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A Model of Commodity Prices
After Sir Arthur Lewis

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Abstract

The long-run dynamics of commodity prices is studied through the interaction of supply and demand. Demand is driven by world wide income. The description of supply is based on Sir Arthur Lewis (1954) famous paper on growth with unlimited quantities of labor. The model generates a stationary commodity price around the supply price while commodity supply and world income are cointegrated. It is fitted for six commodities, cocoa, coffee,rice, sugar, copper and tin, to annual data over (part of) the past century.
Keywords : commodity prices.

Résumé

Nous étudions la dynamique de long terme des prix des matières premières comme résultant de l'interaction entre offre et demande. La demande est tirée par le revenu mondial. L'offre suit la description proposée par Lewis (1954), dans son article sur la croissance avec une disponibilité infinie de travail. Le modèle engendre un prix de matière première stationnaire autour du prix d'offre, alors que la quantité produite est cointégrée avec le revenu mondial. Il est ajusté pour six biens, cacao, café, riz, sucre, cuivre et étain sur données annuelles sur le siècle dernier.
Mots clés : prix des matières premières.

Introduction

In spite of an extensive literature, the behavior of the prices of primary commodities remains poorly understood. The long-run stagnation, or even secular decline, of the prices of tropical commodities has been attributed to the exercise of market power by Northern manufacturers, and to the supposed low elasticity of demand for primary commodities, Prebisch (1959), Singer (1950). The variability of commodity prices has been attributed to supply shocks confronting inelastic demand, and to the behavior of speculators, Deaton and Laroque (1992). But none of these accounts are fully satisfactory, either theoretically or empirically. The precise nature of the market power of the North has never been fully explained, nor is it clear in the absence of an account of supply, why it should be that low demand elasticities generate stagnant or declining prices. The theory of short run dynamics is better understood, but it has a good deal of difficulty accounting for the evidence. In Deaton and Laroque (1992) we showed that a model in which excess supplies were independently and identically distributed over time, the presence of risk neutral speculators could lead to behavior which replicated some of the characteristics of commodity prices, notably long periods of stagnant prices interrupted by sharp upward spikes. However, the speculative model, although capable of introducing some autocorrelation into an otherwise i.i.d. process, appears to be incapable of generating the high degree of serial correlation of most commodity prices. If excess supplies are allowed to be first-order autoregressive, the model can provide a better fit to the data, Deaton and Laroque (1996). However, and contrary to our expectations before doing the work, we found that, in order to fit the data, the autocorrelation coefficients of excess supply had to be almost as large as the autocorrelation in the prices themselves. The introduction of speculative inventories, although affecting the skewness and

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kurtosis of the series, does not appear to contribute much to the autocorrelation of prices. We are therefore left without a coherent explanation for the high degree of autocorrelation in commodity prices, just as we have no coherent explanation for the trend.

In this paper, we turn away from inventories as an explanation for the short-run dynamics of prices, and focus instead on the longer-run determinants. In our previous work, our main concern was with the effect of speculative storage on otherwise i.i.d. excess supplies, which were themselves, following much of the previous literature, driven more by supply than demand. Weather driven quantity shocks are the archetypal driving forces for models of agricultural prices, if only because demand seems an unlikely candidate to explain variability. However, precisely because demand is more highly autocorrelated, it is a good candidate to explain autocorrelation, and this is one of our starting points. On the supply side, we start from the account of Sir Arthur Lewis (1954) in his famous paper on growth with unlimited supplies of labor. Lewis was concerned with finding an explanation for the fact that, in spite of technical progress in the industry, the price of West Indian sugar persistently declined relative to the prices of imported manufactured goods. He argued that, as long as there was an infinitely elastic supply of labor at the subsistence wage, world sugar prices could not rise, and might even decline with local technical progress. Lewis' model provides our starting point on the supply side.

We propose a time-series version of the Lewis model in which commodity supply is infinitely elastic in the long run, and in which the rate of growth of supply responds to the excess of the current price over the long run supply price. Demand is linked to the level of world income and to the price of the commodity. In this simple framework, the commodity price is stationary around its supply price, and commodity supply and world income are cointegrated. Because there

are long lags in supply, at least for some commodities, the price process reverts only slowly to its mean, and in the short run is driven by fluctuations in world income, itself a strongly trending process. In this way, the model predicts that in the short run, prices will move with income, which is non-stationary but, unlike income, they will be stationary in the long run.

That such an account is broadly consistent with some of the evidence is illustrated in Figures 1 and 2 for the case of sugar, the commodity of most concern to Lewis. Figure 1 shows, on log scales, world real income in billions of 1980 (purchasing power parity) dollars, together with world production of sugar in hundreds of millions of quintals, see Appendix for sources. Both series trend strongly upward, with the trend of sugar production somewhat less than that of world income, consistent with a long-run income elasticity somewhat less than unity. By contrast, the world price of sugar, shown as an index in Figure 2, has not risen relative to the US CPI (a convenient deflator) over the long run. In common with many commodity prices over the long run, the trend is small relative to the variability, so that it is possible to see upward or downward "trends" over prolonged periods. Over the whole period, the price is at least roughly consistent with its being a stationary time-series.

In our previous work, the short run autocorrelation of commodity prices came from the fact that for speculative arbitrageurs to hold inventories, expected price growth must match interest and holding costs; in the long run, we assumed a stationary excess of supply over demand, with occasional stockouts guaranteeing that price processes are stationary. In the current model by contrast, supply and demand are described separately, and price behavior comes from the action of an integrated (trending) demand process against a supply function that is infinitely elastic in the long run but not the short run. Although we do not attempt to do so, it should be noted that

there is nothing in principle that would prevent the incorporation of speculative arbitrage into the Lewis model proposed here.

The Lewis argument is addressed to agricultural commodities. For mineral products, first dealt with by Gray (1914) and Hotelling (1931), the owners of the reserves must receive an adequate income for holding their stock of capital. In the long run therefore arbitrage guarantees that the discounted price of the resource in situ stays constant, or that the observed rate of growth of the price equals the interest rate. Note that this parallels the short-run behavior of inventories of agricultural commodities. But in (only apparent) contradiction of Hotelling, the market prices of minerals, like the market prices of agricultural crops, do not exhibit clear trends. In fact the arbitrage argument applies to the shadow price of resources in the ground, while the observed price series are for the extracted material. Hotelling himself, see also Halvorsen and Smith (1991), noted that the price in the ground may decline if extraction costs increase when the overall remaining stock is depleted. In a similar vein, if the extraction costs are the main component of the observed price, and if these costs are the wages of subsistence workers employed to do the extraction, the Lewis model is more relevant than the Hotelling story for understanding prices. This will be the case if in situ stocks of the minerals are very large, so that extraction costs dominate rents in commodity prices, and it is that version of events that we follow here. Even if it is true that labor is the main component of costs for both agricultural and mineral products, there are other differences, for example in the nature of productivity shocks, and we will note and discuss these as we develop and interpret the model.

Section 1 of the paper presents our version of the Lewis model, first in a stripped down form, and then in a form suitable for empirical implementation. Section 2 discusses our data and

presents preliminary descriptive analysis in light of the model. Section 3 presents estimates and their interpretation. Section 4 concludes.

Section 1: A model of commodity prices

We start with a simple version of the model which illustrates the main issues, and then state a more formal version that will be used as the basis for the empirical analysis in subsequent sections. Consider the partial equilibrium model for a typical commodity that is traded internationally. Final demand is assumed to be a log-linear (constant elasticity) function of world income (world GDP) and of the world price. The rate of growth of world income is assumed to be a stationary stochastic process, with the (unconditional) mean growth constant over time so that, in time-series language, the logarithm of world income is a non-stationary integrated of order one, $I(1)$, process. Formally,

$$d_t = A y_t - B p_t + k + \xi_t^d \tag{1}$$

where lower case d_t, y_t, and p_t are the logarithms of quantity demanded, income, and price, A, B, and k, are parameters, and ξ_t^d is a stationary, unobservable, $I(0)$ random variable. We expect that $A > 0$, so that demand, exclusive of price movements, is increasing in world income.

The supply process is less standard, and is a simple version of the Lewis model. We write

$$s_t = s_{t-1} + D(p_t - p^*) + \xi_t^s \tag{2}$$

where s_t is the logarithm of supply, and ξ_t^s is a supply shock, also an unobservable, stationary, $I(0)$ random variable. The price p^* is interpreted as the marginal cost of production on marginal land, or the marginal cost of extraction for a mineral. In line with the Lewis assumption of unlimited supplies of labor at the subsistence wage, p^* is taken to be constant. Because $D > 0$,

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supply is increased when price is above marginal cost, and vice versa when price is below marginal cost. We assume that the error term ξ_t^s is stationary and $I(0)$. In particular, we need to permit both permanent (more or less land, a new mine, or a technological shift) and transitory (weather, pests, miner strikes or epidemics) shocks to supply so that, for example, we might have

$$\xi_t^s = \eta_t + v_t - v_{t-1} \tag{3}$$

where η_t and v_t are the permanent and transitory shocks respectively. In much of the discussion in the literature, prominence is given to weather shocks for agricultural products, and such shocks would normally be thought of as transitory. For minerals, shocks are perhaps more likely to be permanent. Even so, shocks that affect labor costs or labor productivity could have much the same effect on both types of commodities.

In the absence of inventories, price is determined by equalizing supply and demand, so that

$$p_t = (B+D)^{-1}(Ay_t + k - s_{t-1} + Dp^* + \xi_t^d - \xi_t^s). \tag{4}$$

If (4) is substituted into the supply process (2), we get the stochastic process for supply:

$$s_t = (B+D)^{-1}[Bs_{t-1} + ADy_t + Dk - DBp^* + D\xi_t^d + B\xi_t^s], \tag{5}$$

or

$$\Delta s_t = (B+D)^{-1}[D(Ay_{t-1} - s_{t-1}) + AD\Delta y_t + Dk - DBp^* + D\xi_t^d + B\xi_t^s]. \tag{6}$$

Equation (4) can be rewritten to give s_{t-1} as a function of p_t. Leading the result by one period gives s_t in terms of p_{t+1}, and the two equations can be inserted into (5) to eliminate supply and its lag. Lagged one period, we obtain

$$p_t - p^* = (B+D)^{-1}[B(p_{t-1} - p^*) + A\Delta y_t + \Delta \xi_t^d - \xi_t^s]. \tag{7}$$

These two equations, (6) and (7), capture in stripped-down form the central features of our implementation of the Lewis model. In spite of the fact that world income is non-stationary, with

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possible positive growth, equation (7) shows that the commodity price is stationary, fluctuating around its long-run value of $p^* + A\mu/D$, where µ is the mean growth rate of income, $E(\Delta y)$. This long run value of the price guarantees that, over the long-run, supply increases at the same rate as world income so that, as shown in (6), output of the crop is cointegrated with world income. Of course, the Lewis model only supposes that supply is infinitely elastic in the long run; in the short run, price will respond to fluctuations in demand and supply. But price has no long-run trend.

The supply and demand disturbances in the structural model (1) and (2) are typically autocorrelated. To accommodate this, and to develop a model for the empirical implementation whose residuals are innovations, we now introduce an autoregressive formulation.

We start by generalizing the original demand and supply equations to include more realistic responses to prices. Demand is likely to be a function, not only of current income and prices, but also of past and expected future income and prices. Similarly, we would normally think of forward-looking profit maximizing producers as responding to expected future prices. One modeling strategy would be to write down structural supply and demand functions depending, among other things, on expected future variables, and then to proceed as usual for rational expectations models, postulating time-series processes for prices, and solving for their properties. Such a strategy has the potential advantage of yielding restrictions on the lag structure of prices, but only if we are confident about the underlying structure of supply and demand functions. Given that we do not have such information, we adopt a reduced form distributed lag specification while emphasizing that such a model, while not necessarily incorporating all the restrictions from a structural form, encompasses a model of rational, forward-looking behavior.

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Our model includes world income in the demand function, but excludes it from the supply function. This is a standard assumption, and is central to a Lewis interpretation. Lewis wanted to know why West Indians remained poor, and the price of sugar low, in a world where income and the demand for sugar were steadily increasing. If income were included in the supply equation, there would be no story to tell. More formally, the exclusion of income from the supply equation will allow us to identify its parameters in the last section of the paper, though our reduced form results do not depend on it.

We now write:

$$\Delta d_t = A(L)y_t - B(L)p_t + C(L)d_{t-1} + k + \varepsilon_t^d \tag{8}$$

$$\Delta s_t = D(L)(p_t - p^*) + E(L)\Delta s_{t-1} + \varepsilon_t^s \tag{9}$$

where L is the lag operator, $A(L)$, $B(L)$, $C(L)$, $D(L)$, and $E(L)$ are finite polynomials in the lag operator, and we assume that

$$D(1) \neq 0, \quad C(1) \neq 0, \quad A(1) \neq 0, \quad D(0) + B(0) \neq 0. \tag{10}$$

As before, we assume that y_t is $I(1)$ and, in addition, that the error terms ε_t^d and ε_t^s are innovations and that enough lags have been introduced to ensure this.

The price can be eliminated from (8) and (9) by multiplying the former by $B(L)$, the latter by $D(L)$, and adding, so that, using the notation q_t to denote both supply and demand, $q_t = s_t = d_t$, we have

$$\begin{aligned} [D(L) + B(L)]\Delta q_t = {}& D(L)[A(L)y_t + C(L)q_{t-1}] + B(L)E(L)\Delta q_{t-1} \\ & + D(1)k - B(1)D(1)p^* + D(L)\varepsilon_t^d + B(L)\varepsilon_t^d. \end{aligned} \tag{11}$$

while, for the price,

$$[D(L) + B(L)]p_t = A(L)y_t + C(L)q_{t-1} - E(L)\Delta q_{t-1}$$
$$+ k + D(1)p^* + \varepsilon_t^d - \varepsilon_t^s$$

(12)

Equation (12) implies that production is cointegrated with world income. To see this, note first that, since $A(L)$ is finite, $A(1)$ is nonzero, and y_t is $I(1)$, $A(L)y_t$ on the right hand side of (11) is also $I(1)$. Suppose that q_t is integrated of order m. Then because $C(1)D(1)$ is nonzero, the first term on the right hand side of (11), and thus the right-hand side itself, is integrated of order $\max(1, m)$. If m were 2 or larger, the right-hand side would be integrated of order $m \geq 2$ while the left-hand side would be integrated of order $m - 1$, which is a contradiction. Similarly, if $m \leq 0$, the right hand side is integrated of order 1, and the left-hand side integrated of order less than –1, again a contradiction. In consequence, $m = 1$, and since the right hand side is $I(0)$, so is $A(L)y_t + C(L)q_{t-1}$, so that q_t and y_t are cointegrated. Consequently, by equation (12), the price p_t is stationary.

In order to estimate the model, it is convenient to rewrite the equations to put them into vector error-correction model (VECM) form. Start from the first term on the right-hand side of (11), and rewrite as

$$A(L)y_t + C(L)q_{t-1} = [A(1)y_{t-1} + C(1)q_{t-1}] + \tilde{A}(L)\Delta y_t + \tilde{C}(L)\Delta q_{t-1}$$

(13)

so that all three terms on the right hand side are stationary. The first term, in square brackets, is referred to as the "cointegration term." If (13) is substituted into (8) and (8) and (9) are solved for p_t and Δq_t, we get two equations with current Δq_t and p_t on the left-hand side, while the right hand side has the cointegration term, Δq_{t-1} and its lags, p_{t-1} and its lags, and Δy_t and its lags. If we are prepared to maintain that Δy_t is strictly exogenous, this form would be sufficient, but instead, we complete the system by adding an equation for the change in income

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$$\Delta y_t = a_0 + a_1[A(1)y_{t-1} + C(1)q_{t-1}] + F(L)\Delta y_{t-1} + G(L)\Delta q_{t-1} + H(L)p_{t-1} + \varepsilon_t^y \tag{14}$$

where ε_t^y is an innovation. With this final substitution, we obtain a three equation system in

VECM form,

$$\Delta q_t = b_{q0} + b_{q1}(\theta y_{t-1} - q_{t-1}) + B_{qq}(L)\Delta q_{t-1} + B_{qp}(L)p_{t-1} + B_{qy}(L)\Delta y_{t-1} + \eta_t^q \tag{15}$$

$$p_t = b_{p0} + b_{p1}(\theta y_{t-1} - q_{t-1}) + B_{pq}(L)\Delta q_{t-1} + B_{pp}(L)p_{t-1} + B_{py}(L)\Delta y_{t-1} + \eta_t^p \tag{16}$$

$$\Delta y_t = b_{y0} + b_{y1}(\theta y_{t-1} - q_{t-1}) + B_{yq}(L)\Delta q_{t-1} + B_{yp}(L)p_{t-1} + B_{yy}(L)\Delta y_{t-1} + \eta_t^y. \tag{17}$$

These three equations will be estimated in Section 3 below. Because the supply equation (9)

excludes world income or its rate of growth, and because the demand equation (8) excludes

nothing, see also (2) and (1), only the parameters of the supply equation are identified, together

with the cointegration parameter θ, which is the long-run income elasticity of demand for the

commodity. The algebra for the identification is tedious, but does not differ substantively from

the elementary treatment of identification in supply and demand systems. Because the system is

overidentified, there are restrictions that must hold on (15)-(17) to make them consistent with the

structure. The ratio of the coefficient on the cointegration term in the quantity equation, b_{q1} to

the coefficient on the cointegration term in the price equation, b_{p1} must be the same as the ratios

of the polynomials on Δy_{t-1}, so that

$$\frac{b_{q1}}{b_{p1}} = \frac{B_{qy}(n)}{B_{py}(n)} \tag{18}$$

for all n up to the maximum lag on Δy_{t-1}. Provided the restrictions are satisfied, the ratio is the

short-run elasticity of supply to price, $D(0)$. The original supply equation is obtained by

subtracting $D(0)$ times the price equation (16) from the quantity growth equation (15); this

identifies all the parameters of (9).

Conditional on the validity of the cointegration of y_t and q_t and of the stationarity of p_t, the system can be consistently and efficiently estimated by standard FIML applied to the three equations, with or without the restrictions, with the FIML variance covariance matrix used to construct t-tests, F-tests, and likelihood ratio tests, see Ahn and Reinsel (1990) and Watson (1994).

Section 2: Data and preliminary analysis

In our previous work on commodity prices, we worked entirely with price data, mostly with relatively long historical data for most of the 20th century. There are great advantages to the price data. They are high quality data, available over long periods of time, and in recent years, at high frequency, and they cover a large number of commodities. Nevertheless, a fuller understanding of the processes involved would seem to require an examination of quantities as well as covariates such as income, and given our previous lack of success in providing a coherent account of price behavior, it is necessary to take the broader view. Unfortunately, long-run production and income data are a great deal harder to come by than price information, and a good deal less accurate. In particular, there is an almost complete absence of adequate long-run data on inventories of commodities, so that our neglect of this aspect of the problem is forced by data considerations if for no other reason. In the Appendix, we provide brief details of the construction and sources for the production and income data that we use; since this work is not easily reproduced, we also present the data. They include a series for real world income, which runs from 1900 to 1987, and this is matched to world production data for cocoa (from 1901), for coffee (from 1930), for copper, for rice (from 1904), for sugar (from 1903), and for tin (from 1901). Average annual

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prices for all of these goods are available from the same World Bank sources that were used in our earlier work, and these were deflated, as before, by the U.S. consumer price index.

We begin by presenting some descriptive statistics in Table 1. Column 2 shows that the deflated prices all had negative growth rates over most of the 20th century; this is the well-researched decline in the terms of trade for primary commodities. However, it should be noted from the next two columns that none of these trends are significantly different from zero; even using the (smaller) standard error that allows for possible serial correlation, in only one case, rice, is the estimated rate of decline larger than its standard errors, and then only marginally so. The lack of significant trends is consistent with the stationarity of the price predicted by the theory, though it is far from ruling out non-stationary alternatives. Of course, the standard errors are large because the prices are so variable, so that the findings in the top half of the table might be summarized by saying that prices exhibit some downward trend, but the trend is small relative to variability.

In contrast to prices, production levels tend to exhibit significant positive trends. All the coefficients are positive, and except for coffee and tin, which each rose at less than one percent a year, all are significantly different from zero. World income grew at 2.94 percent a year from 1900 to 1987, so that Table 1 is not inconsistent with the underlying Lewis view that, in the long run, demand drives supply with no effect on price.

Table 2 reports the results of using unit root tests to investigate the stationarity issues further. We show the results of regressions of the rates of growth of prices, production, and world income on the lagged logarithm of the level, and five lagged values of growth rates. For a series that is $I(1)$, the coefficient $\rho - 1$ on the lagged logarithm should be zero, and the comparison of the

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standard *t*-value against appropriate critical values can be used to test the null of *I*(1). If the series

is integrated with non-zero drift, the *t*-statistic can be compared against the usual distribution; if

there is no drift, the critical values are non-standard, and are given, for example, in Hamilton

(1994). It is also interesting to test the *joint* hypothesis that the drift is zero and the coefficient on

the lagged logarithm is zero, so that the series is *I*(1) without drift. The *F*-statistic in the table is

calculated in the usual way, and gives a test that is valid under the null if compared against

special critical values, see Hamilton (1994) and the notes to the table.

The major practical problem with all of these tests is lack of power; it is typically difficult to

reject the null, and failure to do so must not be taken as a confirmation. For example, the top part

of the table shows only two rejections, for cocoa and coffee, both in the first column, where we

test the null of *I*(1) under the hypothesis that the series is *I*(1) with non-zero drift. Because the

coefficients on the lagged price levels are negative, the departure is in the direction of

stationarity, as suggested by the model. But for the other commodities, and for cocoa and coffee

under the alternative specification of *I*(1) without drift, it is impossible to reject the null of

integration, nor can we reject the hypothesis that the data are indeed *I*(1) without drift. Clearly,

we cannot use these tests to reject the null that prices are integrated, which would contradict the

Lewis model.

Nevertheless, it is clear that these results cannot be taken too seriously. Indeed, one of the

most obvious characteristics of commodity price series is the combination of high

autocorrelations at high frequency, coupled with a lack of long-run trend. In Deaton and Laroque

(1992), we calculated variance-ratio or persistence statistics, which provided evidence in favor of

stationarity. Standard unit root tests, such as those used here, work with a small number of lags,

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and are liable to miss the slow mean reversion that is captured by the variance-ratio statistics.

Note that the results in the top half of the table are also consistent with stationary autoregressive

models for prices. For example, the standard errors on the lagged coefficient are such that for no

commodity can we reject the hypothesis that the coefficient on lagged price is 0.8, or –0.2 for

$\rho - 1$. The unit root tests are essentially uninformative about the stationarity or otherwise of

commodity prices.

The unit root tests for production and for world income are presented in the bottom half of

the table. While they suffer from the same sort of problems as the price tests, there are much

larger and more obvious drifts in the production (and income) series, and the joint tests for

integration without drift reject in a number of cases. Of more concern are the rejections of

integration for cocoa and tin; while the rejection is marginal for the former, the production of tin

appears to be better represented by a stationary than a non-stationary process.

Table 3 shows cointegration tests for production and demand. These follow the original

suggestion of Engle and Granger (1987) of first calculating an OLS regression of log production

on log income, and then analyzing the residuals. In this case, the coefficient in the first regression

has the interpretation of the long-run income elasticity of demand. These are presented in the first

column. Apart from tin, and more surprisingly, coffee, the elasticities are not particularly low. The

estimated residuals are used in the same type of regression described above, regressing the change

on the lagged level and on five lagged changes. The *t*-statistic on the lagged level is used, again

with tailored critical values, to test the null of no cointegration. If there is no cointegration, the

first-stage regression is spurious, the residuals should contain a unit root, so the test against unity

is a test for $I(1)$; the different critical values from those in Table 2 reflect the fact that the residuals

involve an estimated parameter. Apart from tin, and almost for rice, we cannot reject the null of no cointegration. While the absence of cointegration would be a problem for the Lewis model, the results likely owe as much to lack of power as to any genuine failure of cointegration; in particular note that all the estimated coefficients on $\hat{u}_{t-1}$ are less than 0.85, and that five out of the seven are 0.7 or less.

The predictions of the Lewis model that prices are stationary and that quantities and world demand are cointegrated are not obviously confirmed by these simple tests. Prices are slow to revert to their long run means, as are the ratios of commodity production to world income. But it is well-known that such slow reversion is poorly captured by tests that rely on a few low-order autocorrelations, and we take the view that the descriptive tests are essentially neutral as far as the validity of the model is concerned.

Section 3: Results of estimating the model

Tables 4 and 5 show the reduced form and structural parameter estimates for each of the goods, cocoa, coffee, and copper in Table 4, and rice, sugar and tin in Table 5. For each commodity, the top three panels present the reduced form parameters, for the price equation, (16), for the production equation, (15), and for the world income equation, (17). The row labeled "cointegrating" is the parameter estimate on the cointegration term $\theta y_{t-1} - q_{t-1}$, the difference between (logarithmic) demand and supply. Other rows correspond to the coefficients on lags of price, production change, and income change. The fourth panel shows the estimate of the cointegrating constant θ; this is the estimate of the long-run elasticity of demand, already estimated by the two step Engle–Granger procedure in Table 3. The final panel shows the

structural parameters for the supply equation—the demand equation is not identified except for the long-run elasticity from the cointegrating relationship.

Except for rice, for which we could only obtain sensible results with a single lag, we show results with two lags of prices, production and world income growth. We tested the overidentification restrictions (18) using likelihood ratio tests from FIML estimation with and without the restrictions. The restrictions easily passed the test for all of the commodities, and we present only the restricted estimates, which allow us to recover unique estimates for the structural parameters.

The cointegrating parameters provide elasticities of demand that are not very different from those shown in Table 3, and which range from 1.03 for copper and 0.90 to cocoa, to 0.48 for coffee and 0.15 for tin. All of these are quite precisely estimated, with standard errors between 0.04 and 0.08.

The estimated coefficients of the cointegrating term in the production and price equations are all positive, and for each good, at least one of the coefficients is significantly different from zero. Conditional on lagged prices, production, and world income, an imbalance between lagged demand and lagged supply leads to an increase in price, or output, or both. Although the demand equation is not identified, the model predicts what we see, that these reduced form coefficients be positive, when the cointegration term does not enter the world income equation and the coefficients $B(0)$ and $D(0)$ are both positive. To see this, note first that from the world income estimates in the third panel, we see that in no case are there significant effects of the cointegrating term, lagged quantity changes, or lagged prices, an absence that can be formally confirmed by likelihood ratio tests. Suppose then that all of these coefficients are zero. Then use equation (17)

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to substitute for $y_t = \Delta y_t + y_{t-1}$ in (11) and (12) which yields, after some manipulation, (15) and (16). This calculation shows that b_{q1} and b_{p1} are respectively equal to $D(0)/(D(0) + B(0))$ and $1/(D(0) + B(0))$. Although $B(0)$ is not identified, both terms should be positive, which is what we see.

   The lagged values of the growth of world income are generally insignificantly different from zero in the reduced form estimates, the only exception being Δy_{t-2} in the copper equation. These weak results are worth noting because the acceptance of the overidentification test depends on them. Although we can accept the overidentification that comes from exclusion of world demand from the supply equation (2), world demand plays such a limited role beyond its effects in the cointegrating term that the test is quite unimpressive.

   World income is well-modeled as an AR(1) in first-differences with an autocorrelation coefficient of 0.4. Lagged prices, lagged production growth, and the shortfall of supply over demand have essentially no detectable effects on the rate of growth of world income, something that can be confirmed by a series of Granger non-causality tests, all of which are easily passed. This result is perhaps not surprising given the limited importance of these commodity markets in the world economy.

   The response of supply to price is detailed in the bottom panel which shows the structural estimates of the supply equation. A pattern that is repeated across all of the commodities is one in which there is a positive instantaneous effect of price on production, followed by a negative effect at one lag. At the third lag, the response is in all case positive (except for rice where it is constrained to be zero) and the sum of the responses is (again in all cases) positive. But once again, although the signs are right, the results are not always significantly different from zero, and

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we find a significantly positive long run price response of the growth of supply for only cocoa and coffee. The offsetting effects in the first and second period can perhaps be attributed to the existence of a short supply response in which the *level* of supply responds to the *level* of prices, so that the growth of supply is linked to the growth of prices. This short run response might be linked to inventory behavior. Since it is extremely difficult to obtain accurate data on inventories, the production series that we use are almost certainly in part consumption series. If so, and if price increases elicits a short-run response out of inventories, there will appear to be a short-run response of "production" to price.

The Lewis model postulates that long-run supply is infinitely elastic, so that the elasticity we are interested in here is by how much the rate of growth of production responds to a difference between the current price and the long-run equilibrium price. These elasticities are computed by dividing the sum of the supply coefficients (shown as "total") in the last panel by one plus the sum of the coefficients on the lagged Δy terms. Apart from tin, where all the supply parameters are very imprecisely estimated, and which has an (absurd) estimated supply elasticity of 1.8, these elasticities lie in a sensible range, ranging from 0.03 for rice to 0.16 for copper. According to the last, for example, the rate of growth of supply will be 0.16 percentage points higher (from say, 2 percent a year to 2.16 percent a year) for every percentage point that the copper price exceeds its long run equilibrium. Only for cocoa and coffee do these estimates approach statistical significance.

The final panel shows an important difference between the supply functions for the foods (cocoa, coffee, rice, and sugar) and those for minerals (copper and tin). For the foods, the estimated coefficients on the lagged production growth terms are negative, and in most cases

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significantly so, while for the minerals, the coefficients are insignificantly positive. Such findings are consistent with the view that, for agricultural crops, the most important shocks are weather shocks, which are transitory, while for minerals, permanent shocks are likely to be dominant. If we look back to equation (3), such a pattern would induce what we see here, which is negative serial correlation in *growth* rates for agricultural crops, because the changes in the weather from one year to another is itself serially correlated, with little no serial correlation for minerals, where the shocks are permanent, with no supposition of negative autocorrelation in the differences.

Section 4: Summary and conclusions

We have proposed a statistical model of commodity prices based on Sir Arthur Lewis' account in which the price of tropical produce is held down by the existence of unlimited supplies of labor in tropical countries. In our version of the model, prices are stationary around a long-run trend, production is cointegrated with world income, and the rate of growth of supply responds to deviations of price from its long-run equilibrium. We have fitted this model to long-run data for six commodities, cocoa, coffee, copper, rice, sugar, and tin, over (some subset) of the years 1900 to 1987.

Our final assessment of the model is mixed. The results of Tables 4 and 5 can certainly be interpreted in a Lewis framework. The deviation of long-run demand from long-run supply exerts upward pressure on both price and production and, except for one commodity (tin), the rate of growth of supply responds positively to deviations of price from its long-run value. However, only for coffee and cocoa, are these long-run supply effect6s significantly different from zero. In spite of the enormous growth of world income in the 20th century, the associated increase in supply has

been forthcoming without an increase in the real price of these commodities. As Lewis predicted, increases in the real commodity prices must wait for the elimination of poverty in the tropics.

But it should also be noted that we have not succeeded in providing any crucial evidence or piece of evidence that would convert a skeptic to the Lewis story. The lack of long-run trend in commodity prices is a remarkable fact that is consistent with the Lewis' account, but as far as our model is concerned, we used the insight in constructing the model, so that its success cannot be counted as any additional support for our formulation. One source of difficulty is that the reversion of prices to their long run base is very slow, so that even a century of data is not enough to give clear results on either the stationarity of prices or the cointegration of production and output, and the empirical evidence is never very clear in rejecting alternatives. We saw in Section 2 that the mechanical application of standard unit root tests would lead to the conclusion that prices are integrated processes, something that can easily be interpreted in terms of the low power of such tests, especially against slow mean reversion. Nevertheless, we are left without any direct statistical support for the model from the time-series tests.

The more detailed results in Tables 3 and 4, while consistent with the Lewis model, suffer from lack of statistical significance, and the fits of the models come mostly from the univariate time-series representations that are of little interest in the current context. The exceptions are cocoa and coffee, the two commodities whose production is confined to the tropics, and for which the Lewis model is most obviously consistent with the data. For all the commodities, the price equations fit well, but only because we are working in levels and regressing price on its own lag. As in our work on speculative storage, our "explanation" of the autocorrelation of prices is essentially an assumed autoregressive process. The production and world income equations are

essentially autoregressions in first-differences, and the terms of interest play a relatively minor role. We have spent a great deal of time trying to dissect these results further, to find a crucial piece of evidence that would either support the model, by being hard to interpret without it, or else would refute it. But as is often the case with economic time series, it is hard to find clear cut evidence that would convince a true skeptic.

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Table 1: Summary data on prices, production, and income

Commodity	dates covered	mean rate of growth	standard error	corrected standard error
Prices				
Cocoa	1901–87	–0.0084	0.029	0.023
Coffee	1901–87	–0.0004	0.026	0.020
Copper	1901–87	–0.0111	0.019	0.013
Rice	1901–87	–0.0168	0.021	0.015
Rubber	1948–91	–0.0254	0.054	0.024
Sugar	1901–87	–0.0197	0.040	0.026
Tin	1901–87	–0.0003	0.021	0.015
Production				
Cocoa	1902–88	0.0339	0.012	0.008
Coffee	1931–90	0.0088	0.026	0.014
Copper	1901–90	0.0333	0.014	0.008
Rice	1905–87	0.0223	0.008	0.006
Rubber	1947–90	0.0407	0.011	0.013
Sugar	1904–94	0.0253	0.008	0.006
Tin	1902–87	0.0048	0.016	0.009
World Income				
Income	1901–87	0.0294	0.004	0.004

Notes: The dates covered exclude the first observation lost to differencing. The mean rate of growth is the average of the change in logarithms over the period shown. The standard errors are standard errors of the mean rate of growth, in the first column ignoring serial correlation, and in the second, using the Newey-West procedure with 10 (annual) lags.

Table 2: Time-series characteristics of prices, production, and world income

Commodity	constant	s.e.	$\rho-1$	s.e.	t	F	test 1	test 2	test 3
Prices									
Cocoa	–0.228	(0.109)	–0.228	(0.058)	–2.08	2.21	✕	✓	✓
Coffee	–0.287	(0.123)	–0.185	(0.077)	–2.41	2.89	✕	✓	✓
Copper	–0.101	(0.049)	–0.110	(0.059)	–1.86	2.10	✓	✓	✓
Rice	–0.061	(0.042)	–0.077	(0.072)	–1.06	1.20	✓	✓	✓
Rubber	0.460	(0.460)	–0.162	(0.138)	–1.18	2.02	✓	✓	✓
Sugar	–0.113	(0.060)	–0.166	(0.093)	–1.79	1.94	✓	✓	✓
Tin	0.179	(0.102)	–0.116	(0.063)	–1.84	1.72	✓	✓	✓
Production									
Cocoa	0.327	(0.133)	–0.042	(0.019)	–2.14	6.09	✕	✓	✕
Coffee	0.803	(0.878)	–0.074	(0.083)	–0.89	0.67	✓	✓	✓
Copper	0.161	(0.152)	–0.014	(0.019)	–0.72	4.68	✓	✓	✓
Rice	0.202	(0.366)	–0.008	(0.017)	–0.45	5.51	✓	✓	✕
Rubber	–0.073	(0.186)	0.014	(0.186)	0.60	5.03	✓	✓	✕
Sugar	0.035	(0.020)	–0.005	(0.014)	–0.34	3.47	✓	✓	✓
Tin	2.683	(0.958)	–0.225	(0.081)	–2.79	4.02	✕	✓	✓
World Income									
World income	–0.084	(0.108)	0.006	(0.006)	1.05	9.03	✓	✓	✕

Notes: For each row of the table, a regression is run with the dependent variable the change in logarithm, and the independent variables a constant, the lagged logarithm, and five lagged changes of logarithms. The first five columns shown are the estimates of the constant term, its standard error, the coefficient on the lagged logarithm, its standard error, and its t-value. The sixth column shows an F-test for the joint hypothesis that both the constant term and the coefficient on the lagged logarithm are zero. The three test columns report acceptance (✓) or rejection (✕) at the five percent level of (1) the hypothesis that the coefficient on the lagged logarithm is zero, under the assumption that the constant term is non-zero, so that standard inference is applied to the t-ratio, (2) the same hypothesis, but under the assumption that the constant term is zero, so that this augmented Dickey Fuller test, using the same t-statistics as (1), is tested using nonstandard distributions, here Table B.6 (Case 2) in Hamilton (1994), (3) the hypothesis that both the constant and the coefficient on the lag are zero using the F-test in column 6 and the distributions given in Table B.7 (Case 2) in Hamilton which are calculated under the null that the restrictions hold.

Table 3: Cointegration tests for the log of production and the log of world income

Commodity	long-run elasticity	coefficient on $\hat{u}_{t-1}$	standard error	t-value for 1
Cocoa	0.89	0.848	0.055	–2.75
Coffee	0.39	0.637	0.142	–2.55
Copper	1.08	0.605	0.131	–3.02
Rice	0.70	0.702	0.091	–3.28
Rubber	0.78	0.648	0.144	–2.45
Sugar	0.84	0.765	0.086	–2.72
Tin	0.22	0.431	0.135	–4.13

Notes: The long run elasticity is the OLS coefficient on the logarithm of world income in the cointegrating regression of log production on log output. The residuals from this regression are then regressed on their own lag and on five lagged first differences. The coefficient on the lag is shown, together with its estimated standard error, and the conventional *t*-value for the hypothesis that the coefficient is unity. Critical values for this *t*-value statistic are given in Hamilton, Table B8, Case 2. Only the value for tin exceeds its 5 percent critical in Hamilton's table.

Table 4: Reduced form and structural estimates of cocoa, coffee, and copper

	Cocoa		Coffee		Copper	
	coefficient	st. error	coefficient	st. error	coefficient	st. error
Price						
constant	−4.35	(1.93)	0.13	(0.44)	−4.44	(1.55)
cointegrating	0.36	(0.16)	0.25	(0.13)	0.37	(0.13)
p_{t-1}	0.94	(0.12)	0.80	(0.14)	1.10	(0.12)
p_{t-2}	−0.22	(0.12)	0.03	(0.14)	−0.23	(0.12)
Δq_{t-1}	0.21	(0.30)	0.15	(0.20)	−0.07	(0.16)
Δq_{t-2}	0.08	(0.27)	0.08	(0.18)	0.09	(0.15)
Δy_{t-1}	−0.35	(0.53)	0.08	(0.45)	0.36	(0.38)
Δy_{t-2}	−0.76	(0.57)	−1.33	(0.66)	−0.19	(0.35)
R^2/# obs	0.79	84	0.78	45	0.81	85
Production						
constant	−1.05	(0.70)	0.55	(0.39)	−5.43	(1.29)
cointegrating	0.11	(0.06)	0.24	(0.09)	0.46	(0.10)
p_{t-1}	−0.05	(0.04)	−0.36	(0.08)	0.16	(0.10)
p_{t-2}	0.05	(0.04)	0.46	(0.08)	−0.21	(0.09)
Δq_{t-1}	−0.46	(0.11)	−0.59	(0.12)	0.09	(0.13)
Δq_{t-2}	−0.22	(0.10)	−0.13	(0.11)	0.17	(0.12)
Δy_{t-1}	0.10	(0.16)	0.07	(0.43)	0.45	(0.46)
Δy_{t-2}	−0.22	(0.18)	−1.26	(0.45)	−0.23	(0.44)
R^2	0.26		0.65		0.29	
World income						
constant	0.57	(0.29)	−0.04	(0.10)	−0.39	(0.35)
cointegrating	−0.05	(0.03)	−0.06	(0.02)	0.03	(0.03)
p_{t-1}	0.02	(0.02)	0.02	(0.01)	−0.04	(0.03)
p_{t-2}	−0.00	(0.02)	−0.00	(0.01)	0.03	(0.03)
Δq_{t-1}	0.02	(0.04)	−0.07	(0.03)	0.03	(0.04)
Δq_{t-2}	0.04	(0.04)	−0.04	(0.02)	0.02	(0.04)
Δy_{t-1}	0.43	(0.11)	0.51	(0.11)	0.48	(0.13)
Δy_{t-2}	−0.12	(0.11)	−0.27	(0.11)	−0.16	(0.13)
R^2	0.24		0.39		0.21	
cointegration						
Δy_{t-1}	0.90	(0.05)	0.48	(0.08)	1.03	(0.04)
D_0	0.29	(0.23)	0.95	(0.49)	1.25	(0.37)
D_1	−0.32	(0.24)	−1.01	(0.47)	−1.22	(0.44)
D_2	0.11	(0.07)	0.43	(0.15)	0.08	(0.16)
total	0.08	(0.04)	0.27	(0.10)	0.12	(0.07)
E_0	−0.53	(0.16)	−0.73	(0.20)	0.18	(0.18)
E_1	−0.24	(0.15)	−0.21	(0.20)	0.06	(0.14)
total	−0.77	(0.33)	−0.94	(0.59)	0.24	(0.50)

Table 5: Reduced form and structural estimates of rice, sugar, and tin

	Rice		Sugar		Tin	
	coefficient	st. error	coefficient	st. error	coefficient	st. error
Price						
constant	5.66	(1.77)	–6.05	(4.83)	0.75	(1.03)
cointegrating	0.55	(0.19)	0.42	(0.34)	0.11	(0.11)
p_{t-1}	0.76	(0.07)	0.84	(0.12)	1.17	(0.11)
p_{t-2}	..	..	0.11	(0.12)	–0.32	(0.11)
Δq_{t-1}	0.37	(0.29)	–0.05	(0.59)	–0.13	(0.14)
Δq_{t-2}	..	..	0.59	(0.54)	0.01	(0.14)
Δy_{t-1}	0.38	(0.50)	0.66	(0.65)	0.10	(0.16)
Δy_{t-2}	..		–0.44	(0.53)	–0.11	(0.17)
R^2/# obs	0.79	82	0.64	82	0.80	84
Production						
constant	0.65	(0.69)	–2.13	(1.03)	3.38	(0.89)
cointegrating	0.06	(0.07)	0.16	(0.07)	0.37	(0.09)
p_{t-1}	0.01	(0.03)	0.02	(0.02)	0.15	(0.09)
p_{t-2}	..	..	0.00	(0.02)	–0.09	(0.09)
Δq_{t-1}	–0.28	(0.11)	–0.07	(0.12)	0.22	(0.11)
Δq_{t-2}	..	..	–0.07	(0.11)	0.09	(0.11)
Δy_{t-1}	0.04	(0.07)	0.25	(0.17)	0.34	(0.43)
Δy_{t-2}	..		–0.16	(0.17)	–0.38	(0.41)
R^2	0.13		0.17		0.27	
World income						
constant	–0.32	(0.35)	0.34	(0.57)	0.04	(0.23)
cointegrating	–0.03	(0.03)	–0.02	(0.04)	0.00	(0.03)
p_{t-1}	0.00	(0.01)	–0.00	(0.01)	0.01	(0.02)
p_{t-2}	..	..	0.00	(0.01)	–0.00	(0.02)
Δq_{t-1}	–0.05	(0.06)	–0.05	(0.07)	0.01	(0.03)
Δq_{t-2}	..	..	0.03	(0.06)	0.04	(0.03)
Δy_{t-1}	0.40	(0.10)	0.48	(0.11)	0.42	(0.12)
Δy_{t-2}	..	..	–0.17	(0.11)	–0.14	(0.11)
R^2	0.18		0.20		0.20	
cointegration						
Δy_{t-1}	0.56	(0.06)	0.79	(0.05)	0.15	(0.07)
D_0	0.11	(0.12)	0.37	(0.37)	3.37	(3.46)
D_1	–0.07	(0.11)	–0.29	(0.33)	–3.80	(4.14)
D_2	..	..	0.04	(0.07)	0.98	(1.26)
total	0.04	(0.03)	0.12	(0.09)	0.54	(0.58)
E_0	–0.32	(0.11)	–0.05	(0.28)	0.65	(0.73)
E_1	..	..	–0.29	(0.30)	0.05	(0.46)
total	–0.32	(0.11)	–0.34	(0.48)	0.70	(4.24)

Appendix: Data and sources

We use three types of data, on world income, on prices, and on production. World income data come from Maddison (1989). Maddison's book has annual series on GDP for 16 (current OECD) countries from 1900 to 1987. To make them comparable, he uses purchasing power parity conversion figures from the OECD and Eurostat for the OECD countries to yield "international dollars" used for conversion of domestic levels. The series have been converted to indices which are then linked to the 1980 benchmark international dollar figure to create an internationally comparable series for each country which can then be summed over countries. The series shown in the Table is in billions of 1980 constant dollars. Price data come from the World Bank, and were first used in the study by Grilli and Yang (1988). They are shown as index numbers, as is the US consumer price index. The production data come from a wide range of sources, which are briefly summarized here. Recent annual data on crops (here cocoa, coffee, rice, and sugar) can be readily obtained from the FAO website, http://www.fao.org. Cocoa production comes from various issues of Gill and Duffus'serial *Cocoa Statistics*: the units in the table are thousands of metric tons. Coffee data come from the Brazil's *Departamento Nacional do Cafe's* Annual Statistics: the units are thousands of 60 kg bags. Data on copper production are taken from the serial *Mettalstatistik*: units are thousands of metric tons. Rice production comes from the FAO, with historical data from FAO(1965); units are millions of quintals. Historical data on sugar are available in FAO (1961); units are hundreds of millions of quintals. Tin production comes from various yearbooks of the *International Tin Council*; units are metric tons.

| date	price cocoa	price coffee	price copper	price rice	price sugar	price tin	US cpi	cocoa production	coffee production	copper production	rice production	sugar production	tin production	world GDP
1900	8.99	4.59	21.72	22.77	33.19	4.78	25.0 0	.	.	452	.	.	.	603
1901	8.46	3.60	21.62	20.47	26.86	2.68	25.00	115	.	529	.	.	90424	630
1902	8.51	3.04	14.80	19.79	21.46	4.28	26.00	126	.	557	.	.	85547	637
1903	8.56	3.10	17.77	25.04	22.99	4.49	27.00	127	.	593	.	1.1	91948	657
1904	8.78	4.32	17.20	20.88	30.61	4.48	27.00	159	.	662	718	1.2	93472	659
1905	8.62	4.59	20.92	23.49	32.72	5.01	27.00	149	.	693	733	1.1	96012	689
1906	8.83	4.43	25.87	27.61	24.86	6.37	27.00	151	.	725	690	1.3	98450	738
1907	10.71	3.50	26.84	29.64	26.15	6.10	28.00	151	.	725	704	1.4	99873	759
1908	7.44	4.60	17.73	30.75	30.02	4.71	27.00	195	.	766	661	1.3	105867	729
1909	6.37	4.87	17.42	24.20	29.55	4.75	27.00	212	.	851	690	1.5	112370	779
1910	5.99	5.76	17.10	24.15	31.90	5.46	28.00	223	.	872	977	1.5	111354	785
1911	6.32	7.80	16.61	31.61	35.42	6.76	28.00	251	.	887	963	1.7	112776	818
1912	6.69	8.86	21.93	36.47	30.61	7.37	29.00	244	.	1019	1035	1.6	118262	853
1913	7.44	7.20	20.49	28.55	22.87	7.07	29.70	261	.	982	992	1.8	127711	881
1914	6.64	6.37	18.25	26.91	30.96	5.48	30.10	289	.	926	1020	1.9	118872	829
1915	8.94	5.32	23.19	27.25	38.82	6.17	30.40	290	.	1058	1035	1.8	122022	856
1916	7.60	5.87	36.50	25.15	51.25	6.95	32.70	321	.	1376	1135	1.8	120396	930
1917	5.99	5.65	36.47	21.71	54.18	9.88	38.40	351	.	1443	1193	1.8	120294	907
1918	6.90	7.03	33.05	24.72	49.73	14.19	45.10	281	.	1395	1207	1.9	117450	924
1919	9.96	13.73	25.08	26.55	59.34	10.12	51.80	445	.	1050	934	1.9	115113	911
1920	7.28	10.57	23.43	31.24	140.15	7.72	60.00	404	.	967	1135	1.6	114198	911
1921	4.17	5.76	16.77	35.77	36.36	4.78	53.60	371	.	528	1049	1.8	111455	901
1922	4.92	7.92	17.95	39.56	32.84	5.20	50.20	428	.	863	1150	1.9	115824	962
1923	4.07	8.19	19.35	37.56	58.99	6.82	51.10	456	.	1250	1293	1.9	119990	1024
1924	4.07	11.79	17.47	40.85	44.80	8.02	51.20	486	.	1331	1150	2.1	137160	1074
1925	5.08	13.62	18.84	41.17	26.27	9.26	52.50	490	.	1410	1236	2.4	139294	1114
1926	6.16	12.34	18.52	44.27	26.04	10.44	53.00	472	.	1468	1236	2.5	138684	1156
1927	8.46	10.35	17.34	41.01	30.96	10.29	52.00	530	.	1513	1221	2.4	155245	1184
1928	6.85	12.84	19.55	37.10	25.57	8.06	51.30	507	.	1716	1221	2.6	173736	1221
1929	5.57	12.23	24.30	37.03	20.17	7.22	51.30	551	.	1948	1265	2.8	192227	1274
1930	4.39	7.14	17.42	29.17	14.43	5.07	50.00	540	41021	1596	1236	2.8	174854	1200
1931	2.78	4.87	10.90	16.37	13.02	3.91	45.60	532	29396	1387	1308	2.9	140310	1123
1932	2.36	5.87	7.46	14.40	8.33	3.52	40.90	557	41491	897	1279	2.4	94082	1048
1933	2.36	5.04	9.42	12.23	11.37	6.25	38.80	628	33767	1008	1279	2.2	81178	1063
1934	2.78	6.14	11.31	15.91	13.96	8.34	40.10	590	43028	1267	1394	2.3	114198	1117
1935	2.68	4.93	11.61	20.79	18.53	8.06	41.10	701	31577	1467	1244	2.3	130658	1181
1936	3.64	5.26	12.71	20.41	20.29	7.42	41.50	737	36653	1696	1332	2.5	173025	1283
1937	4.50	6.09	17.67	21.63	20.64	8.69	43.00	758	42583	2285	1417	2.7	197815	1353
1938	2.78	4.26	13.42	19.85	17.01	6.76	42.20	736	39171	2010	1317	2.7	154229	1351
1939	2.57	4.10	14.71	19.21	17.71	8.05	41.60	807	38024	2124	1323	2.7	157683	1447
1940	2.73	3.93	15.16	23.09	15.95	7.97	42.00	690	32220	2397	1323	2.9	227381	1495
1941	4.07	6.26	15.83	25.81	19.82	8.32	44.10	672	26120	2525	1221	2.8	243535	1625
1942	4.76	7.42	15.81	28.35	29.67	8.31	48.80	677	26348	2672	1260	2.7	117145	1776
1943	4.76	7.42	15.81	29.63	28.62	8.31	51.80	612	25923	2693	1228	2.5	137363	1945

date	price cocoa	price coffee	price copper	price rice	price sugar	price tin	US cpi	cocoa production	coffee production	copper production	rice production	sugar production	tin production	world GDP
1944	4.76	7.42	15.81	29.63	28.97	8.31	52.70	572	24484	2509	1298	2.6	99568	1995
1945	4.76	7.53	15.81	29.63	34.48	8.31	53.90	620	22144	2172	1254	2.3	87376	1838
1946	6.16	10.24	18.54	34.18	41.63	8.72	58.50	660	25675	1848	1129	2.2	87681	1631
1947	18.68	14.78	28.12	54.72	56.29	12.46	66.90	623	29296	2229	1394	2.5	109423	1656
1948	21.25	15.00	29.57	57.99	49.61	15.87	72.10	599	27917	2323	1416	3.0	149555	1746
1949	11.56	18.10	25.76	50.08	48.79	15.88	71.40	783	30918	2268	1553	2.8	159918	1807
1950	17.18	25.86	28.50	42.24	58.40	15.27	72.10	768	28911	2525	1572	2.9	164897	1950
1951	19.00	30.52	32.47	44.61	66.50	20.32	77.80	813	30285	2662	1705	3.3	165100	2116
1952	18.95	29.48	32.47	48.29	48.91	19.26	79.50	652	29725	2766	1832	3.6	167945	2200
1953	19.86	29.48	38.64	53.98	39.99	15.32	80.10	811	32297	2802	1979	3.5	172822	2304
1954	30.94	39.83	39.84	48.79	38.23	14.68	80.50	788	32016	2852	1942	3.9	171704	2340
1955	20.07	31.03	50.30	43.72	38.00	15.15	80.20	815	33922	3112	2098	3.8	170688	2484
1956	14.61	35.69	56.11	42.30	40.81	16.21	81.40	855	43670	3470	2197	4.0	169062	2570
1957	16.38	35.17	39.69	42.39	60.52	15.39	84.30	911	34582	3556	2165	4.2	165710	2648
1958	23.71	25.86	34.57	43.97	41.05	15.21	86.60	786	46230	3449	2241	4.5	117653	2674
1959	19.59	22.24	41.84	40.84	34.83	16.32	87.30	923	52001	3693	2199	5.2	121107	2826
1960	15.20	21.21	43.00	38.53	36.83	16.22	88.69	1053	66421	4242	2189	5.0	138684	2961
1961	12.10	19.66	40.15	42.17	34.13	18.12	89.57	1189	52814	4394	2158	5.5	138684	3095
1962	11.24	18.62	41.06	47.21	34.95	18.33	90.68	1140	58275	4555	2266	5.2	143967	3255
1963	13.54	18.10	41.06	44.27	99.69	18.65	91.75	1176	53416	4624	2470	5.3	143500	3420
1964	12.53	24.31	42.88	42.54	68.85	25.20	92.99	1234	56891	4799	2629	6.0	149200	3609
1965	9.26	23.79	46.99	42.11	24.86	28.49	94.47	1508	35878	4963	2543	6.5	155100	3821
1966	13.06	21.72	48.53	50.42	21.81	26.23	97.29	1226	66359	5220	2612	6.4	167100	4015
1967	15.58	20.17	51.30	63.59	23.34	24.53	100.00	1351	44443	5060	2778	6.7	172900	4155
1968	18.41	20.17	56.15	62.29	23.22	23.69	104.22	1354	51721	5459	2891	6.7	183100	4384
1969	24.46	20.69	63.78	57.74	39.52	26.30	109.85	1242	43410	5943	2956	7.0	178000	4605
1970	18.31	26.90	77.42	44.49	43.98	27.85	116.35	1435	48078	6403	3167	7.3	186700	4748
1971	14.34	23.28	69.01	39.86	53.01	26.76	121.27	1499	40154	6477	3181	7.4	188100	4916
1972	17.29	25.86	67.92	45.45	87.14	28.37	125.26	1583	53083	7063	3082	7.6	196300	5165
1973	34.47	32.07	78.99	108.14	112.94	36.38	133.05	1398	57166	7511	3362	7.8	189100	5459
1974	52.51	34.14	102.85	167.46	351.36	63.36	147.76	1448	43792	7576	3333	7.9	183600	5485
1975	40.04	33.62	85.26	112.18	240.42	54.33	161.25	1548	62433	7182	3591	8.2	181200	5461
1976	58.50	73.97	92.34	78.63	135.81	60.73	170.49	1510	54307	7658	3504	8.2	180200	5725
1977	108.39	124.66	88.30	84.10	95.23	85.47	181.59	1339	42777	7854	3723	9.0	188600	5930
1978	97.41	85.86	87.90	113.54	91.48	100.66	195.41	1503	52571	7671	3881	9.1	196700	6180
1979	94.20	89.48	123.79	102.36	113.29	113.87	217.46	1495	60028	7765	3773	8.9	200100	6374
1980	74.40	80.69	137.37	134.06	336.24	135.26	246.85	1626	62258	7786	3993	8.5	200000	6456
1981	59.41	66.21	112.38	149.23	198.90	115.51	272.36	1660	66064	8355	4125	9.3	204600	6610
1982	49.60	72.42	97.79	90.53	99.05	104.53	289.12	1734	77311	8041	4239	10.1	190600	6578
1983	60.57	68.05	104.44	85.60	99.53	103.07	298.46	1523	62366	8048	4518	9.7	173000	6769
1984	70.11	74.55	89.58	77.93	61.31	99.73	311.15	1513	67676	8236	4702	9.9	167100	7107
1985	65.66	75.53	87.98	66.74	48.09	94.66	322.23	1944	67449	8380	4734	9.8	158200	7339
1986	60.98	100.52	86.67	65.54	73.03	58.56	328.40	1961	74764	8466	4739	10.0	141300	7541
1987	58.76	58.66	112.46	71.71	81.56	63.58	340.39	1994	57569	8742	4575	10.4	136300	7759
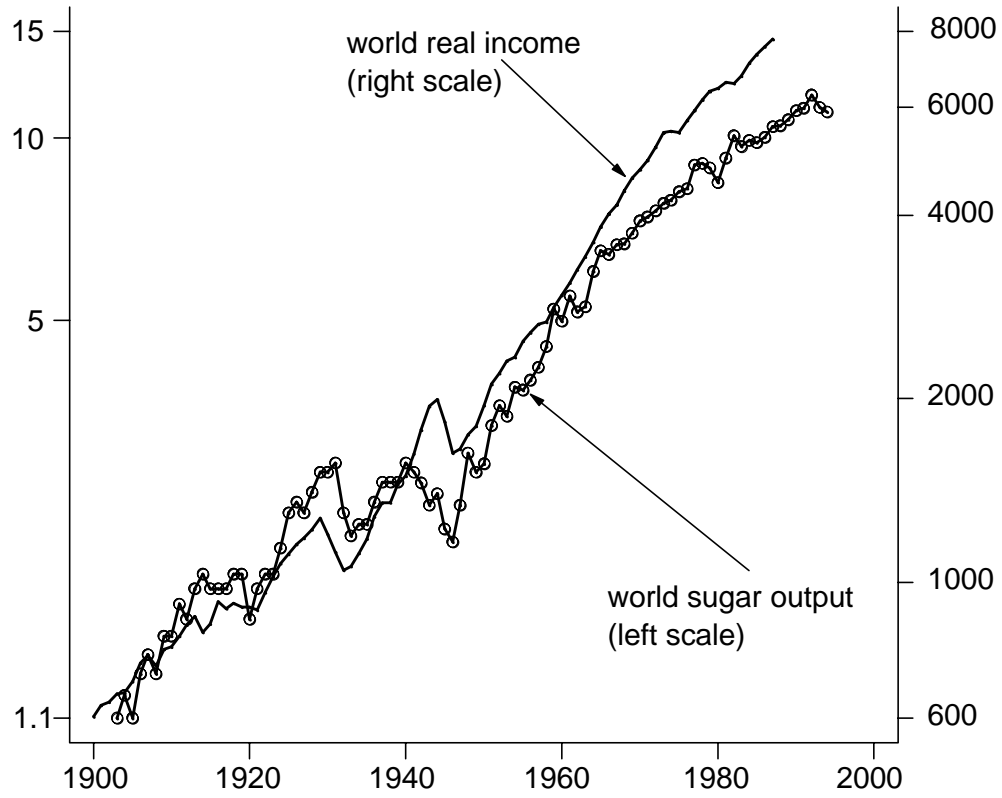
Figure 1: Sugar production and world real income
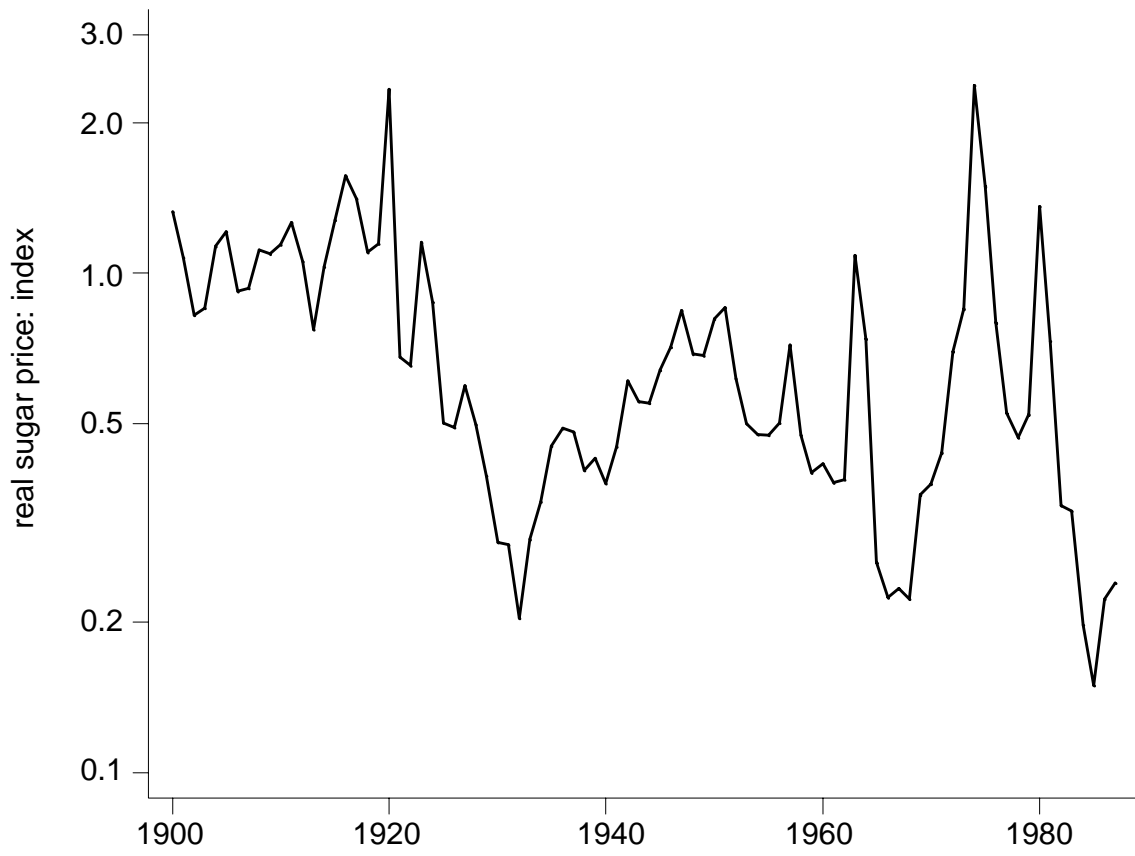
Figure 2: Sugar prices, deflated by the U.S. consumer price index