. Some examples of the decline in imports of commodities by the FSU are shown in Table 1. As the bottom panel of Chart 1 makes plain, there was little difference up to and including 1988 between a measure of aggregate demand that included the economies in transition and the more often-used measure that focuses on western industrial countries. Hence, a priori, one would not expect any substantive differences in the econometric results by using one or the other measure. Since 1989, owing to the output collapse in the transition economies, however, these two indices paint a very different picture of aggregate demand conditions. The industrial country index suggests a flat, lackluster performance while the more comprehensive measure signals a recession comparable in magnitude to the recession following the first oil shock in 1973 and the more recent downturn in the early 1980s.

However, the impact of economic developments in Eastern Europe and the FSU on international commodity markets has not been limited to a reduction in their demand for primary commodities. In effect, some of the more substantial effects appear to have been on commodity exports, especially in the metals markets, where the FSU is an important supplier. As can be seen in Table 2, this supply increase mostly reflected the sharp decline in domestic demand, which responded to the declines in the level of activity in the defense industry and in poorly competitive manufactures, and to disruptions in interrepublican trade. Other factors may have also contributed to the increase in the volume of exports of metals: (1) increased profitability in energy-intensive metals production and exports, owing to the still very low domestic price of energy, (2) arbitrage opportunities arising from discrepancies between domestic and international prices in the context of partial price and trade liberalization, (3) a reduction in stock levels that are no longer justified from national security or economic standpoints, and (4) export activity linked to capital flight. Overall, the increase in exports of metals and the fall in imports of some grains and other commodities since 1989 have contributed to the observed weakness in the aggregate prices of primary products.

These stylized facts provide clues for the econometric investigation. While the macroeconomic conditions in industrial countries have traditionally been considered the main determinant of commodity prices developments, it seems evident that other forces have played a significant role over the recent past. Based on the arguments made in this section, it

Table 1. Demand of the Former Soviet Union for Selected Commodities

Import volumes of:	Percent change 1989-92	FSU imports as a share of world imports: 1989 (percent)
Cocoa 1/	-48.1	4.8
Corn	-62.7	26.0
Tea	-55.7	26.9
Wheat 2/	-17.0	21.3

Source: International Tea Committee and World Grain Situation and Outlook.

1/ Grindings of raw cocoa (closer to consumption rather than imports).
2/ Percent change is through November of 1993.

Table 2. Supply from the Former Soviet Union of Selected Commodities

Exports of:	Percent Change 1989-92	FSU exports as a share of world exports: 1992 (percent)
Aluminum	219.4	8.3
Copper	71.2	5.4
Zinc	686.0	2.2

Source: World Metal Statistics

appears necessary to include a supply variable to account for the booming exports of primary products (Morrison and Wattleworth (1987) using annual data also consider supply effects), and to take into account the change in the demand for commodities of the FSU.

III. A Framework

In the analysis that follows it is assumed that the commodity is nonstorable and internationally traded. There are three countries (or country blocks), two of these are industrial commodity importers, and the third country can be thought of as a developing commodity supplier.

1. Demand for commodities

The demand for commodities is usually formulated as the demand for an input that is used for the production of final goods. Two countries demand commodities as inputs: the United States and an aggregate of the rest of the industrial countries. Production in each one of these two countries takes place under a Cobb-Douglas technology. By duality, the cost function corresponding to that technology is the following:

$$C(y,q,\omega) = yAq^{\alpha}\Omega \tag{1}$$

where y is the level of output in the United States, q is the price of non-oil commodity inputs relative to the price of United States output, and A is a constant. Ω is given by:

$$\Omega = \Pi\omega_i^{\beta'} \tag{2}$$

Where the ω_i represent real product prices of all the other inputs and factors used in production. Similarly, for the other industrial countries, the dual cost function is given by:

$$C^*(y^*,q,R,\omega^*) = y^*A^*(qR)^{\alpha}\Omega^* \tag{3}$$

where R is the ratio of the price of United States output to the output of other industrial countries (the real exchange rate of the U.S. dollar) and variables with a star superscript have the same definition as in the United States case but correspond to the "other industrial country" grouping. Conditional factor demands can then be obtained by the corresponding partial derivative of the cost functions. Therefore, the demand for commodities by the United States and other industrial countries will be given by:

$$M(y,q,\omega) = yA\alpha q^{\alpha-1}\Omega \tag{4}$$

and:

$$M^{*}(y^{*},q,R,\omega^{*}) = y^{*}A^{*}\alpha q^{\alpha-1}R^{\alpha-1}\Omega^{*} \tag{4}$$

2. Supply and market clearing

An aggregate of developing countries produce and export the commodity, the supply of which is assumed to be fixed at a point in time. In this simplest framework, we do not attempt to formulate an aggregate supply function for commodities, largely because of the diversity of economic conditions in the broad spectrum of producer countries. Further, past studies have had limited success in endogenizing supply. For instance, one of the important determinants of the supply increase for a set of developing countries was the debt crisis in the 1980s, which forced them to improve returns to commodity exporters, among other adjustments. Gilbert (1989) tried to capture this effect by using the debt service ratio for a group of developing countries as an explanatory variable for commodity prices, but had very limited success. One problem is that while the debt crisis provided the backdrop for efforts to increase exports of commodities, indicators such as debt-to-GDP ratios do not provide good proxies for the incentives offered to commodity suppliers on a quarterly basis. It is also the case that developing countries in Asia, without debt-servicing difficulties, have liberalized their trade regimes and improved export incentives. In addition, as noted in Reinhart and Wickham (1994), technological improvements, which are difficult to quantify empirically since they are largely unobservable, have also played a key role in boosting commodity supply in recent years. Hence in this simple framework we treat commodity supplies as exogenous. 1/

Commodity prices will then be determined so as to equalize existing supply to the total demand by the two countries:

$$Q = M + M^{*} \tag{6}$$

In order to avoid inconvenient nonlinearities, we will assume that the relative shares in commodity demand by the two countries remain constant, namely:

$$\frac{M}{M + M^{*}} = \lambda; \qquad \frac{M^{*}}{M + M^{*}} = 1 - \lambda \tag{7}$$

We can then form a composite demand for commodities using (4) and (5) above. The market-clearing commodity price can then be obtained by equating supply and (composite) demand and is given--in log terms--by the following

1/ Deaton and Laroque (1992) also assume an exogenous supply of commodities.

expression:

$$logq = K + \frac{1}{1-\alpha} logIPW - (1-\lambda) logR - \frac{1}{1-\alpha} logC \quad (8)$$

where $logIPW = \lambda \log y + (1-\lambda)\log y^{*}$ represents the aggregate level of production in the two countries (standing for world industrial production), and K includes constant terms and terms in the other factors of production.

Equation (8) is a partial equilibrium specification of the market for commodities. A general equilibrium representation should specify the endogenous determination of the supply of commodities Q, of the real exchange rate R, and of the level of composite output IPW. 1/ These variables will be determined jointly by aggregate demand conditions, factor market equilibrium, government policies, etc. in the two countries and in the countries where commodities production takes place. As shown in Reinhart (1991), such a model yields a specification of real commodity prices comparable to equation (8).

Having outlined the minimal structure required to link real commodity prices to several key macroeconomic determinants, the next section will examine the empirical relevance of the suggested framework.

IV. Empirical Results

This section proceeds as follows: first, the problems that have characterized existing empirical models of commodity price determination are discussed; second, the results from econometric estimation of the main determinants of commodity prices following the general lines of the framework developed above are presented; third, using dynamic simulations, the out-of-sample forecasting performance of competing specifications is evaluated; and lastly, an attempt is made to quantify how the relative importance of the various factors has evolved over time.

1. Problems with the conventional approach

Almost all the work on commodity price determination has used a single-equation framework. The analyses differ by the indices used, estimation period, frequency, and exact set of right-hand-side variables. However, OLS is the universal technique of choice.

Consider, for example, Dornbusch's examination of the commodity price-exchange rate linkage in Dornbusch (1985 and 1986). The basic equation estimated is:

1/ For such a model, see Reinhart (1991).

$$q_t = \beta_0 + \beta_1 IPW_t + \beta_2 R_t + u_t \tag{9}$$

where, as before, IPW is a measure of industrial production in the major industrial countries. 1/ Using first differences of the logs of the variables, Dornbusch estimates the coefficients for industrial production and the real exchange rate to be about 2.25 and -1.5 respectively. While the signs are as anticipated, these estimates, as Dornbusch relates, are troubling. Specifically, commodity prices appear to be excessively sensitive to fluctuations in the real exchange rate. Recall that, as shown in the previous section, the elasticity of commodity prices with respect to the real exchange rate that clears the commodity market is given by, $-(1-\lambda)$, which is between zero and one in absolute value. If the two commodity-importing countries (or blocks of countries) are equal in size and share the same technology, then we would expect a value closer to -0.5, rather than the -1.5 found. 2/

This result is easily replicated. We estimated equation (9) using the quarterly data from 1971:1 to 1992:3 for the IMF all-commodity index; OLS techniques yield the coefficients given in Table 3. However, as noted in the previous section, industrial production (a weighted average of y and y^*) is an endogenous variable. Further, as shown in Reinhart (1991), in a general equilibrium setting real commodity prices and the real exchange rate are jointly determined, so the real exchange rate is also not an appropriate right-hand-side variable. Therefore, a specification such as (9) estimated by OLS suffers from simultaneity bias. Further, the omission of a commodity supply measure and the possible mismeasurement of aggregate demand (as Eastern Europe and Soviet Union are excluded from previous studies) suggests a fundamental misspecification problem. Not surprisingly, the parameter estimates are unreliable.

To illustrate the simultaneity bias problem we perform the Hausman test for contemporaneous correlation (for a discussion see Leamer (1985)). The real exchange rate, R_t, can be decomposed into two parts: a prediction generated by an auxiliary regression using variables known to be strictly exogenous (therefore uncorrelated with the error term) and all else. 3/ Simultaneity bias would appear as a correlation between the residuals from the auxiliary regression and the residuals of the structural equation.

1/ As noted earlier, the real exchange rate of the U.S. dollar is included to correct for the fact that commodity prices are measured by a dollar-denominated index and deflated by a dollar-denominated price index, whereas the relevant measure for the non-U.S. industrial countries is the price of commodities relative to the price of their output.

2/ The share of the United States in the total trade of primary commodity-exporting countries with industrial countries is about equal in size to the share of 13-country "bloc" used in the empirical work.

3/ The instrument set used for this exercise is described at the bottom of Table 4.

Table 3. Determinants of the Real Commodity Price:
"Conventional" Demand-driven Model 1/
1971:1-1992:3

Constant Term	IPW_t	R_t	R^2	D.W.
-0.02 (-4.22)	1.99 (5.28)	-1.52 (-3.40)	0.38	1.91

1/ Definitions of all the variables appear in the Data appendix. First differences of log levels are used for all variables. The above equations include two lags for production and the real exchange rate. The numbers in parentheses are t statistics.

Or, as Hausman has shown (Hausman (1978)), if the actual variable is significant in a regression that includes both the actual and the projection, then simultaneity bias is present.

The results are presented in Table 4. As anticipated, the inclusion of an instrumental projection for the real exchange rate in a specification such as (9) did not eliminate the significance of the real exchange rate, indicating the presence of simultaneity bias. Hence, the implausible parameter estimates shown in Table 3 follow from an invalid inference resulting from the wrong estimation strategy. In the remainder of this section, simultaneity is dealt with by an estimation strategy that treats **all** the right-hand-side variables as potentially endogenous.

However, implausible parameter estimates are not the only problem associated with this model. The empirical performance, as gauged by its forecasting performance out-of-sample, deteriorates considerably after 1984 as already noted by Morrison and Wattleworth (1987). In Chart 2 the dynamic forecasts from the estimation of equation (9) are plotted under the label "model 1". As is evident from Chart 2, after 1984 this model loses track of the evolution of commodity prices; specifically, there is a systematic overprediction that continues to the present. The decline in commodity prices in the early 1980s was accompanied by recession in several industrial countries and a strong appreciation of the dollar (factors captured in the demand-driven model). Similarly, during the 1983-84 the rebound in economic activity in most industrial countries would predict a recovery in commodity prices. However, during the years that follow there is a sharp depreciation in the real exchange rate of the dollar and growth remains strong, both of these factors would suggest a rebound in real commodity prices. Commodity prices do recover by a modest 13.5 percent in the 1986-89. However, as Chart 2 illustrates, the predicted recovery in that same period is 27 percent, far exceeding the actual experience. The overprediction persists through 1992, highlighting the importance of some of the omitted variables.

In what follows, we assess the empirical relevance of two key omitted variables. Specifically, we examine the role of commodity supply in affecting commodity prices, and the impact of the decline in demand from the FSU.

2. <u>The expansion of supply</u>

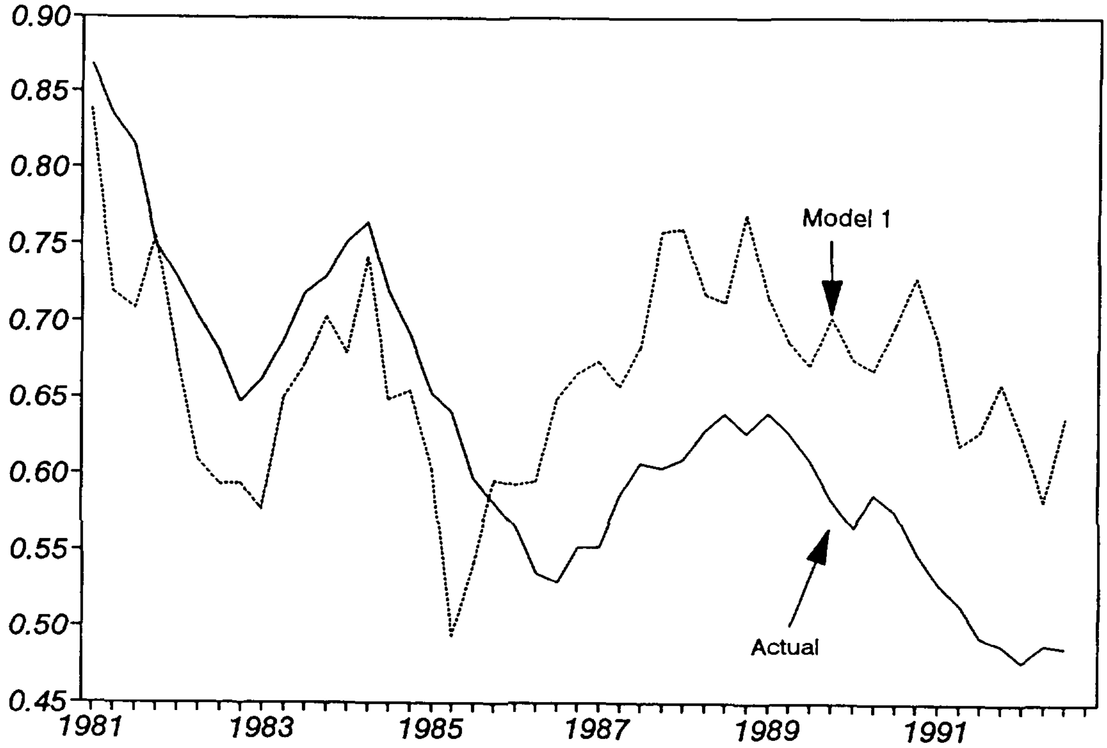
As argued above, the large expansion in commodity exports in the 1980s suggests the presence of strong supply side forces in commodity markets. To proxy for supply developments, we incorporate the volume of primary commodities imported by the industrial countries as a determinant of the price equation, in a manner analogous to equation (8) in section III. As noted earlier, to counter the possible endogeneity bias introduced in the regression by the supply variable, the supply variable was also instrumented out, using lagged values of this variable as instruments. The estimated equation is the following:

Table 4. The Hausman Test for Simultaneity 1/
1971:1-1992:3

Constant Term	IPW_t	R_t	Instrument for R_t	R^2	D.W.
-0.02 (-2.72)	2.07 (5.56)	-0.73 (-3.93)	0.61 (1.97)	0.42	1.85

1/ As before, first differences of log levels are used for all variables. The above equations include two lags for industrial production and the real exchange rate. The variables used to construct an instrument for the real exchange rate are: its own lagged values, current and lagged values of world production, the real United States fiscal deficit, and real oil prices (see Data appendix for details). The numbers in parentheses are t statistics.

Chart 2. Real Commodity Prices: Actual and Forecast



Sources: Commodity Research Bureau and the authors.

$$q_t = \beta_0+\beta_1 IPW_t+\beta_2 R_t+\beta_3 Q_t+u_t \quad (10)$$

Equation (10) was estimated using quarterly data for 1971:1-92:3. To elude nonstationarity problems (see Reinhart and Wickham (1994) for a fuller discussion of the time series properties of commodity prices), we avoid employing levels (or log-levels) in the econometric analysis. 1/ The seasonality patterns evident in some of the regressors and instruments are dealt with by using four-quarter differences (rather than first differences) of all the variables. This filter has the advantage of simultaneously eliminating the stationarity problems as well as the seasonality issues. However, employing four-quarter changes does raise some estimation problems. Specifically, this transformation introduces a moving-average process in the error structure of the regression. Since the observations are quarterly, a shock to commodity prices in a given quarter could affect the error terms for the next three quarters--that is the disturbances will follow a third-order moving average process. An instrumental variables approach would yield consistent estimates of the coefficients, but not of the covariance matrix, as the errors are no longer identically and independently distributed. To obtain a consistent estimate of the covariance matrix, the estimation strategy adopted follows the generalized least squares (GLS) procedure therefore, we use the variance-covariance matrix outlined in Hansen and Hodrick (1980). No lagged variables are introduced. The instruments employed are: lagged values of all the right-hand-side variables (recall the filtered variables are all stationary, so employing lagged values as instruments does not pose any estimation problems), lagged values of the four-quarter changes in the log of real oil prices, and the real fiscal deficit in the United States.

The estimation results, reported in Table 5, have a number of satisfactory features, and generally support the theoretical priors. First, the coefficient on the supply variable has the correct sign (indicating that an expansion in supply, other-things-equal, reduces commodity prices) and the relationship is statistically significant. The supply coefficient at -0.9 suggests that an increase in commodity supply translates to an almost proportional decline in its price, which is in line with the general view that the demand for commodities is inelastic. Second, the "excess sensitivity" of commodity prices to real exchange rates that characterized the demand-driven model, disappears altogether. In effect, the coefficient of the real exchange rate, at -0.62, is now within the dictates of theory. Third, the parameter estimates appear to be robust irrespective of the choice of sample period, this will be discussed further. Fourth, and more importantly (as discussed below), the predictive performance of this specification is superior to specifications that exclude a supply variable and outperform the forecasts from a random walk model at longer-term forecast horizons.

1/ The variables of interest all have unit roots (i.e. are nonstationary).

Table 5. A Model of Real Commodity Prices with Alternative Measures of Demand: Instrumental Variables with Consistent Estimation of the Variance-Covariance Matrix 1971:1-1992:3 1/2/

Constant Term	IPW_t	IPW_{2t}	R_t	Q_t	R^2
-0.03 (-1.39)	1.40 (5.02)	**	-0.62 (-4.18)	-0.96 (-4.17)	0.76
-0.04 (-1.66)	**	1.54 (5.57)	-0.62 (-4.32)	-0.95 (-4.24)	0.76

1/ Definitions of all the variables appear in the Data appendix. Four-quarter differences of log levels are used for all variables. The above equations include no lagged variables. The numbers in parentheses are t statistics.

2/ Hansen-Hodrick moving average correction.

3. The fall in demand from the former Soviet Union

Some of the impact of the FSU developments on commodity prices is already captured in the supply proxy. Recall that supply is proxied by primary commodity imports of the largest industrial countries; these import figures (particularly for Europe) already include their imports of metals from the FSU. However, as illustrated in Table 1, the effect on commodity markets of the economic developments in the countries FSU and Eastern Europe has also been characterized by the large drop in the domestic demand for commodities since 1989. Even in those commodity markets where transition economies are net exporters, the increases in exports can largely be traced to a fall in domestic demand that broadened the exportable balances, as discussed in Section II. Because this drop in the demand for commodities was closely associated to the drop in aggregate output, we proxy this "aggregate demand factor" by incorporating the countries of Eastern Europe and the FSU into our index of industrial production.

Therefore, we construct a new aggregate index of industrial production, IPW2, in which the transition economies are represented with a weight that corresponds to their share in commodity market imports. The equation to be estimated thus becomes:

$$q_t = \beta_0+\beta_1 IPW_{2t}+\beta_2 R_t+\beta_3 Q_t+u_t \tag{11}$$

Estimation results, displayed in Table 6, are encouraging, although the significance levels show only a minor improvement relative to the specification that does not include developments in the transition economies (for the entire sample). More importantly, there is a marked improvement in the out-of-sample predictive ability of this equation, most noticeable in the 1989-92 period, when the output collapse in the transition economies materializes. In Chart 3 we plot dynamic forecasts obtained through the application of the three estimated specifications. Model 1, corresponding to equation (9), includes conventional demand-side determinants only; model 2, corresponding to equation (10), adds a supply proxy to the estimated equation, and model 3, corresponding to equation (11), incorporates the transition economies in the measure of world industrial production. The poor forecasting performance of model 1 after 1984 and a much more adequate performance of model 3 can easily be established from the chart. Table 6 provides some summary information of the forecasts produced by the three models. It can be seen that the pairwise correlation with actual values is contrastingly higher for model 2 and model 3.

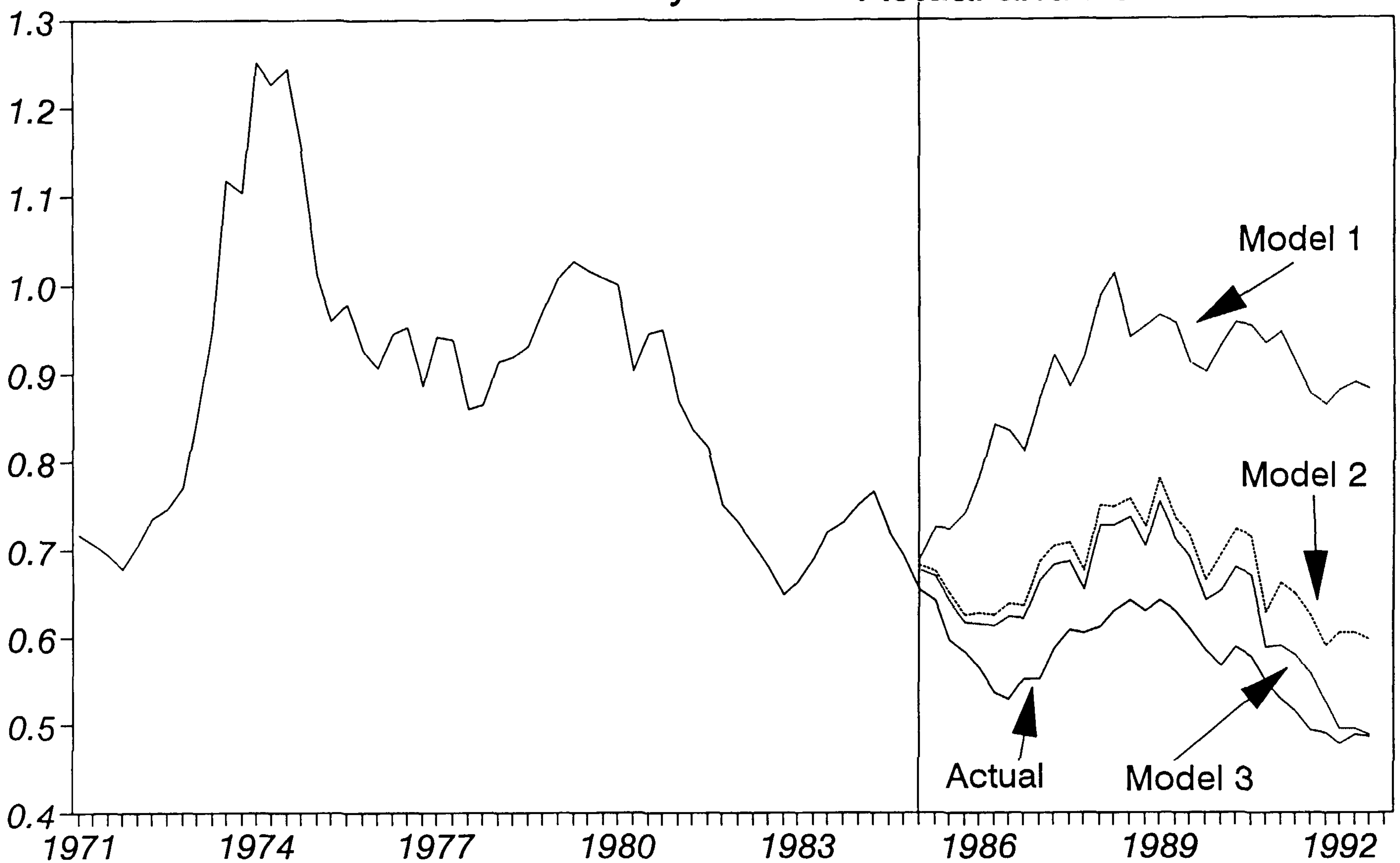
A further assessment of the performance of the estimated equations was obtained by the comparison of their forecasting abilities to an alternative, purely time-series based, forecasting model. The logical and customary alternative specification is the random walk model. This type of test has been applied to exchange rate models. For example, Meese and Rogoff (1983a and 1983b) have shown that (nominal) exchange rate models routinely fail to predict out-of-sample relative to the random walk model in the floating rates period (see also Mussa (1986)). In the context of commodity prices,

Table 6. Descriptive Statistics of Actual Commodity Prices and the Dynamic Forecasts 1985:1-1992:3 1/

	Actual	Model 1	Model 2	Model 3
Mean	0.57	0.88	0.67	0.64
Standard deviation	0.05	0.08	0.05	0.07
Minimum value	0.48	0.68	0.59	0.49
Maximum value	0.65	1.01	0.78	0.75
Pairwise correlation with actual values	1.00	0.03	0.81	0.92
Standard error of the correlations	**	(0.14)	(0.11)	(0.07)

1/ These forecasts are plotted on Chart 3.

Chart 3. Real Commodity Prices: Actual and Forecasts



Sources: Commodity Research Bureau and the authors.

Kaminsky and Kumar (1990) showed that a random walk model is also the natural specification for a purely time-series based forecasting equation.

Such test underscores the superior predictive performance of model 3. The three different structural equations were reestimated for the sample period 1971 to 1984 and then dynamically simulated over 1985 to 1992. The results of these estimations are presented in Table 7. As noted earlier, the parameter estimates appear to be robust irrespective of the choice of sample period. For example, the estimation results presented in Table 5, which span the entire 1971:1-1992:3 sample, are comparable in both fit and order of magnitudes to the parameters of the estimation results summarized in Table 7, which are based on the 1971:1-1984:4 sub-period. Table 8 reports Theil's u-statistic, which compares the root-mean-squared error of the model forecast to the random walk model forecast of no change over the whole horizon. A value in excess of one indicates that the model underperformed the random walk forecast over the corresponding horizon. The results indicate that model 1 is outperformed by the random walk model over the whole forecast period of nearly eight years. Model 2 has much smaller prediction errors, but it only overtakes the forecasting ability of the random walk model for horizons longer than six years. Model 3 has much smaller forecasting errors, and starts to outperform the random walk model for horizons between one and two years.

4. What caused the price decline?

The econometric estimation carried out in the last section permits us to quantify the relative importance of the different factors that are commonly associated with the decline in the prices of commodities during the last decade. A variance decomposition of the explained change in commodity prices, reported in Table 9, produces a very definite temporal pattern. Supply shocks account for about 40 percent of the variance for the period 1971-84, but this share rises to over 60 percent for the period 1985-88. Conversely, industrial production in industrial countries accounts for 25 percent of the variance of commodity prices in 1971-84, but the proportion falls to just over 5 percent for 1985-88. While industrial production in the transition economies of Eastern Europe and the FSU account for a minor fraction of the variance in the early part of the sample, this share increases to over 26 percent for the period since 1989. The real exchange rate of the U.S. dollar explains a fairly stable proportion of the variance of commodity prices throughout the sample subperiods. 1/

1/ This variance decomposition is net of the fraction of the variance of commodity prices explained by the pairwise covariances of the different explanatory variables (which cannot be attributed to a specific variable) and of the unexplained part (the variance of the regression residual).

Table 7. Estimates of the Alternative Specifications Used for the Dynamic Forecasts of Commodity Prices 1971:1-1984:4 1/

Model Number	Constant Term	IPW_t	IPW_{2t}	R_t	Q_t	R^2
1	-0.05 (-1.94)	1.57 (12.71)	**	-0.68 (-2.44)	**	0.55
2	-0.03 (-1.01)	1.36 (5.66)	**	-0.68 (-3.23)	-0.85 (-3.16)	0.75
3	-0.04 (-1.53)	**	1.74 (5.98)	-0.65 (-3.29)	-0.85 (-3.27)	0.75

1/ Four-quarter differences of log levels are used for all variables. The above equations include no lagged variables. The numbers in parentheses are t statistics. An asterisk indicates the variable was not included in the equation.

Table 8. Out-of-sample Forecasting Performance of Alternative Models: A comparison to a Random walk Estimation Period: 1971:1-1984:4 1/
Forecast Period: 1985:1-1992:3

Horizon	Model 1 "Dornbusch demand-driven model"		Model 2 "Adding a supply variable"	
	RMS error 2/	Theil u	RMS error	Theil u
1 quarter	.324	16.385	.106	5.353
4 quarters	.340	6.059	.111	1.974
8 quarters	.353	4.332	.115	1.416
12 quarters	.363	4.044	.116	1.298
16 quarters	.367	4.596	.117	1.466
20 quarters	.381	5.388	.119	1.674
24 quarters	.393	3.864	.117	1.153
28 quarters	.392	2.395	.113	.694
31 quarters	.393	1.922	.110	.537

Horizon	Model 3 "Full structural model"	
	RMS error	Theil u
1 quarter	.072	3.645
4 quarters	.075	1.339
8 quarters	.076	.939
12 quarters	.073	.819
16 quarters	.068	.848
20 quarters	.059	.839
24 quarters	.043	.426
28 quarters	.020	.124
31 quarters	.001	.004

1/ Estimates of the equations employed to generate these forecasts are reported in Table A-1 in the appendix.
2/ Root mean squared error.

Table 9. Real Commodity Prices: Variance Decompositions
Percent of the Explained Variation 1971:1-1992:3 1/

Period	IPW_t (Industrial Countries)	IPW_t (FSU)	R_t	Q_t
1971:1-1992:3	16.7	6.7	30.1	46.5
1971:1-1984:4	25.1	4.2	30.4	40.3
1985:1-1988:4	5.6	0.6	32.3	61.5
1989:1-1992:3	7.5	26.6	27.1	38.8

1/ Ignores covariance terms.

V. Possible extensions

The preceding analysis has addressed several of the problems that have plagued the structural approach to commodity price determination in the past. An estimation strategy that recognizes the endogeneity of the regressors was adopted and two important omitted variables were incorporated in the analysis (commodity supply and demand from the FSU). While the empirical results obtained using the richer specification are encouraging, there remain a number of areas where the foregoing analysis could be extended.

First, as noted in Reinhart and Wickham (1994) the "unobserved process" of technological change appears to have had an important impact in increasing world commodity supply (particularly of agricultural commodities in developing countries). This impact is only imperfectly captured in our measure of supply, which focuses on industrial country imports of primary commodities. It may be worthwhile to attempt to model this secular (and probably largely irreversible) unobserved process. 1/

Second, since it is often argued that the breakdown of several important International Commodity Agreements has contributed importantly to the weakness in commodity prices in the 1980s and 1990s, it appears reasonable to attempt to account for these discrete events when modelling commodity prices.

Third, agricultural, fiscal and other policies in industrial countries appear to have some effect on commodity price behavior (see Alogoskoufis and Varangis (1992) and Reinhart (1991)), it may be possible to consider commodity price behavior in the context of a fuller, general equilibrium framework.

Lastly, the approach adopted in this paper, in line with most of the previous literature, has ignored the role of inventories on commodity prices by treating all commodities as nonstorable and stressing the role of flows versus stocks. A careful empirical treatment of this issue would appear to be important, particularly for categories such as metals.

1/ Possibly along the lines in which the unobserved process of "financial innovation" is modelled in VX, De Gregorio, Reinhart, and Wickham (1994).

The Effect of Oil Prices

A number of studies have identified the high level of comovement between the prices of different commodities. 1/ While in this paper we are only concerned with the behavior of the aggregate index of non-oil commodities, that literature poses the question of what is the influence of oil prices on the determination of the prices of the other commodities. This appendix investigates that linkage and finds that, while the price of oil is a significant explanatory variable, its inclusion in the regression does not fundamentally alter the conclusions drawn in the main section of this paper.

The most logical reason for the inclusion of oil prices is its role as another input in the aggregate production function. 2/ Thus, for example in the case of the United States, we could express the cost function as:

$$C(y,q,p,\omega) = yAq^{\alpha}p^{\beta}\Omega \tag{A1}$$

where p is the relative oil price in terms of United States output. Following this approach, the expression for the non-oil commodity price index would be:

$$\log q = K + \frac{1}{1-\alpha}\log IPW_2 - (1-\lambda)\left(1+\frac{1-\beta}{1-\alpha}\right)\log R - \frac{1}{1-\alpha}\log Q - \frac{1-\beta}{1-\alpha}\log p \tag{A2}$$

The results of estimating equation A2 in the same fashion as the previous formulations are displayed in Table A1. The coefficient on oil prices is highly significant, and the inclusion of this variable improves the significance of the other explanatory variables as well. However, the values of the coefficients are little changed from the specification reported in Section IV, implying that our main conclusions are robust to the inclusion of oil prices in the regression.

1/ Pindyck and Rotemberg (1988), in fact, estimate that the comovement among the prices after of commodities, taking into account common influences, is excessive and may reflect "herding" behavior in financial markets.

2/ This approach is followed, for instance, by Holtham (1988), who considers the roles of multiple production inputs.

Table A1. A Multi-input Model of Real Commodity Prices that Includes Oil: Instrumental Variables with Consistent Estimation of the Variance-Covariance Matrix 1971:1-1992:3 1/2/

Constant Term	IPW_{2t}	R_t	Q_t	P_t	R^2
-0.05 (-4.30)	1.50 (7.96)	-0.61 (-6.36)	-0.78 (-6.28)	0.11 (6.47)	0.86

1/ Four-quarter differences of log levels are used for all variables. The above equation includes no lagged variables. The numbers in parentheses are t statistics.

2/ Hansen-Hodrick moving average correction.

Data Appendix

Variable	Description and sources
IPW_t	Industrial production index for industrial countries, seasonally adjusted. Source: International Financial Statistics, IMF.
IPW_{2t}	Weighted index of industrial production index for industrial countries, seasonally adjusted and real GDP for the FSU. Constructed by the authors. The FSU annual real GDP series was interpolated to construct a quarterly index. Sources: International Financial Statistics, and World Economic Outlook, IMF.
q_t	IMF non-oil all-commodity index deflated by the U.S. GNP deflator. Sources: International Financial Statistics, IMF and United States Department of Commerce.
R_t	IMF index of the real exchange rate of the United States relative to other industrial countries. Based on value added deflators in manufacturing. Source: International Financial Statistics, IMF.
Q_t	Primary commodity imports excluding oil denominated in U.S. dollars for 14 industrial countries, including the United States deflated by the IMF non-oil all-commodity index. Constructed by the authors from the following sources: International Financial Statistics and Supplement on Trade Statistics, IMF and Trade Data Systems, United Nations.
g_t	United States Federal Budget deficit (unified budget basis) deflated by the U.S. GNP deflator. Used only as an instrument. Sources: United States Department of the Treasury and Office of Management and Budget, and United States Department of Commerce.
p_t	Saudi Arabian benchmark price for light crude deflated by the U.S. GNP deflator. Used as an instrument and as a regressor in the regression reported in Table A1 in the Appendix. Sources: International Financial Statistics, IMF and United States Department of Commerce.

The 14 industrial countries that make up the supply index are: Canada, Japan, Austria, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden, United Kingdom, Switzerland, Belgium and the United States.

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